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The Analysis of Religious Assortative Marriage

**An Application of Design Techniques
for Categorical Models**

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THE ANALYSIS OF RELIGIOUS ASSORTATIVE MARRIAGE

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Religious Assortative Marriage
An Application of Design Techniques
for Categorical Models.**

*Het Analyseren van Kerkelijk Gemengde Huwelijken
Een Toepassing van Modelleringsstechnieken voor Modellen met
Categorische Variabelen*

**Een wetenschappelijke proeve op het gebied van
de Sociale Wetenschappen**

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Part 1

Chapter 1

Introduction

As its title suggests, this dissertation deals with two distinct topics: substantive analyses of religious assortative marriage on the one hand, and design techniques for categorical models on the other. At the time the research proposal for this project was formulated, it was assumed that the methodological aspects had already been adequately addressed in the field of mobility research, so the main focus would be on the theoretical and empirical questions with regard to religious assortative marriage. As will be explained below, the available “mobility models” turned out to have important shortcomings, which led me to experiment with design techniques in order to find more suitable solutions. These experiments did indeed bear fruit and provided the material for part 2 of this dissertation, on design techniques for categorical models. The theoretical and empirical questions regarding religious assortative marriage are addressed in part 1, using these design techniques.

Briefly stated, the purpose of this research project was to analyze square tables of the religious denominations of marriage partners, in order to gain insights in the openness of Dutch society with respect to religion. The analyses were to distinguish themselves from earlier work on religious assortative marriage through the use of special loglinear modelling techniques, such as used in mobility research and recent studies of assortative marriage. The research proposal for this project posed four questions, which are answered in different chapters of part 1:

- How did religious assortative marriage in the Netherlands change through time in the course of the twentieth century?
- How do explanations for changes and variations in religious assortative marriage fare in experimental tests?
- How does religious assortative marriage compare with another dimension of the openness of society, educational assortative marriage?
- How does religious assortative marriage in the Netherlands compare with religious assortative marriage in Germany?

Part 2 of this dissertation deals with design techniques for categorical models. The term “design” is used here rather than “model” in order to avoid confusion with statistical models such as the loglinear model. Whereas I strove in part 1 to keep the methodological aspects as simple as possible, the material in part 2 is discussed at a high level of abstraction. For example, design techniques are discussed in relationship to generalized linear models, rather than just the loglinear models used in the analyses in part 1. Familiarity with matrix algebra is useful for a full comprehension of the methods in part 2.

Part 2 deals with four questions that arose in the course of this project:

- How can a design for a loglinear model be created that will provide information on both inmarriage and outmarriage?

- How can parsimonious designs be derived from a full interaction effect, in particular when the deviation contrast (the restriction that parameters sum to zero) is used for the interaction effect?
- How can trend-smoothing designs be implemented in categorical models?
- How can non-linear designs be implemented in categorical models?

The remainder of this chapter contains an overview of the theoretical and methodological aspects of this research project. Theories on stratification, secularization, pillarization and modernization were drawn upon in order to clarify the need for measures of relative religious assortative marriage such as used in the analyses, and to explain differences and changes in assortative marriage patterns. The discussion of the theoretical background of religious assortative marriage is followed by a non-technical explanation of the methodological problems and their proposed solutions. This introductory chapter ends with an outline of the ensuing chapters and a brief presentation of the most important results.

Theoretical background of religious assortative marriage

STRATIFICATION

The purpose of studying assortative marriage patterns is to gain insights into the openness of society with respect to the trait of the marriage partners being analyzed. In an open society, there will be frequent contacts between members of different groups¹, and a higher incidence of marriages between groups will be a good indicator for a higher incidence of relationships of a less intimate nature. It is of course conceivable that members of two hostile groups fall in love, as in the famous story of Romeo and Juliet. In general however, only a proportion of cross-acquaintanceships between members of two groups will evolve into cross-friendships, and only a proportion of these friendships will evolve into intermarriages.

There have been studies of assortative marriage patterns along several dimensions, such as education, occupation, ethnicity, as well as religion. The openness of society has also been examined by studying father to son mobility with respect to occupation, income, class, education. By studying both assortative marriage patterns and mobility on several dimensions, a detailed picture of the openness of society can be created.

However, an examination of the causes of assortative marriage show that not all of them relate to the openness between groups. On the basis of Blau's (1977, 1984) theory of inter-group relations, a distinction can be made between *supply factors* and *barrier factors*. Supply factors relate to the contact opportunities for members of different groups, but not to the preferences of group members for interaction with one group, rather than another. Barrier factors on the other hand, determine the probability that individuals will choose to interact with members of one group rather than another.

Whether or not the distinction between supply factors and barrier factors is considered relevant depends on whether the researcher is interested in the frequencies or in the probabilities of mixed marriages. In the study of *absolute* assortative marriage, the focus is on the frequency of mixed marriages, and whether these are due to supply factors or barrier factors is immaterial. However, information on the openness of society is best reflected by the probabilities of mixed marriages. Therefore, special modelling techniques are used to separate the

influence of supply factors from that of barrier factors, in the analysis of *relative* assortative marriage.

Among the supply factors are group size and spatial dispersion of the groups. Since members of larger groups have a greater probability of meeting other members of their own group, then there will be, all other things being equal, a larger proportion of homogamous marriages in larger groups. If the same proportion of homogamous marriages were to be found for a smaller group, then this would mean that members of the smaller group were going to considerable effort to find other members. The spatial dispersion of groups amounts to a refinement of the specification of group sizes: a group can be small in one region, but large in another.

Three barrier factors that can be distinguished are individual preferences, group norms, and physical segregation. The fact that individuals have a preference for interaction partners with similar status and attitudes is common knowledge. This preference is treated as a premise by Blau (1977) and Blau and Schwartz (1984), but it has also been the subject of social psychological research (social comparison theory; Festinger 1954, Suls and Miller 1977). An interesting alternative view is presented by Becker (1981). On the basis of economic theory, he posited that in order to create as efficient a household as possible, marriage partners would choose a partner with different, but complementary abilities. This is too simple a model and Becker introduces other factors that make the choice of a similar partner a better choice, but the point itself is intriguing.

The choice of partner is not purely a matter of individual choice however. There can be norms forbidding association with members of other groups, with sanctions such as ostracism for those who do not heed them. An extreme case was the Nazi law against marriages between Jews and non-Jews in Germany between 1933 and 1945. Particularly in the past, churches discouraged mixed marriages, and the Catholic church explicitly forbid them until 1966, as did the orthodox Protestant Re-Reformed church in the Dutch case. There can also be informal norms on mixed marriages which everyone somehow knows about, even though they are rarely discussed openly. A man who marries an attractive, but poorly educated woman may be sniggered at behind his back for having married a "bimbo". Note that social norms can influence an individual's choice, but to some extent, individuals can also shape norms. Another alternative is to seek membership of a group with different norms.

The family, in particular the parents, play an important part in enforcing norms. This is a relationship that offspring will not easily want to sever, due to affective ties and to the dependency of offspring on their parents. This dependency is particularly strong if there is an inheritance involved, such as a family farm or business. In other cases, parents provide a dowry or help a young couple in setting up a household. These considerations give (or gave) the parents influence on matters such as choice of marriage partner.

A third barrier factor is the physical segregation of groups. Physical segregation might appear to be identical to the supply factor spatial dispersion, since it also limits contacts. However, there is nothing to prevent an individual from moving from one region to another, whereas segregated areas are only open to certain groups. The formation of ghettos is a very old form of segregation. Another example is the Dutch system of pillarization, in which separate organizations were created for each religious group. These separate organizations, whether in the economic, political, or social field, resulted in limited contacts between denominations. In these cases, a conscious attempt was being made to limit contacts, but this need not always be the case. For example, Mare (1991) posited that the trend toward higher educational inmarriage in the United States was due to the longer duration of education. This

had the unintentional result of limiting contacts between persons of different school types, such as college and high school.

SECULARIZATION

Beside being an indicator for the openness of society, religious assortative marriage has also been viewed as an indicator of secularization. This may need some clarification. Secularization is often interpreted as the growth of the category "unchurched", at the cost of the religious denominations. But as we noted above, group size is a supply factor which is controlled for when determining measures of relative assortative marriage. The measures of relative assortative marriage themselves relate to the ingroup preferences between religious denominations, but are these aspects of secularization?

In fact, secularization is a complex phenomenon, in which several inter-related aspects can be discerned. Felling, Peters, Schreuder (1991) distinguish worldview, church involvement, and salience of beliefs as aspects of secularization. Worldview itself is composed of 8 correlated dimensions, of which the Christian worldview is only one, along with inner-worldliness, agnosticism and nihilism. The process of secularization entails lower degrees of church involvement, shifts from the Christian worldview to other worldviews, and with lower salience of beliefs.

If by secularization we refer to the lessening importance of religion in society, then religious assortative marriage can be considered to be yet another aspect of secularization. The extent in which religion is a stratification dimension, i.e. the extent in which social cleavages run along religious lines, indicates how important religion is in society. In addition, the amount of either absolute or relative assortative marriage indicates how effective norms proscribing religiously mixed marriages in fact are.

Relative assortative marriage might be expected to be a relatively independent aspect of secularization, since it is independent of the size of the group with no denomination. The size of this category is a crude measure of church involvement, which is itself strongly related to other aspects of secularization such as Christian worldview and salience of beliefs. However, because the size of the category "no denomination" is only a crude measure of church involvement, the religious denominations contain members with varying degrees of church involvement, and the measures of relative assortative marriage could still be strongly affected by other aspects of secularization.

The scale of church involvement used by Felling, Peters, Schreuder (1991) divides the unchurched into ex-members, as well as unchurched of the first and second generation. Church members can be divided into marginal members who rarely attend services, modal members who regularly attend services, and core members, who also take part in church activities. Ideally, the scales of husband's and wife's denomination in the analysis of religious assortative marriage would distinguish between active, practising members and between marginal and ex-members. Religious assortative marriage can be expected to be stronger for active members, since norms against mixed marriages would be more effective for them than for non-active members, and because their own preferences for partners with similar religious attitudes would be stronger as well². The trend of religious assortative marriage might also be different for active versus non-active members. For example, one hypothesis might be that religious assortative marriage did not change for active members, and that changes found for denominations as a whole are due to shifts toward a greater proportion of non-active members.

Unfortunately, it was not possible to test hypotheses on the influence of church involvement on religious assortative marriage, since the data did not distinguish between active and non-active members. C.B.S. (1982) shows that when respondents are simply asked as to their denomination, a large proportion of ex-church members report their former religion³. Since the data used here were collected in this fashion, the denominations in our analyses comprise all of those who identify to some extent with the religious group, and the category "no denomination" is relatively homogeneous, composed largely by the unchurched of the first and second generation, and for a small proportion by ex-members. This is not an unacceptable situation, since the focus is on religious group identity, and we are therefore interested in the behavior of all those who identify with each of the denominations. However, the inability to distinguish between active and non-active members masks interesting information, and research on the relationship between church involvement and religious assortative marriage would be desirable.

PILLARIZATION

The importance that religion, or at least a religious ingroup mentality, had at one time in Dutch society is evidenced by the system pillarization, with its separate organizations for religious groups. The relationship between religious assortative marriage and pillarization was first discussed by Kruijt (1957). Kruijt made a distinction between organizational pillarization and "psychological", or individual pillarization, and treated the amount of "intranubium" (inmarriage) as an aspect of individual pillarization. An important difference between organizational pillarization and individual pillarization is that the former occurred along a political as well as a religious dimension, since separate organizations were also created for the socialist and liberal groups. Individual pillarization on the other hand, relates only to tensions between religious groups.

There is still no consensus as to why the system of pillarization arose in the Netherlands, but the most convincing theories link it to attempts by religious elites to protect their flocks from the effects of modernization, secularization, and socialism. Bax (1988) notes that the process of modernization also brought these new religious elites to power in the second half of the nineteenth century. Furthermore, modernization required something like the new pillarized organizations based on ideological principles, at the same time as it provided the infrastructure for such organizations. The pillarized organizations therefore fought the onset of a modern, secular society, using means provided by modernization.

As noted earlier, organizational pillarization was a barrier factor, since it led to "physical segregation" of religious groups. Following Kruijt, the hypothesis in the analyses was therefore that organizational pillarization would strengthen individual pillarization. On the other hand, although theories on pillarization often focus on the role of elites, the system of pillarization also required some support at other levels of society. Religious assortative marriage and other aspects of individual pillarization relate to this grass-root support: people did not wish to associate with members of other denominations, and the pillarized organizations gave them this isolation. Lijphart (1968) argues that pillarized organizations made peaceful coexistence between the antagonistic religious groups possible, while allowing for the necessary coordination through contacts between the elites. The other side of this is that organizational pillarization prevented people from meeting members of other denominations and overcoming their prejudices.

Organizational pillarization provided the isolation people of all walks of life wanted, and the individual pillarization under the people provided the grass-root support which organizational pillarization needed. The external forces of modernization, which are discussed in the following paragraph, are hypothesized to have changed this. For various reasons, modernization led to the erosion of individual pillarization. Organizational pillarization appeared to have had a dynamic of its own and could remain stable even after support for the system had started to ebb⁴. However, once the process of organizational depillarization set in, this led to an increase in contacts between religious groups, which strengthened the process of individual depillarization and further decreased the support for pillarized organizations.

MODERNIZATION

The analyses in the following chapters show a trend toward less religious inmarriage from the mid 1950s on. Related studies showed that Dutch society became more open in other respects as well. Ganzeboom and de Graaf (1984) showed that absolute and relative occupational mobility increased between 1954 and 1977, and Ganzeboom and de Graaf (1989) showed that relative educational mobility had increased as well. An analysis of educational assortative marriage by Sixma and Ultee (1983) for the Netherlands, as well as an international comparative study of educational assortative marriage by Ultee and Luijkx (1990), also a trend toward greater openness of Dutch society in this respect.

Kerr (1960) posited that an explanation for these shifts toward greater openness of society is the process of modernization. As noted above, modernization has also been regarded as a cause of depillarization (Bax 1988). However, "modernization" is a catch-all term, which subsumes a number of processes. Important aspects are the diffusion of knowledge, increasing investments in human capital, an increase in scale of production and concomitant increases in social and spatial mobility, a shift from ascription standards to achievement standards, the rise of the nuclear family, the rise of the welfare state. What these aspects have in common is that they widen the individual's ideological horizon and/or increase the individual's autonomy. Wider ideological horizons will mean lower ingroup preferences, while greater individual autonomy will mean that sanctions on social norms will be less effective. Modernization will also lead to more contacts between different groups and will thus weaken physical segregation. In this way, modernization will lead to a deterioration of the barriers between different groups.

The individual's ideological horizon can be widened directly, through education, or indirectly, through the increasing contacts with other groups in modern society (Blau and Schwartz 1984). Social mobility, both intergenerational and intragenerational, dissolve the individual's older social networks and create new ones. Spatial mobility has a similar effect. Urbanization brings a wide variety of different groups in contact with each other and is incompatible with wide spread intolerance of differences. Enterprises in a competitive society are incompatible with ascription standards; the shift from ascription to achievement should permeate other aspects of society as well.

Changes in the individual's network also increase his/her autonomy. A key sanction for disobeying norms on the choice of marriage partner is ostracism by the group. In a situation in which the individual is a member of several groups of a far less permanent nature, this sanction becomes less effective. The enlargement of scale of enterprises and the decrease of employment in agriculture means that there will be less inheritance of family businesses, thus depriving parents of a key sanction of their offsprings' actions. The rise of the welfare state

further decreases children's dependence on parents. It also meant that churches and pillarized organizations lost control of an important factor binding members to them.

Modernization can therefore be expected to lead to more religiously mixed marriages. The increased ideological horizon of individuals will be accompanied by a greater tolerance for partners with other (religious) attitudes and to shifts in norms regarding contacts with other groups. The greater autonomy of the individual will make sanctions from disapproving members of his/her social network less effective. Modernization will also affect religious assortative marriage indirectly, through effects on secularization and depillarization. The diffusion of knowledge through higher levels of education is the aspect of modernization most relevant to secularization. The organization of churches is also at odds with the democratic standards of modern society, which could alienate church members. Some attempts have been made to modernize the church, to reconcile its teachings with modern notions and to bring its organization up to date (Goddijn 1973, Dekker 1992). However, these have failed to stem the process of secularization from the 1960s to the mid 1980s, as measured either by church attendance or by a wide number of religious attitudes (Felling, Peters, Schreuder 1991).

Modernization will also affect the process of depillarization, both directly and through secularization. Secularization was an important cause of depillarization, since the declining importance of religion in society removed the support base for the system of pillarization (Bax 1988, Pennings 1991). In general, the widened ideological horizon of individuals became untenable with pillarization, and the waning of individual pillarization weakened support for the system of organizational pillarization. Modernization also affected pillarized organizations directly in some ways. For example, the rise of the welfare state took away a major role of pillarized charitable organizations. Thus, by direct and indirect means, modernization should lead to a deterioration of the barriers between religious groups.

Methodological issues

SIMPLE STATISTICS

This project was of course not the first to try to analyze religious assortative marriage. Van Leeuwen (1959) and Dekker (1965) had studied religious assortative marriage in the Netherlands. Heer (1962) is an often cited study of religious assortative marriage in Canada, and Besanceney (1970) contains an overview of studies in the United States. However, these studies were unable to adequately measure relative assortative marriage, since the techniques available to them could not control properly for the influence of the supply factor, differences in group size.

Most analyses of religious assortative marriage, including recent studies by Bax (1988) for the Netherlands and Glenn (1982) and McCutcheon (1988) for the United States, used or were derived from the percentage homogamous marriages (or marrying individuals⁵) per denomination. The percentage homogamous marriages is equal the number of marriages in which both partners were of the denomination, divided by the total number of marriages in which one or both partners were of that denomination.

To illustrate this and other simple statistics, table 1 contains a marriage table for the Netherlands in 1953. The high values on the diagonal cells of the table indicate a strong amount of assortative marriage. To calculate the percentage homogamous Catholic marriages,

Table 1

Table of husband's denomination by wife's denomination for the Netherlands, 1953

Husband's denomination	Wife's denomination					Total
	Re-Reformed	Reformed	other	none	Catholic	
Re-Reformed	6091	1338	87	292	177	7985
Reformed	1423	20780	681	2418	2035	27337
other	73	572	938	355	185	2123
none	303	2795	507	9132	1400	14137
Catholic	169	1638	222	1110	31216	34355
Total	8059	27123	2435	13307	35013	85937

table 1 would be collapsed into a two by two table with the categories "Catholic" and "non-Catholic", as in table 2. In 1953, the percentage homogamous Catholic marriages is equal to $31216/(31216+3139+3797)*100\% = 81.8\%$.

It was soon realized that the percentage homogamous marriages is a measure of absolute assortative marriage – it simply indicates to what extent mixed marriages take place. All other things being equal, it will be higher for larger groups, since members of these would often meet due to chance alone. However, most researchers wanted a measure of relative assortative marriage, that would control for the effects of group size and would therefore reflect the strength of barriers between religious groups. By splitting the analysis into smaller regional units such as provinces, spatial dispersion can also be controlled for, so that measures of relative assortative marriage reflect the joint influence of individual preferences, norms, and physical segregation.

Attempts were made to correct the percentage homogamous marriages, using the expected frequencies of marriages. These can be calculated using the marginals of the marriage table, under the assumption that the choice of marriage partner is independent of religious denomi-

Table 2

Table of husband's denomination by wife's denomination for Catholics versus non-Catholics, in the Netherlands, 1953

Husband's denomination	Wife's denomination		Total
	Catholic	Non-Catholic	
Catholic	31216	3139	34355
Non-Catholic	3797	47785	51582
Total	35013	50924	85937

nation⁶. In table 2, the expected number of marriages in which the husband is Catholic and the wife is not, equals $40.0\% \times 59.3\% \times 85937 = 20358$. Table 3 contains the expected frequencies of marriages in 1953, given the marginals of table 2. With these values, the expected percentage of Catholic homogamous marriages can be calculated as $13977 / (13977 + 20358 + 21016) \times 100\% = 25.3\%$.

Table 3
Expected frequencies, based on the marginals of table 2 and
assuming random choice of partner

Husband's denomination	Wife's denomination		Total
	Catholic	Non- Catholic	
Catholic	13997	20358	40.0%
Non-Catholic	21016	30566	60.0%
Total	40.7%	59.3%	100.0%

By taking the difference between the actual and the expected percentage homogamous marriages, an adjusted percentage homogamous marriages could be calculated that takes differences in group size into consideration. A problem of the adjusted percentage is that it can never reach 100% and that its range will be larger for small groups with small expected percentages, than it will be for larger groups. Glenn (1984) proposed to correct this by dividing the adjusted percentage (for individuals) by 100%, minus the expected percentage of homogamously marrying individuals.

A similar index was used by Van Leeuwen (1959) and Dekker (1965) for the Netherlands and by Heer (1962) for Canada. This "index of indifference", first put forward by Müller (1950) as the "Konnuptialindex", divides the percentage of heterogamously marrying individuals by the expected percentage of heterogamously marrying individuals⁷. For example, in table 2, the percentage of heterogamously marrying Catholics would be equal to $(3139 + 3797) / (2 \times 31216 + 3139 + 3797) \times 100\% = 10.0\%$ (the number of homogamous Catholic marriages is multiplied by 2, since the percentage relates to individuals, not marriages). The expected percentage of heterogamously marrying Catholics equals $(20358 + 21016) / (2 \times 13997 + 20358 + 21016) \times 100\% = 59.6\%$. The index of indifference would then be equal to $10.0\% / 59.6\% = .168$.

Mobility research was confronted with similar problems and showed that the fundamental problem lay in the use of expected frequencies based on the marginals of the table. In calculating the expected frequencies, the effects of group size are derived under the assumption that no assortative marriage takes place. Statistics based on the expected frequencies therefore constitute an analysis of the residuals of a model of independence of the row and column variables, a model which the researcher assumes to be incorrect (Featherman and Hauser 1978). Unless the model of independence does in fact fit the data, the marginal frequencies will be due to some extent to the association between the row and column variables. Techniques are therefore necessary which can determine the effect of group size on assortative marriage patterns, while taking this association into account.

A simple statistic that does not have these shortcomings is the odds-ratio⁸. The odds-ratio is based on the probabilities that different types of marriages occur and therefore forms an adequate representation of the association in a table. In table 2, the probability that a Catholic husband has a Catholic wife is 31216/34355 and the probability that a Catholic husband has a non-Catholic wife is 3139/34355. Therefore, the odds of a Catholic husband having a Catholic versus a non-Catholic wife are 31216/3139. The odds for a non-Catholic husband having a Catholic versus a non-Catholic wife are 3797/47785. The ratio of these two odds indicates how greater the odds are that a Catholic husband will have a Catholic wife, than that a non-Catholic husband will have a Catholic wife. For table 2, the odds-ratio is equal to $(31216 \cdot 47785) / (3139 \cdot 3797) = 125.2$.

Table 4
Simple statistics for religious assortative marriage in the Netherlands in 1953

	Re-Reformed	Reformed	other	none	Catholic
1 actual percentage homogamous marriages	61.2	61.7	25.9	49.9	81.8
2 expected percentage	4.9	18.8	1.3	8.7	25.3
3 adjusted percentage	56.3	42.9	24.6	41.2	56.5
4 index of indifference	.265	.347	.604	.398	.168
5 odds ratio	124.2	26.1	43.5	29.6	125.2
6 log odds ratio	4.8	3.3	3.8	3.4	4.8

† The index of indifference is based on the number of marrying individuals, whereas the other statistics are based on the number of marriages

In order to illustrate the different conclusions that these statistics can lead to, table 4 contains simple statistics on religious assortative marriage for all five denominations, based on table 1. The actual percentages of homogamous marriages in row 1 would indicate that the vast majority of Catholic marriages were homogamous. Mixed marriages were somewhat more common among orthodox Re-Reformed Protestants and liberal Reformed Protestants, and even more so in the category "no denomination". The largest proportion of mixed marriages could be found in the category "other denominations". However, it would be incorrect to draw inferences on the openness of the religious groups from these percentages – that would lead to the untenable conclusion that liberal Reformed Protestants were just as closed a group as the orthodox Re-Reformed Protestants.

The expected percentages of homogamous marriages are in the second row of table 4. The values are determined by group size and are large for Catholics and Reformed Protestants, and small for Re-Reformed Protestants and "other denominations". The third row of table 4 contains "adjusted percentages", the difference between the actual and the expected percentages. The adjusted percentages would indicate that Catholics and Re-Reformed Protestants were the most highly closed groups, and that Reformed Protestants were substantially more open. The category "none" appears to be as open as the Reformed Protestants, and the "other denominations" seem to be by far the most open group of all.

Row 4 of table 4 contains the values of the "index of indifference". This statistic would indicate that Catholics were by far the most closed group, followed by Re-Reformed

Protestants. The liberal Reformed Protestants were the next most open group, followed by the category "none". Here again, the tiny category "other denominations" appears to be most open of all.

The fifth row of table 4 contains odds-ratios. Odds-ratios are multiplicative measures and values should be compared by looking at how many times higher one value is than another, and not by examining differences. Since it is more natural to look at differences, the log values of the odds-ratios are given in row 6. These log odds-ratios indicate that Catholics and Re-Reformed Protestants were considerably more closed than the rest of the denominations. Unlike the adjusted percentages or the index of indifference, the (log) odds-ratios indicate that the category "other denominations" was considerably more closed than Reformed Protestants or "none".

Cynics hold that "Facts are stubborn, but statistics are more pliable". Table 4 might seem to be a case in point. However, it is important to note that the actual percentage of homogamous marriages is a measure of absolute assortative marriage. It will be a useful measure when the focus is simply on the extent in which mixed marriages occur. For hypotheses on relative assortative marriage, a statistic must be used that can correctly control for differences in group size. The expected frequencies as calculated using the marginals of the table are not in fact good indications of the effects of group size, since they are based on the assumption of independence of the partners' denominations. The odds-ratio on the other hand, is derived in a straightforward fashion from the probabilities of different types of marriages.

This discussion indicates the necessity of estimating the association between partners' denominations and of the effects of group size at the same time in one step. The effects of group size would then take the association into account, and vice versa. This can be done using log-linear models, which are discussed in the following paragraph. An interesting point is that a loglinear model for a two by two table such as table 2 can represent the association as a log odds-ratio. This is further proof that the odds-ratio does correctly control for differences in group size.

LOGLINEAR MODELS

In the above discussion, it was argued that early measures of relative assortative marriage were unable to correctly control for differences in group size, because the expected frequencies of types of marriages were calculated under the assumption of no association between the partners' denominations. Loglinear models address this problem by calculating measures of the relative sizes of the denominations for both husbands and wives, given the association between the partners' denominations. Unlike the simple statistics, loglinear models can be applied to tables with more than two categories. Furthermore, loglinear models are able to test for specific patterns of association and to test whether or not this pattern is constant for a group variable such as "year of marriage", "province", etc. Through the use of goodness of fit tests, sampling fluctuations and other insubstantive differences between the actual frequencies and the expected frequencies under the model can be detected, so that a parsimonious description of the association between the partners denominations can be derived.

The loglinear model breaks down the cell frequency into an overall parameter, a row variable parameter, a column variable parameter, and an interaction effect parameter. These parameters are multiplicative, i.e. the cell frequency under the model is equal to the overall parameter times the row variable parameter, times the column variable parameter, times the interaction effect parameter. The overall parameter itself is dependent on the number of cases.

In the analysis of marriage tables, the row variable and column variable parameters relate to the sizes of the denominations for husbands and wives, given the association between these under the model. The interaction effect parameters indicate how many times more frequent the type of marriage was than expected on the basis of these size effects and are therefore adequate measures of relative assortative marriage. By calculating the logarithms of parameters, the multiplicative model can be transformed into a linear one. Log parameters are more abstract in meaning, but are easier to interpret.

Restrictions which make the parameters relative to each other are necessary in order to be able to estimate these parameters. The easiest restriction is to set the parameter for a reference category to zero. This restriction, the simple contrast, makes the parameters relative to this reference category. A second example of restrictions that can be placed on parameters is the difference contrast. Parameters using the difference contrast show only the increase from one category to the next. In the case of an interaction effect, the association will be described by a set of log odds-ratios, which indicate the likelihood of moving up one category. This shows that odds-ratios calculated for a two by two table do in fact control for the effects of group size, given the association in a table.

A third example of possible restrictions in a loglinear model is the "deviation contrast". This is the commonly used restrictions that the sum of the parameters equals zero. One parameter is then redundant for each variable and can be calculated afterwards. The parameters are relative to each other and this makes their interpretation very straightforward. The designs for relative assortative marriage used in this paper are based on this contrast.

Loglinear mobility models

A characteristic of loglinear models for mobility or assortative marriage patterns is their use of special designs, which impose extra restrictions on the association parameters. In this way, insubstantive fluctuations can be eliminated from the association effects. Because of this the association can be described more parsimoniously and hypotheses on the nature of the association can be tested.

Hout (1983) contains an overview of a number of special designs that have been developed for mobility research, and Goodman (1984) contains Goodman's most important publications on this subject. Analyses by Johnson (1980) on religious assortative marriage, Hout (1982) on occupational assortative marriage and Sixma and Ultee (1983) and Ultee and Luijkx (1990) on educational assortative marriage, and Kalmijn (1991a,b) on dual trait analyses such as religious and educational assortative marriage simultaneously, have shown that loglinear analyses provide a powerful tool for these types of analyses, as well as for mobility research.

At the onset of this project, it was thought that certain mobility models would also be suitable for the analysis of religious assortative marriage. Many mobility models assume ordered categories and therefore could not be used, but three designs were considered as options: the levels model, the crossings parameter model and the log-multiplicative row and columns model II. Unfortunately, all three models turned out to have serious drawbacks.

The levels model (Featherman and Hauser 1978) divides the association parameters into a limited number of levels, within which parameters are equal. It is a simple design and does not assume ordered categories, which would at first sight make it a prime candidate for use in this project. However, the levels model had been criticized by Pöntinen (1982) and MacDonald (1981) on the grounds that the model was indeterminate: different designs with entirely different substantive implications nevertheless had the same fit. In chapter 7, it is argued that the reason for this model indeterminacy is that no distinction is made between

restrictions imposed by the levels model on substantive grounds, and restrictions which are necessary in order to identify the model. A related disadvantage is that it is unclear what the precise meaning is of the parameters of a levels model.

A second alternative was the crossings parameter model (Goodman 1968), which was the model used by Johnson (1980) in his study of religious assortative marriage in the United States. A disadvantage of this model is that its assumption of ordered categories is not fulfilled for the analysis of religious assortative marriage⁹. Johnson (1980) used what he refers to as an "R-order" of the religious categories to overcome this, for which the religious denominations are ordered according to similarities between them, as determined in the work of others (Johnson 1980: 82-84).

The crossings parameter model estimates a parameter for each "crossing" from one category to the next, indicating the strength of barriers between denominations. In this way, it shows that relative heterogamy becomes systematically more uncommon as the social distance between denominations is larger. In order to create a model that will fit the data well, it would be necessary to fit parameters to the diagonal cells. However, this so called "quasi" crossings parameter model requires that the diagonal parameters for the highest and for the lowest diagonal cells are fixed to zero. This would mean that there was no propensity to in-marriage among Re-Reformed Protestants and Catholics, and that any in-marriage that did take place was the result of barriers between denominations. This would not be an acceptable hypothesis.

An alternative restriction that would make it possible to fit parameters to all diagonal cells in a crossings parameter model would be to stipulate that the barrier between the first and second category was equal to the barrier between the last and second to last category. This would mean that the barrier between Re-Reformed and Reformed Protestants would be equal to the barrier between Catholics and the category "no denomination". This restriction would also be unacceptable. The fact that the two alternative quasi crossings parameter models have such different substantive implications, but the same model fit is another example of model indeterminacy (see chapter 7). As was the case for the levels model, no distinction was made between restrictions that were imposed for substantive reasons, and restrictions required to identify the model.

A third alternative that was considered for use was the quasi row and column model II (rc2; Goodman 1979). The model estimates new scale values for the row and column variables, such that the association in the table would be uniform, if these scale values were used (chapter 11 contains a discussion of this model). The rc2 model is different from other mobility models, in that it has both multiplicative and additive parameters in single model, whereas all other mobility models have additive loglinear parameters. The model is closely related to correspondence analysis (Goodman 1985) and can be expanded to a multi-dimensional version. Since it makes no assumptions on the ordering of the scales, it would appear to be an ideal model for the analysis of religious assortative marriage. Unfortunately, the results using the rc2 model could not be meaningfully interpreted. The scale value parameters of a version with diagonal parameters simply did not make sense. Scale value parameters of a model with no diagonal parameters were interpretable¹⁰, but this model had a very poor fit.

The levels model, the crossings parameter model, and the rc2 model all had important shortcomings. In the absence of alternatives, the best course of action would have been to concentrate on solving the problems with rc2 models. One solution might be to use a multi-dimensional version. Or perhaps the model should be modified to separate the issue of in-marriage propensity (the diagonal parameters) from that of social distances (the scale value

parameters). The programs developed in chapter 11 provide the tools for the purpose of experimentation with uni-dimensional and multi-dimensional rc2 models. The rc2 model remains an attractive model, since its placement of categories in a uni-dimensional or multi-dimensional space accords closely with everyday notions of social distance.

Design techniques

Rather than try to make do with an unsatisfactory model, I began experimenting with design matrix techniques. A key element in this was the use of contrasts. Contrasts relate to the type of restriction used in models with categorical independent variables. Such models define an overall parameter, a parameter for each category of each variable, and parameters for all combinations of categories. However, it is not possible to derive estimates of this full set of so-called *model parameters* without further restrictions. A contrast defines identifiable parameters as linear combinations of these model parameters (Lammers 1984, Bock 1975, Finn 1974). For example, the deviation contrast defines the identifiable parameters as the difference between the model parameters and the mean value of the model parameters. Through the use of elementary matrix operations, a design matrix for estimating the identifiable parameters can be derived.

In a subsequent step, new parameters with special restrictions can be derived from existing parameters. By creating models in this fashion, the problems of model indeterminacy of the levels model and crossing parameter model can be avoided: first the restrictions are implemented that are necessary in any case, then restrictions based on substantive arguments are implemented. If two models happen to have the same fit, then this can be attributed to the fact that the parameters of the first have a different meaning (i.e. are relative in a different sense), than the parameters of the second.

The model for religious assortative marriage had to be able to answer two questions: (a) How strong is the propensity to inmarriage for each denomination? (b) In the event of outmarriage, which denominations are attracted to each other and which denominations avoid each other? The deviation contrast is the most suitable contrast for answering these questions. As noted above, the deviation contrast corresponds with the often used restriction that the sum of parameters equals zero. For estimation, the parameters for one category of each variable is redundant, but these values can be calculated afterwards as the negative sum of the other parameters. In this way, interaction parameters can be derived for each cell of the table, providing information on the inmarriage propensity of each denomination, and on the occurrence of the different types of outmarriage.

Through the use of the deviation contrast, a model was obtained that could answer questions with regard to both inmarriage and outmarriage. The next step was to impose extra restrictions, in order to derive parsimonious models with less parameters to be interpreted, and to test substantive hypotheses. A first way of doing this was to specify that the interaction is symmetric. This design was used in Hendrickx, Lammers, Ultee (1989), a (Dutch language) descriptive analysis of the trend of religious assortative marriage in the Netherlands. In chapter 7 techniques are discussed for implementing other restrictions, in particular the steps necessary for imposing equality or zero-value restrictions on those parameters which are not directly estimated, but calculated afterwards from the negative sum of the other parameters.

As chapter 7 shows, the basic ideas of the levels model and the crossings parameter model can be imposed as restrictions on deviation contrast parameters. A model using the levels restriction is particularly attractive for data with unordered categories. This restriction imposes an equality restriction on the outmarriage parameters for two or more pairs of denominations.

Because this restriction is applied to deviation contrast parameters, problems of model indeterminacy are avoided. The levels restriction can be implemented quite easily, using a symmetric interaction effect with redundant categories on the diagonal cells. The levels restriction was used in the analysis religious assortative marriage in the Netherlands between 1938 and 1983, in chapter 2.

Still, the levels restriction model was not totally satisfactory. The restriction reduced the number of parameters to be interpreted, but because the levels shifted from year to year, interpretation was still fairly complex. This is a property of the deviation contrast: if an inmarriage parameter becomes lower, then some of the outmarriage parameters for that denomination must become less negative as well, since the parameters sum to zero. Since inmarriage changed through time, the levels must also change through time¹¹.

Reflection on this problem led to the conclusion that the fact that mixed marriages between two denominations were scarce would not always indicate an aversion between them – it could simply be a result of their preferences for inmarriage. On the other hand, it is conceivable that a denomination has a low preference for inmarriage, but very strong likes and dislikes for one denomination over another, in the event of outmarriage. What was needed was a measure of social proximities between the denominations, that controlled for their propensities to inmarriage, as well as for group size effects.

Chapter 8 describes how this can be achieved. The interaction parameters for a square table using the deviation contrast can be redefined into three sets of parameters: diagonal parameters, symmetric deviances parameters, and skew symmetry parameters. The diagonal parameters indicate the propensity to inmarriage, the symmetric deviances parameters indicate the social proximities between denominations, and the skew symmetry parameters (Sobel, Hout, Duncan 1985, Yamaguchi 1990) indicate the difference between men and women in the social proximities.

By redefining the total association into sub-terms in this manner, highly complex effects can be broken down into substantively meaningful components, which can be interpreted one at a time. In the analysis of educational assortative marriage in chapter 4 for example, the association between partners' educations turns out to be asymmetric, with no regularities through time. By breaking this down into a component on inmarriage, a component on social proximities between educational categories, and a component on the differences between the social proximities for men and women, important insights can be derived, in spite of the complexity of the model.

However, the model for educational assortative marriage was exceptionally complex. All models for religious assortative marriage showed the association to be symmetric, and with the exception of the model for religious assortative marriage in the dual trait analysis¹² in chapter 4, the symmetric deviances parameters turned out to be constant through time. Chapter 3 shows that the symmetric deviances parameters were also constant across provinces and categories of municipal size, and chapter 5 shows that they were constant through time in Germany, as well as in the Netherlands. The amount of information to be interpreted was therefore greatly reduced. Substantively, this result indicates that, in spite of strong changes in ingroup preferences of the denominations through time, the pattern of attraction and aversion between different denominations did not change.

The work on designs based on the deviation contrast has shown considerable progress, but there is still room for improvement. As discussed in chapter 8, the symmetric deviances parameters for a 4 by 4 table yield a single set of social proximity measures between the categories. This can also be derived using the "mirror" restriction for ordered categories, but

solutions for unordered categories have not been worked out yet. The lack of parsimony of the social proximity measures still complicates the interpretation.

In addition to developing designs for the association in square tables, I have also done some work on restrictions for trend parameters. Many fluctuations in trend parameters can be insubstantive and can obscure the developments that are important. A common practise is to test whether or not the trend is linear. This can be extended through the use of the polynomial contrast, which can test for linear, quadratic, cubic, or higher order polynomial trends. This way, the trend can be described by a flowing line, thus simplifying the interpretation. In chapter 4, the polynomial contrast was applied to certain effects across marriage cohorts. Another method for smoothing the trend is discussed in chapter 9. By imposing a moving average contrast on difference contrast parameters, insubstantial fluctuations in the trend can be eliminated. Because a full set of parameters can be derived from the estimated values, the results are still as easy to interpret as those of simpler models.

In the search for adequate design techniques, I also looked into nonlinear designs in models such as the loglinear or logit model. Chapter 6 contains a brief discussion of two such designs: Sobel's diagonal reference model and an extension of this design to an interaction effect, the proportional asymmetry model. Chapter 10 contains a comparison of the diagonal reference model with its linear design counterparts, the square additive model and Hope's halfway/difference model. Chapter 11 is a technical description on how nonlinear designs can be incorporated in models in the generalized linear model framework, such as analysis of variance, loglinear, logit, and probit models. Goodman's rc2 model is one of the designs discussed in this chapter.

Overview of the following chapters

Part 1 of this dissertation deals with the substantive analyses. Chapter 2 starts with a discussion of the trend of religious assortative marriage in the Netherlands between 1938 and 1983. Religious inmarriage was initially quite high for Re-Reformed Protestants and Catholics. The liberal Reformed denomination was the most open group, followed closely by the category "no denomination", and "other denominations" had an intermediate position. Religious inmarriage among Re-Reformed Protestants and Catholics was stable between 1938 and 1953 and even increased slightly. However, after 1953, Re-Reformed Protestant and Catholic inmarriage started to decrease, dropping sharply in the 1960s and 1970s. This decline tapered off in the 1980s, but had not yet levelled off in 1983. Inmarriage did not change much for Reformed Protestants or the category "no denomination", and religious inmarriage rose for the category "other denominations", presumably because of a larger portion of non-Christian religions, such as Islamic and Hindu denominations. In 1983, the category "other denominations" was the most closed group, followed by Re-Reformed Protestants and Catholics. Reformed Protestants and the category "none" were still the two most open groups.

Chapter 2 also examines whether religious assortative marriage varied by province. If it did not, then spatial dispersion of the religious denominations would not be a problem. However, it turned out that religious assortative marriage did vary quite substantially by province. Inmarriage was especially low in the provinces Noordholland, Zuidholland and Utrecht. This was consistent with the hypothesis that modernization leads to lower religious

assortative marriage, since these province were characterized by aspects of modernization such as high rates of spatial mobility, urbanization, and industrialization.

Chapter 3 is a continuation and refinement of chapter 2. In chapter 2, it is asserted that the variation of religious inmarriage across provinces was not so strong as to completely invalidate results found at the national level. This assertion is tested in chapter 3 by comparing the parameters for religious assortative marriage from an analysis at the national level with parameters from an analysis at the provincial level. The differences between parameters controlling for province, and parameters for national level data turned out to be negligible.

The main hypothesis addressed in chapter 3 was whether aspects of modernization, such as spatial mobility, urbanization, occupational structure, prosperity, could explain the variation in religious inmarriage across provinces that we found in chapter 2. This could be tested by incorporating variables for the differences between provinces with regard to such aspects of modernization as covariates in the analysis. Higher rates of migration turned out to be an important explanatory variable. Both the occupational structure and the mean income of provinces could explain much of the variance of religious assortative marriage across provinces. A higher prominence of the service sector and a relatively high average income in provinces were associated with greater openness.

Explanatory variables for urbanization performed poorly, but a separate analysis of religious assortative marriage by municipal size, the variations of inmarriage by municipal size were larger than variations by province. Religious inmarriage varied by year of marriage, municipal size, and year/size category. The trend of religious inmarriage, controlling for municipal size, did differ strongly from the trend found in an analysis at the national level. Religious inmarriage became lower for larger categories of municipal size, indicating that social control could have played an important role.

In chapter 4, religious assortative marriage is compared with educational assortative marriage in a simultaneous, "dual trait" analysis. As expected, the association between partners' denominations was much stronger than between partners' educations. However, although there was a strong trend to lower religious assortative marriage, there was a slight increase in educational inmarriage in the period up to 1970. The social proximities between educational categories also showed a much more pronounced pattern, with strong attraction between some categories, and strong aversion between others. This chapter also contains new modelling innovations. Because education has ordered categories, it was possible to impose special restrictions, such as a "mirror" restriction on the symmetric deviances parameters and a "hollow" restriction on skew symmetry parameters. As mentioned above, the polynomial contrast was used for trend smoothing.

Chapter 5 contains a comparison of religious assortative marriage in the Netherlands and Germany. In order to compare the data for the two countries, the religious denominations had to be recoded to four categories (Catholic, Protestant, other, Jewish). On the other hand, the trend for the Netherlands could be analyzed over a longer period, using data for 1914 and 1935, which was only available with four categories. The German data spanned an even longer period, from 1901 to 1936 and from 1951 to 1986.

The marriage patterns up to World War II were fairly similar in both countries. However, in the 1950s, Catholic and Protestant inmarriage in the Netherlands was considerable higher than in Germany. The difference shrank for Catholics from the 1960s onward. However, the difference for Protestants changed only slightly. An analysis in which denominations were not merged showed that the German Lutheran Protestants had a similar inmarriage preference to the Dutch Reformed Protestants. The Dutch Re-Reformed Protestants were a much more

closed group, but became more open from 1960 onward, whereas Dutch Reformed inmarriage and German Lutheran inmarriage changed very little.

In part 2 of this dissertation, design techniques for categorical models are discussed. Chapter 6 contains a brief outline of contrasts. A comparison is made between two models for unequal main effects, Hope's (1971) halfway/difference model, and an alternative design by Sobel, Hout, Duncan (1985). An examination is made of the influence of contrasts on the perception of the strength of asymmetries. In addition, two nonlinear designs are discussed: Sobel's (1981, 1985) diagonal reference model for unequal main effects, and a proposed extension of the basic idea of this model to interaction effects, in a proportional asymmetry model.

Chapter 7 contains a fuller discussion of contrasts and their relevance for models for square tables, such as mobility models. The problem of model indeterminacy is discussed and related to the fact that some mobility designs fail to distinguish between restrictions imposed for substantive reasons, and restrictions that are required for the model to be identified. The use of the deviation contrast for mobility designs is discussed and methods are discussed for implementing the basic ideas behind the levels model and crossings parameter model, by imposing restrictions on deviation contrast parameters.

In chapter 8, special designs based on deviation contrast parameters are discussed. The full interaction effect can be split into three sub-terms, which correspond with the ingroup preference, the social proximities between categories, and the differences between social proximities for men and women. These designs were used in the analyses of chapters 3, 4 and 5. Methods for deriving more parsimonious models are also discussed, including special restrictions are also discussed, such as the "hollow" and "mirror" restrictions.

Chapter 9 discusses the macro program GLIMMAT, a set of SAS macros for experimenting with contrasts and special designs. GLIMMAT uses the SAS matrix language PROC IML to create a design matrix with specifiable contrasts for each variable. A second macro called GLIMEST¹³, can be used to estimate GLM-type models (e.g. analysis of variance, loglinear, logit, probit) using this design matrix. The chapter contains a description of the program and shows how a new design, the moving average restriction for difference contrast parameters, can be developed using the program.

Chapter 10 contains a discussion of designs for mobility models with a dependent variable. These models deal with quite different problems than models for frequency tables and use analysis of variance, rather than loglinear models. The basic problems of design and their solutions are identical, however. The main purpose of this chapter is to compare Sobel's nonlinear diagonal reference model with its linear counterparts, the mainstream square additive model and Hope's halfway/difference model. This is also briefly alluded to in chapter 7.

Chapter 11 closes the section of design techniques with a discussion of nonlinear designs in GLM-type models. The GLIM macro from the SAS sample library shows how GLM-type models can be estimated using the nonlinear regression program PROC NLIN. Chapter 11 discusses how this can be adapted to allow nonlinear designs to be estimated as well. Programs are presented for estimating existing designs, such as the diagonal reference model and the (multi-dimensional) rc2 model, as well as for new designs such as a "power distance" model, in order to illustrate the steps from conception to implementation.

¹ The term "group" is used here in a broad sense, to denote social categories, collectivities, or actual social groups.

² That religious assortative marriage would be stronger for active members is the most likely hypothesis. It is of course conceivable that for active members, similar religious attitudes are important and *denomination* less so, and that religious assortative marriage would be weaker for this group. Religion might also be a binding factor for non-active members struggling with their faith, who feel a need to talk with others in a similar position.

³ If a single-phase question is used, i.e. if respondents are simply asked what their religious denomination is, then many ex-members tend to report their former religion. If a two-phase question is used in which respondents are first asked whether they have a denomination, and if so, which, then ex-members are placed in the category "no denomination", which becomes much larger. Most of the data used in the analysis consists of the self-reported denominations of bride and bridegroom when applying for a marriage license, which amounts to the use of a single-phase question.

⁴ Kruijt (1959, 1961) found that organizational pillarization was still flourishing around 1960. Nevertheless, he predicted that organizational pillarization had peaked and would start to decline, presumably based on less tangible evidence that support for pillarized organizations was waning. Our results in the following chapters show that individual pillarization as measured by the inmarriage preference of religious groups, peaked in the mid-1950s and then started to decline.

⁵ Many researchers calculated the percentage of homogamously (or heterogamously) marrying individuals, rather than the percentage homogeneous marriages (Besanceney 1970: 53-54). The percentage homogeneous marriages for a particular denomination can be calculated from a 2 by 2 table by:

$$\% \text{ homogamous marriages} = \frac{f_{11}}{f_{11} + f_{12} + f_{21}} \quad (i)$$

Since each homogeneous marriage is composed of two homogeneously marrying individuals, the percentage homogeneously marrying individuals is equal to:

$$\% \text{ homogeneously marrying individuals} = \frac{2f_{11}}{2f_{11} + f_{12} + f_{21}} \quad (ii)$$

Rodman (1965) provides simple formulas for transforming measures based on marriages into measures based on individuals, and vice versa. If x is the mixed marriage rate for marriages and y is the mixed marriage rate for individuals, then

$$y = \frac{100x}{200 - x} \text{ and } x = \frac{200y}{100 + y} \quad (iii)$$

For example, 81.8% of the Catholic marriages were homogamous in 1953, so 90.0% of the Catholics married homogamously.

⁶ The expected frequencies for cell (i,j) of a table, assuming independence of the two variables, can be calculated by:

$$g_v = \frac{f_{i+} f_{+j}}{f_{++}} \quad (\text{iv})$$

where f_{i+} is the row-sum for row i , f_{+j} is the column-sum for column j , and f_{++} is the total sum of the table. Based on the marginals of marriage table, the probability of a husband having denomination i equals f_{i+}/f_{++} , and the probability of a wife having denomination j equals f_{+j}/f_{++} . The joint probability of a marriage in which the husband's denomination is i and the wife's denomination is j and assuming independence of husband's and wife's denomination equals $f_{i+} f_{+j} / f_{++}^2$. Multiplying this by the total number of marriages f_{++} gives the expression for the expected number of marriages in equation (iv).

With the expected frequencies for a two by two table, the expected percentage homogamous marriages for a denomination can be calculated as:

$$\text{expected \%} = \frac{g_{11}}{g_{11} + g_{12} + g_{21}} = \frac{f_{1+} f_{+1}}{f_{1+} f_{+1} + f_{1+} f_{+2} + f_{2+} f_{+1}} \quad (\text{v})$$

⁷ Dekker (1965: 158) gives the following equation for calculating the indifference index:

$$I = \frac{a}{1-b}$$

$$\text{where } a = \frac{f_{12} + f_{21}}{f_{1+} + f_{+1}} \quad (\text{vi})$$

$$\text{and } b = \frac{f_{1+} + f_{+1}}{2f_{++}} = \frac{2g_{11} + g_{12} + g_{13}}{2g_{++}}$$

Note that this equation relates to marrying individuals rather than marriages. In equation (vi), a is the proportion of heterogamously marrying members of a denomination, b is expected proportion of homogamously marrying members, so $1 - b$ is the expected proportion of heterogamously marrying members. b is also equal to the proportion of marrying persons that are a member of the denomination, since the expected frequencies reproduce the marginals exactly:

$$g_{11} + g_{12} = \frac{f_{1+} f_{+1}}{f_{++}} + \frac{f_{1+} f_{+2}}{f_{++}} = \frac{f_{1+} (f_{+1} + f_{+2})}{f_{++}} = f_{1+} \quad (\text{vii})$$

since $f_{+1} + f_{+2} = f_{++}$.

⁸ The odds-ratio θ for a two by two table can be calculated by:

$$\theta = \frac{f_{11}/f_{12}}{f_{21}/f_{22}} = \frac{f_{11} f_{22}}{f_{12} f_{21}} \quad (\text{viii})$$

Since the probability of being in cell (i,j) is equal to f_{ij}/f_{++} , the frequencies in equation (viii) may be replaced by the corresponding probabilities. The second expression for the odds-ratio shows that in the example in the text, "husband" and "wife" may be switched.

⁹ For the denominations to be used in our analyses, Re-Reformed Protestants and Catholic should be at the opposite poles. Reformed Protestants would be near Re-Reformed Protestants, and might be followed by the category "other", since this is for a large part composed of small Protestant denominations. The category "no denomination" would have to be

placed at a large distance from the orthodox Re-Reformed Protestants, and at a more or less equal distance from Catholics and Reformed Protestants. This would make the best ordering to be: "Re-Reformed, Reformed, other, none, Catholic". A correspondence analysis of marriage table data showed that this would in fact be the best uni-dimensional ordering, but that a two-dimensional solution was required to fit the data properly.

¹⁰ The scale values of a regular rc2 models had the rank order used in table 1: Re-Reformed, Reformed, other, none, Catholic ("other" and "none" might switch places in some models). In this ordering, Re-Reformed Protestants and Catholics form opposite poles, and the liberal Reformed Protestants are placed close to their orthodox brethren. The scale values of the rc2 version with diagonal parameters indicated as rank order: Reformed, Re-Reformed, Catholic, other denomination, no denomination. It makes little sense that the liberal Reformed Protestants would be the polar opposite of "no denomination", or that the social distance between them and Catholics would be larger than between orthodox Re-Reformed Protestants and Catholics.

¹¹ This is not to say that the results in chapter 2 are incorrect. The difference with later work lies in the interpretation of parameters for off-diagonal cells. In Hendrickx, Lammers, Ultee (1989) and in chapter 2, these are interpreted as measures of the social proximities between the denominations. In later work, these parameters are interpreted only as measures of the relative frequency of mixed marriages (i.e. controlling for group size), and it is argued that measures of the social proximities between denominations should be independent of the propensities to inmarriage. However, the parameters for religious inmarriage in chapter 2 would be almost the same if the designs discussed in chapter 8 were to be used, rather than the levels restriction, and their interpretation is not affected.

¹² This analysis was based on synthetic cohorts, whereas other analyses were based on real cohorts. The results in chapter 4 indicate that the slight changes in social proximities across cohorts can be attributed to selective attrition.

¹³ The GLIMEST macro was adapted from the GLIM macro in the SAS sample library.

Chapter 2

Religious Assortative Marriage in the Netherlands 1938-1983

Abstract

In this paper, we test for a trend toward secularization in Dutch society between 1938 and 1983, using religious assortative marriage as an indicator. We use loglinear modelling techniques similar to those used in mobility analysis, in order to control for the sizes of the denominations. In addition, the factor spacial dispersion is controlled by repeating the analysis for provinces in the years 1938, 1963 and 1983.

In the theoretical section, we use Blau's macro-sociological theory of intergroup relations to provide a theoretical foundation for the research techniques we used. This is supplemented by a specification of the mechanisms through which macro-sociological factors such as industrialization can influence individual decisions, resulting in religious assortative marriage.

Inmarriage for members of the orthodox Protestant Re-Reformed church and for Catholics followed a similar trend: more or less constant until the end of the 1950s, a sharp drop during the 1960s, and a more gradual decline after 1973. However, inmarriage among members of the liberal Protestant Dutch Reformed Church fluctuated slightly with no apparent trend. This provides qualified support for the proposition that religion has become less salient in Dutch society during the 1960s and 1970s.

The analysis per province shows that in 1938 and 1963, despite a substantial loss of information, the patterns found at the aggregated level were replicated at provincial level. Inmarriage rates tended to be lower in provinces with a relatively high degree of urbanization/industrialization.

Background and research questions

The study of long-term trends is an important subject for sociologists, and various theories of technological and ideological change (Nisbet 1966, Lenski, Lenski and Nolan 1991) provide numerous testable predictions. Among these are the disappearance of fixed class (Kerr 1960, Kerr 1983) and the downfall of the sacred (Weber 1921, Wilson 1967). In this paper, we test for a trend toward secularity for the Netherlands during the 20th century, using religiously mixed marriages as an indicator.

Of the trends predicted by these theories, that from social stability to social mobility re-

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ceived most attention in quantitative research. Mobility research started out as the determination of percentages of mobile persons within some population. It soon was found that *gross* mobility logically depends upon the size of occupational categories. Mobility research then moved on to study an aspect of a population's mobility pattern that is not dependent on this matter. This facet is the unequal outcome of a competition between persons from different origins for one destination rather than another (Goldthorpe 1980: 77). It was dubbed *relative* mobility.

To answer questions about trends in relative social mobility, recent studies applied special loglinear techniques (Hout 1983 gives an overview). These techniques have also been applied to outmarriage between occupational and educational categories, another indicator for the disappearance of fixed class. Findings on absolute and relative educational heterogamy in 23 industrial countries show that social mixing from the 1950s on became more widespread in one of the most intimate bonds between persons (Ultee and Luijkx 1990).

Given the importance people attach to making a match, the pivotal place of marriage in traditional notions of the sacred, and institutional obstacles against rites celebrating religiously mixed marriages, an increase in religious outmarriage indicates a more peripheral place of religion in social life (Glenn 1982, McCutcheon 1988). Thus the downfall of the sacred can be studied through the indicator religiously mixed marriages, in a manner similar to which social mobility and educational heterogamy inform on the disappearance of fixed class. In fact, early studies supplemented questions on what is now termed gross religious outmarriage with those on relative religious outmarriage (Heer 1962). Until now, loglinear techniques have only been applied to the analysis of religious assortative marriage at one single moment (Johnson 1980).

Focusing on gross religious outmarriage, Heer (1962) found a trend toward less religious inmarriage for Canada between 1922 and 1957, Mol (1973) for Australia between 1891 and 1961, and Glenn (1982) for the United States between 1957 and 1973-1978. However, for the Netherlands Dekker (1965) found an increase in gross religious inmarriage between 1947 and 1960. Interestingly, for the Netherlands it also has been found that the shift away from fixed class was far reaching. Ganzeboom and De Graaf (1984) showed that between 1954 and 1977 gross and relative father-son mobility increased. By way of cohort analysis, Ganzeboom and De Graaf (1989) established that from 1891 to until 1960 father-child relative educational mobility expanded too. Sixma and Ultee (1984) found an increase in gross and relative educational heterogamy between 1959 and 1977. Given these findings, the Netherlands is an instructive choice for questions on trends in relative outmarriage.

In the following paragraphs we present results on relative religious assortative marriage in the Netherlands between 1938 and 1983. For every fifth year a table is analyzed that cross-classifies the denomination of husband against that of wife, for all marriages contracted in the Netherlands during that year. The national trend established, we proceed to an analysis of relative outmarriage in separate Dutch provinces for three of the years involved. We do so in order to check whether aggregation masks trends in relative religious assortative marriage at a lower level. The presentation of our results is preceded by a sharpening of our prediction, using Blau's theory of intergroup relations, and by a discussion of the loglinear models used in mobility research and to apply them to the analysis of religious assortative marriage.

Studying relative religious assortative marriage

Goode (1982: xvii) stated about industrialization as a cause of changes in the family that this term represents a kind of grab bag containing very different kinds of processes. He suggested that if we wish to assert that industrialization has some specific effect, we must specify the process by which it changes the resources at the disposal of the individuals. Blau's (1977) macrostructural theory of intergroup relations, and its later application to outmarriage (Blau and Schwartz 1984) is pertinent here. Of its two postulates, one pertains to the salience individuals attach to parameters of social structure, the other to the favorability of the opportunity structures individuals face. Applied to our analysis, the salience of parameters of the social structure pertains to the barriers between denominational groups, which determines the "demand" for partners of a different religion. The opportunity structures pertain to the substantively less interesting matter of "supply" (i.e. the absence or presence) of partners from other denominations.

BARRIERS AGAINST RELIGIOUS OUTMARRIAGE

According to the social comparison theory, people prefer interaction with persons having the same status and the same opinions as themselves (Festinger 1954). Incompatibility of beliefs seems to be the main reason for choosing a marriage partner with the same denomination. If religion is salient, individual preferences for partners with compatible opinions can cause the formation of groups along religious lines, containing norms against religiously mixed marriages, supported by social control. In addition, formal norms such as church laws can be operative. The 1918 Code of Canon Law of the Roman Catholic Church forbid marriages with members of "an heretical or schismatical sect", which included the Protestant denominations. These regulations were relaxed as of 1966 (Besanceney 1970: 115-123). The (orthodox Protestant) Re-Reformed churches had a similar stand in the Netherlands. The (liberal Protestant) Dutch Reformed church discouraged mixed marriages on the grounds that doctrinal differences thwart marital happiness (Dekker 1965: 116-124).

Finally, beside church laws, civil laws can prevail that strengthen religious inmarriage. In the Netherlands until 1970 the civil code stipulated parental approval for persons marrying under 30 years. If permission was withheld, the period between the proclamation of the bans and the actual registration of the marriage was lengthened.

RELIGIOUS OUTMARRIAGE AND THE "SUPPLY" OF MARRIAGE PARTNERS

Individual preferences for a partner with similar beliefs, together with denominational group norms, form barriers that determine the "demand" for a marriage partner with a different denomination. Blau's theory of intergroup relations examines a set of "supply" factors that also affect the gross rate of outmarriage, and must be taken into account in order to determine the relative rate of outmarriage, which indicates the strength of the barriers between denominational groups.

One important supply factor stipulated by Blau (1977) is size. Members of a large denomination will have less trouble finding another member of their own denomination than will members of a small denomination. Another supply factor (Blau and Schwartz 1984) is spatial dispersion. If denominations are concentrated in different parts of a country, then inmarriage

could appear to be high, even if religious denomination is not salient. These two supply factors must be taken into account when analyzing religious assortative marriage.

PREDICTING A RISE IN RELATIVE RELIGIOUS OUTMARRIAGE FOR THE NETHERLANDS

On the basis of these considerations concerning demand and supply of marriage partners, earlier predictions can be qualified. To the extent that industrialism and democracy weaken the salience of religious denomination and enhance opportunities for contact between different denominations, to that extent will industrialism and democracy be accompanied by a trend toward more religious outmarriage. If democracy and industrialism only increase the supply of persons from another denomination, gross percentages of outmarriage go up, but relative outmarriage not. If industrialism and democracy weaken barriers between denominations, loglinear models will indicate more relative outmarriage.

Several concomitants of industrialism seem to make for more gross religious outmarriage only. For instance, industrialism leads to spatial mobility, and in the Netherlands with its traditional concentration of specific denominations in certain provinces, this makes for more strongly religiously mixed areas. However, at the individual level for those of the old majority religion, this change implies an increased supply of persons with a different denomination. In addition, if industrialism is accompanied by an increase in the percentage of the population stating no religious denomination, the supply of persons with a different faith increases for those with a specific denomination.

On the other hand, there are reasons why industrialization could have brought about an increase in relative religious outmarriage in the Netherlands. Industrialization requires coordinated actions of large heterogeneous groups, enhancing skills for dealing with differences. These skills can carry over into other areas of life. Furthermore, industrialization can limit choices based on "older" criteria. Since inheritance of the family business becomes less important for achievement, parental power to sanction partner choice diminishes.

Changes in the nature of states, although not the introduction of general suffrage or the accountability of a government to a parliament (democratization), can make for more relative religious outmarriage too. The separation of church and state led to civil marriage and lowered the barriers the churches themselves had erected against religious outmarriage. The French revolution brought religious freedom to the Netherlands and after several retreats in the 1960s all churches were blessing religiously mixed marriages. It should be emphasized however that from World War I up until the present day every Dutch government funded schools run by the various religious denominations to the same extent as public schools. Despite well-known changes in the Catholic church, and the disappearance of many organizations with a denominational character, a strong Christian political party remains, and there are still many separate Protestant and Catholic schools. This observation implies that any trend toward more relative religious outmarriage in the Netherlands may be quite weak.

In future research, we hope to test the explanatory power of some of these factors related to technological and ideological changes. At this point, we will use loglinear models such as used in mobility research to examine relative in- and outmarriage in the Netherlands between 1938 and 1983. Conclusions will be checked by an analysis per province.

Loglinear models

We noted above that when ascertaining the extent of religious in- and outmarriage, it is important to cancel out the influence of "supply" factors. Almost all research on religious assortative marriage used the percentage of members of each denomination involved in a mixed marriage. This measure has been found to be unsatisfactory because it ignores the number of potential spouses. The number of potential spouses can be used in the calculation of an expected percentage of mixed marriages, based on the size of each denomination and assuming random mating. Heer (1962) and Glenn (1982, 1984) used a statistic based on the difference between the expected percentage of mixed marriages and the actual percentage to quantify the rate of relative mixed marriages. Mobility research faced a similar problem and tried to solve it in a similar fashion, using the ratio of actual percentage mixed marriages to the expected percentage. However, it was found that this measure was unable to take size adequately into account (see Featherman and Hauser 1978: 141-166; Hout 1983: 16-18).

Mobility research found that the size factor could be canceled using loglinear models (Haberman 1979, Hout 1983, Goodman 1984). The model parameters relating to relative assortative marriages for each combination of denomination groom/denomination bride, are based on the ratio of the number of marriages that have taken place for that combination, and the number of marriages expected on the basis of the sizes of the denominations which constitute that combination. This approach is flexible and powerful, because it can provide statistics for patterns of inmarriage and outmarriage, as well as the incorporation of group variables and tests on differences between groups.

Loglinear models are discussed briefly below, after which the results of models we have tested are presented. For those not interested in these technical details we can say that the best model is one with inmarriage rates that differ per denomination and change over time. Relative outmarriage rates for each year separately can be combined into 6 levels (out of a possible 10). However, because outmarriage rates for some combinations rose in relative frequency while others dropped, the content of these levels varies from year to year, particularly from 1963 onward. These results are discussed in the paragraph "Relative inmarriage and outmarriage between 1938 and 1983".

For a saturated model of a square $R \times R$ frequency table, the observed frequency of cell ij is split up into:

- (a) an overall effect,
- (b) a contribution due to membership of category i of the row variable,
- (c) a contribution due to membership of category j of the column variable,
- (d) a surplus contribution due to membership of both category i and category j .

These contributions are multiplicative, i.e.

$$F_{ij} = [\text{overall}][\text{row}_i][\text{col}_j][\text{row}_i, \text{col}_j] \quad (1)$$
$$= \text{row}_i * \text{col}_j$$

The overall effect is the geometrical average of the table. The first order effects row_i and col_j indicate how much higher or lower than this geometrical average the cell frequency would be, taking the row and column marginals into account. The second order effect $\text{row}_i, \text{col}_j$ indicates the presence of association between the row and column variables, and indicates how much higher or lower the frequency is than would be expected on the basis of the grand total of the table and the row and column marginals. A "*" rather than a "." in a second

(or higher) order parameter indicates that inclusion of the high order effect implies the inclusion of all lower order effects for the variables concerned.

A difficulty in the use of multiplicative parameters is that the ratio between two parameters must be examined to see how much they differ in strength, but we have a tendency to look at differences (subtraction) instead. For this reason, the logarithm of parameters are sometimes reported. We chose to present parameters in the form of plots, using a logarithmic scale.

It is clear that the information given by parameters of a loglinear model can only be in relative terms: restrictions must be placed on each term to make one parameter per subscript redundant. The most common restriction is the deviation contrast, which lets each parameter indicate deviation from the (geometrical) average of the parameters of that effect, so that the product over the parameters of an effect is equal to 1. Another common restriction is the simple contrast, which lets the parameters of an effect be relative to a specific category, by fixing the parameter for that category to 1. Other contrasts are possible to suit the purpose of the analysis (Finn 1974).

The purpose in a two way loglinear analysis would be to test whether all second order parameters row, col , are significant. If dropping the term does not have an overly detrimental effect on the fit of the model, it is removed; otherwise the term as a whole is included. In the case of mobility and comparable analyses, a subsequent step to the detection of association in the table is to attempt to describe it in a parsimonious model, by placing constraints on certain subsets of the second order parameters. This can be done for example by fixing parameters to 1, or by constraining parameters to have equal values. The models for mobility tables make use of the fact that these tables are square, which means that the diagonal of the table shows the extent of immobility (in our case in marriage). Off-diagonal effects are often expressed in relationship to the diagonal cells.

Models with restrictions are not saturated and an L^2 statistic can be calculated based on the expected frequencies found under the restricted model. The L^2 statistic has an asymptotic chi-square distribution with degrees of freedom based on the number of restrictions placed on the model (after the appropriate contrast has been applied). If the data are from an aselect sample of the population, then the probability can be calculated that the model holds in the population. If this probability is large, then the discrepancy between observed and expected frequencies can be ascribed to sampling fluctuations.

A problem in many mobility analyses is that often either a very large sample or the population data are being used. The probability of a model is useless in these situations: the sampling fluctuations are minuscule or (in the latter case) nonexistent. The purpose of the analysis in such situations is not statistical induction, i.e. finding a population model from sample data, but statistical description: describing the relationships in as parsimonious a model as possible, while keeping loss of information low.

Raftery (1986) suggested the *BIC* coefficient as a method of dealing with this problem. This measure is derived from Bayesian statistics and is based on the ratio of the probabilities that two alternative models are true, given their observed counts. The *BIC* statistic is equal to $-2\log(B)$, where B is the ratio of the two probabilities. If the saturated model is taken as the alternative model, then for large samples, the value of *BIC* can be found by:

$$BIC = L^2 - df \ln(N) \quad (2)$$

BIC must be less than 0 for a model to be acceptable. The *BIC* coefficient also allows for a quick assessment of the relative fit of two alternative models: the model with lowest *BIC* value is the best model.

The starting point for the analysis of mobility tables and comparable applications is the independence model. In the case of religious assortative marriage, this model tests whether choice of partner is based on size of the denominations only, i.e. the hypothesis of a random choice of partners. This is a model of overall and first order effects only:

$$F_{ij}=[overall][groom,][bride,] \quad (3)$$

The independence model fits the marginals of the table exactly. The expected frequencies are equal to those used for the calculation of the chi-square statistic of any contingency table: the row sum for category i times the column sum for category j , divided by the grand total. For the independence model, this expected frequency is equal to the product of the overall effect, the first order effect for the row variable and the first order effect for the column variable.

The expected values under the independence models are the values used to calculate the expected percentage of mixed marriages in applications by Heer (1962) and Glenn (1982, 1984). If the L^2 of the independence model is significant, we conclude that there is association between the denomination of the marriage partners. This association can be described by fitting the saturated model, which adds all second order parameters $groom,bride,$ to the independence model. The expected frequencies of this model are equal to the observed frequencies and the L^2 is therefore zero. The second order parameters are equal to the observed frequency divided by an expected frequency based on the overall and first order effects. These expected frequencies are not the same as those found under the independence model however, but are adjusted to take the association between denomination bride/denomination groom into account. Note this important difference between loglinear techniques and earlier methods for correcting the gross percentage of outmarriage by deducting the expected percentage of outmarriage. Loglinear techniques estimate an expected rate under the assumption of a particular pattern of association between the denomination of bride and denomination of groom. Earlier methods based their expected rate on the assumption of random mating, i.e. no association.

The saturated model is not parsimonious and it is usually possible to describe the association in the table using fewer parameters and at the same time to test substantive hypotheses on the patterns of mobility or intermarriage. An adaptation of the independence model is the *quasi-independence* model:

$$F_{ij}=[overall][groom,][bride,][diag,] \quad (3)$$

This model (applied to a square table with R categories) has R parameters $diag,$ for the diagonal cells. The restriction has been applied to the second order terms $groom,bride,$ that parameters for off-diagonal cells have equal values. A simple contrast is applied with these off-diagonal cells as contrast category for the $diag,$ parameters, so that these indicate how much higher each diagonal cell is, compared to off-diagonal cells. Substantively, this model allows for variable rates of inmarriage per denomination by fitting parameters to the diagonal cells of the table. For the off-diagonal cells the independence model applies, which means that there are no preferences for certain combinations of mixed marriage over others.

The quasi-independence model is a rather restricted model, since it fits only R parameters more than the independence model. Several models have been developed in mobility research that have less restrictions than the quasi-independence model (such as the crossings parameter model or scaled models of association) for situations where the quasi-independence model turns out to be overly restrictive. Unfortunately, these models assume ordered categories, but

there is no clear way of ordering religious denominations. One model that does not assume ordered categories, the levels model (Featherman and Hauser 1978) has been widely criticized as indeterminate: different versions with apparently different implications turn out to have the same predicted values (see Hout 1983: 37-51).

We dealt with this problem by using the deviation contrast, so that we could be certain that the meaning of our parameters was appropriate and intentional. We began by fitting a relatively unrestricted model, the *quasi-symmetrical* model. This model only imposes the restriction that the relative frequency of these outmarriages is the same for men and women, i.e. the restriction on the second order parameters $groom_i, bride_j$, that $groom_i, bride_j = groom_j, bride_i$. This symmetrical interaction parameter is indicated by $symint_{ij}$:

$$F_{ij} = [overall][groom_i][bride_j][symint_{ij}] \quad (4)$$

The quasi-symmetry model is not parsimonious. We created parsimonious sub-models by imposing an equality constraint¹ on off-diagonal (outmarriage) parameters with near equal values. The characteristics of the quasi-symmetry model still apply here. The deviation contrast is used so that the product over the parameters for the categories of denomination husband and/or denomination wife equals 1, and the parameters are symmetrical. The result is a levels *restriction*, as opposed to the levels model. We will refer to these effects as $levres_{ij}$. Precisely which parameters have been constrained to equal values will have to be specified for the model in question, since these designs are created on the basis of preliminary results, rather than on a priori considerations.

The trend in religious assortative marriage between 1938 and 1983

DATA

For the analyses below, we used unpublished data of the Dutch bureau of statistics C.B.S. on the religious denomination of bridegroom and bride for marriages. There were six categories of religion: (orthodox Protestant) Re-Reformed, (liberal Protestant) Dutch Reformed, Jewish, other religion, no religion, and Roman Catholic. After the second World War, the number of marriages involving Jews became increasingly small; e.g. in 1960 they formed .13% of the marriages in the Dutch population. Given the rather crude categorization used here, this was irrelevantly small. We therefore decided to drop the category Jews from the analysis. Data prior to 1938 unfortunately neglected to distinguish between the orthodox Protestant Re-Reformed denomination, and the liberal Protestant Dutch Reformed denomination, but there are strong differences between the two, as will be shown below. Information on the denominations of marriage partners was no longer collected after 1986. For the analysis of the trend in religious assortative marriage, we used the tables for the years 1938, 1943, 1948, 1953, 1958, 1963, 1968, 1973, 1978 and 1983.

The category "other denominations" contained 3.6% of the Dutch population in 1960. This category consisted until approximately 1970 predominantly of small Protestant denominations. The largest of these are liberal Protestant and comparable to the Dutch Reformed Church. In recent years, this category contains an increasing proportion of non-Christian denominations. In 1971, Islamics, Hindus and Buddhists formed an estimated .44% of the population; this grew to an estimated 2.2% in 1981 (CBS 1982: 25-32).

Figure 1
The religious composition of the
Netherlands, based on the number of
persons marrying, between 1938 and 1983

Figure 1 shows the size of each denomination used in the analyses, as indicated by the number of marriages in that year. Major alterations have taken place in membership of the Dutch Reformed church, whose membership by this criterion has been steadily decreasing, and “no religion”, whose size has been steadily increasing. The size of the group of Catholics has decreased from a peak in the 1960s, and the category “other denominations” has slightly increased in size from the 1960s on. The size of the Re-Reformed church has remained more or less constant.

“Religious denomination” was self-reported by the couple when applying for a marriage license. It has been shown that the phrasing of the question on denomination considerably influences responses (CBS 1988). Two-phase questions of the type “Do you consider yourself a member of a church or religious group? If so, which one?” measure considerably higher numbers in the “no denomination” category, than one-phase questions that simply ask “Which church or religious group are you a member of?”

The last two bars of figure 1 show the estimated size of each denomination in the population in 1983, using single-phase and two-phase questions respectively. The size of the category “no denomination” increases from 29.9% using a single phase question to 46.8% using a two-phase question. Note also that some denominations are more strongly affected by the phrasing of the question than others. The estimated size of the Catholic (37.2% versus 28.3%) and Reformed (19.8% versus 14.1%) denominations were strongly affected, but that of the Re-Reformed Protestants (9.0% versus 7.6%) or “other denominations” (4.1 versus 3.2) were affected to a much less degree.

Religious denomination in the case of a one-phase question should therefore be interpreted as ingroup identification, and as measured here it contains both marginal and practicing members. This is actually preferable for our purposes, since it makes the category “no denomination” more homogeneous than it would otherwise be, and because we are primarily interested in ingroup identification, rather than the strength of religious beliefs.

MODELS

To begin with we applied 5 standard mobility type models in order to test whether there was association between the denomination of the husband and the denomination of the wife, to determine in general terms the nature of this association, and to test whether the association changed during the period 1938 to 1983. The models were:

- (1) An independence model. This tests the hypothesis that the patterns of choice of partner in the 10 tables can be explained by random choice of partner.
- (2) A quasi-independence model that allows inmarriage parameters per denomination, but does not let these vary with time.
- (3) A quasi-symmetrical model that allows different inmarriage rates per denomination, different outmarriage rates per combination of mixed marriage, but imposes the restriction that these parameters are constant across time. This model and model 2 test for the presence of a trend in religious assortative marriage.
- (4) A quasi-independence model that allows inmarriage parameters to vary per denomination and with time.
- (5) A quasi-symmetrical model that lets inmarriage rates vary per denomination and with time and lets outmarriage rates vary per combination of denominations and with time.
- (6) A model with 6 levels of outmarriage, based on the results of model 5. This model is discussed more fully below.

All models used the deviation contrast for all parameters, except for the term *diag_r*. For reasons explained in the paragraph on mobility models, a simple contrast was used.

The goodness of fit statistics for these models are presented in table 1. The very high L^2 and strongly positive *BIC* value of independence model 1 shows that the association between denomination husband/denomination wife is very strong. The strong drop in L^2 in model 2 for only 5 parameters extra shows that a good deal of this association can be attributed to the propensity to inmarriage. However, model 5 shows that both inmarriage and outmarriage pa-

Table 1
Goodness of fit statistics for models of religious assortative marriage in the Netherlands between 1938 and 1983

Model	L^2	<i>df</i>	<i>BIC</i>
1 [main]	924856	160	922665
2 [main][diag _r]	29279	155	27157
3 [main][symint]	18774	150	16690
4 [main][diag _r *time]	11648	110	10142
5 [main][symint*time]	196	60	-625
6 [main][levres*time]	362	100	-1007

main: [overall][groom*time][bride*time]

diag_r: inmarriage parameter per denomination

symint: symmetrical interaction of denomination partner

levres: symmetrical interaction parameters using the deviation contrast, and restricted to 6 levels of outmarriage. The content of these levels depend on the year concerned; see figure 2 for details

rameters that can vary in time are required to describe the data adequately.

Model 5 has very few restrictions and we therefore attempted to create a more parsimonious submodel by restricting outmarriage parameters to equal values. We had hoped that we would be able to impose a levels restriction that would apply to the entire period 1938-1983. However, an equality constraint on the parameters for the combinations "Reformed:other" and "Reformed:Catholic", which had the closest average values in model 5, increased the L^2 to 807 (70 df) and the BIC to -151. This shows that some outmarriage parameters were rising during this period while others were falling; none had (almost) equal values for most of the period.

Due to this, we had to look at the results of model 5 and create special levels restrictions for each table separately. A 6 levels model was adequate for all tables and for the first 5 years the content of these levels did not change greatly. From 1963 on, crossovers from one level to another are frequent, so that the results, although a great deal simpler than in model 5, still remain rather complex. The levels restriction model number 6 has an L^2 of 362 with 100 df and a BIC value of -1007: a considerable improvement over model 5. The results of this model are discussed in the following paragraph.

RELATIVE INMARRIAGE AND OUTMARRIAGE BETWEEN 1938 AND 1983

The results showed that there is a strong association between denomination husband/denomination wife and that there have been changes in the propensity to both inmarriage and outmarriage between 1938 and 1983. The outmarriage parameters can be restricted to six levels, but the content of the levels shifts, particularly in the second half of the period being examined.

The parameters of model 6 with a six levels restriction on deviation contrast parameters are presented in figure 2. The vertical scale is logarithmic, so that vertical distances correspond with ratios between parameters. Entries in the legend have been sorted according to the (geometrical) average parameter value for all years. Inmarriage parameters have values greater than 1; this means that these combinations occurred more frequently than would be expected by the sizes of the denominations. For example, the value of 22 for members of the Re-Reformed church in 1938 indicates that this combination occurred 22 times more than would be expected, given the size of the denominations in 1938. Outmarriage rates are in most cases less than 1. These values indicate how much less frequently these combinations occurred, than expected on the basis of the main effects. For each year, there are 6 "levels" of outmarriage. In figure 2, the letters for outmarriage combinations that have been restricted to equal values are clustered around the point corresponding with the parameter. Note that although the inmarriage parameters for Catholics and Re-Reformed Protestants have equal values in 1953 and 1958, this is coincidental and not part of our design.

Inmarriage rates were initially very high for members of the Re-Reformed church and for Roman Catholics. Inmarriage rates were low for members of the Dutch Reformed church, while inmarriage for people with no denomination or other denomination were intermediate.

Relative inmarriage for the Re-Reformed church and for Catholics followed the same trend in figure 2: more or less constant until the end of the 1950s, a sharp drop during the 1960s, and a more gradual decline after 1973. Note that the decrease in inmarriage rates for Catholics had already started when the church liberalized its stand on mixed marriages in 1966. Inmarriage among members of the Dutch Reformed Church fluctuated slightly with no apparent trend. The same goes for the category "no denomination", although there is a net increase

Figure 2
Religious assortative marriage in the Netherlands, 1938-1983

Parameters of a quasi-symmetry model using the deviation contrast and restricted to six levels of outmarriage

in inmarriage for this group. Inmarriage among members of "other denominations" increased somewhat until 1953, maintained that level or dropped slightly up to 1968, and then started to rise sharply. This sudden increase is assumably due to the increasing proportion of non-Christian denominations in the category "other denominations". Inmarriage among members of "other denominations" was strongest in 1983 and approached the high levels of Catholics and Re-Reformed in the 40s and 50s.

As for outmarriage, the legend of figure 2 shows that with the exception of the combination "Re-Reformed:Reformed", which was the most frequent type of outmarriage, mixed marriages with members of the Re-Reformed church were least frequent. Mixed marriages with persons of no denomination tended to be frequent (with the exception of the combination

Figure 3

“none:Re-Reformed”) and mixed combinations with members of the liberal Dutch Reformed church formed a middle area of frequency. The mixed combinations involving with Catholics and “other denominations” did not tend to cluster together.

A mixed marriage with a Catholic was (on the average) the least popular form of outmarriage for both Re-Reformed and Dutch Reformed Protestants. These combinations rose in popularity however, particularly the combination "Re-Reformed:Catholic", which had by far the greatest net increase between 1938 and 1983. Mixed combinations involving "other denominations" showed the most changes across time. The combination "other:Catholic" became less frequent from 1938 to 1963, but after that date it began to increase, to a slight net increase in 1983. The remaining combinations involving "other denominations" decreased in popularity (the largest net changes for outmarriage parameters between 1938 and 1983) and were most frequently involved in switches of level. These changes are largely due to shifts in

the content of this category. The frequency of combinations involving the category "no denomination" tended to be the most stable. The combination "other:none" dropped considerably in frequency between 1938 and 1983, but the remaining combinations tended to be fairly stable.

It is interesting to compare the loglinear parameters with the percentage of inmarrying persons. Figure 3 shows the actual percentage and the expected percentage based on random mating, of inmarrying persons per denomination between 1938 and 1983. Inmarriage for Catholics appears to be a good deal higher than for other denominations, but closer inspection shows that this is because the expected percentage of inmarriages, based on the size, is also higher for Catholics. It also appears as though inmarriage rates are the same for members of the Re-Reformed and Dutch Reformed churches, but the expected percentage of inmarriage is about 5% for the small Re-Reformed denomination and falls from 32% in 1938 to 11% in 1983 for the Reformed church. This illustrates how the use of percentages can result in misleading conclusions.

Religious assortative marriage per province

In the preceding analysis, the supply factor size has been effectively canceled out, but the factor spatial dispersion has been ignored. However, the denominations are not evenly distributed in the Netherlands. We can use "province" as a group variable in the loglinear analysis to test whether patterns of religious assortative marriage vary strongly per province. We chose the years 1938, 1963 and 1983 to test whether this is the case. It turned out that there are differences between provinces in assortative marriage patterns in 1938, that the differences were smaller in 1963, and that differences had disappeared in 1983. Although there were differences between provinces, the same pattern found at the aggregated level also applied: mixed marriage combinations that occurred with the same relative frequency for the Netherlands as a whole could also be fixed to equal values in an analysis per province. These results are presented in the next paragraph, following a discussion of the models tested.

Figure 4 shows the religious composition of the Dutch provinces in the years 1938, 1963 and 1983. There are strong differences in composition: the Catholics form a strong majority in the southern provinces Noordbrabant and Limburg, the northern provinces Friesland, Groningen, Drenthe have a Protestant majority and a Catholic minority, and the other provinces are a mix.

We fitted an independence model as a baseline for comparison, several quasi-symmetry models and the quasi-symmetry model using the levels restriction, for a total of 7 models. Models that did not impose restrictions on the interaction between assortative marriage patterns and time can be broken down into conditional models for each year. We found that it was instructive to do so, since this brings to light trends in the differences of assortative marriage patterns between the provinces. The models we tested were:

- (1) An independence model that takes into account the sizes of the denominations in each year and each province. We broke this down into models of conditional independence for each year.
- (2) A quasi-symmetry model with inmarriage parameters for each denomination and out-marriage parameters for each combination. These parameters are identical for all provinces and for each year.

Figure 4
The religious composition of the Dutch provinces
 Based on the number of persons marrying in 1938, 1963 and 1983

Years are arranged from top to bottom
 Total number of marrying persons are shown after each bar

- (3) A quasi-symmetry model with parameters that vary for each province, but are constant for all years.
- (4) A quasi-symmetry model with parameters that vary for each year, but are constant for the provinces. This is a key model; its goodness of fit test is a reasonable indication of whether or not there are substantial differences between provinces. This model was also broken down into conditional quasi-symmetry models for each year.

- (5) A quasi-symmetry model with parameters that vary for each year, and vary for each province. The differences between provinces are restricted to be constant for each of the years (and differences between years are constant for all provinces).
- (6) A quasi-symmetry model with inmarriage parameters that vary for each year and for each province with no further restrictions. This model is broken down into conditional models for each year.
- (7) A quasi-symmetry model with a levels restriction on deviation contrast parameters. The form of the levels restriction is conditional on year, so no restrictions were possible on the time factor.

The goodness of fit statistics for these models are given in table 2. The high L^2 and strongly positive *BIC* value for model 1 shows that there is a strong association between the denominations of marriage partners. A symmetrical interaction effect term in model 2 can strongly reduce the L^2 , even if it is constant for all provinces and each year. Allowing the interaction effect term to vary per province in model 3 improves the fit somewhat, but allowing the interaction effect term to vary per year as in model 4 brings about a much stronger reduction in *BIC*. The model is not acceptable by the *BIC* criterion however, so that we must conclude that there are differences between provinces. The breakdown of the interaction between time and the symmetrical association denomination husband/denomination wife shows that

Table 2
Goodness of fit statistics for models of religious assortative marriage per province

Model	L^2	df	<i>BIC</i>
1 [main]	184237	544	177500
1a [main(1938)]	58224	176	56272
1b [main(1963)]	79440	176	77422
1c [main(1983)]	46574	192	44410
2 [main][symint]	11624	534	5010
3 [main][symint*prov]	7596	424	2345
4 [main][symint*time]	6462	514	96
4a [main][symint(1938)]	3019	166	1178
4b [main][symint(1963)]	2486	166	583
4c [main][symint(1983)]	957	182	-1094
5 [main][symint*prov][symint*time]	1949	404	-3054
6 [main][symint*prov*time]	235	204	-2291
6a [main][symint*prov(1938)]	57	66	-675
6b [main][symint*prov(1963)]	93	66	-663
6c [main][symint*prov(1983)]	85	72	-727
7 [main][levres*prov*time]	693	340	-3518
7a [main][levres*prov(1938)]	273	110	-948
7b [main][levres*prov(1963)]	190	110	-1063
7c [main][levres*prov(1983)]	230	120	-1122

main. [overall][groom*prov*time][bride*prov*time]

symint: symmetrical interaction of denomination partners

levres: symmetrical interaction parameters using the deviation contrast, and restricted to 6 levels of outmarriage. The content of these levels depend on the year concerned, see figure 5 for details

the fit of the conditional models 4a-4c improves as time progresses, and that in 1983 a model with no differences between provinces would be quite acceptable.

Models 5 and 6 allow the association between denomination husband/denomination wife to vary with both province and time. Model 5 restricts the differences between provinces to be identical in each of the years (and the differences between years to be equal for each province), and turns out to be the better model of the two according to the *BIC* criterion. It is worthwhile to compare the breakdown of model 6 into condition models with the breakdown of model 4. Restricting the assortative marriage patterns to be equal for all provinces for the year 1983 results not only in an acceptable model by the *BIC* criterion, but in a preferable model. In 1938 and 1963 however, the differences between provinces are quite substantial.

In model 7 we tested whether the restricted association patterns we found for the Netherlands as a whole were also appropriate for the disaggregated tables. We have seen that the assortative marriage patterns are symmetrical, but parameter values for combinations that were near equal in the aggregated analysis may have strongly disparate values per province. This would mean that an aggregated analysis rather strongly misrepresents reality. However, the strongly negative *BIC* for model 7 shows that the levels restrictions hold for the provinces: the parameter values differ but the pattern remains the same. A breakdown of the fit statistics per province (not reported here) showed that the fit according to the *BIC* criterion improved for each province in each of the years, with the exception of Groningen in 1938.

We can conclude that if differences in inmarriage rates per province are ignored, the loss of information is not insubstantial, although differences between provinces have been reduced in recent years. On the other hand, we do not consider the loss of information caused by ignoring differences between provinces to be so great, as to completely invalidate results found on an aggregate level.

DIFFERENCES BETWEEN PROVINCES

Model 7, the best model of the preceding analyses, indicated that analysis on an aggregated level does misspecify assortative marriage patterns, although these differences diminish as time progresses and had disappeared in 1983. Although inmarriage and outmarriage parameters vary between provinces, the outmarriage *patterns* found with the levels restriction in the aggregated analysis were quite appropriate. The model parameters for assortative marriage patterns in 1938, 1963 and 1983 are presented in figure 5. Readers may have to refer to figure 2 for information on the content of the levels in each of the three years.

Figure 5 shows that inmarriage rates tended to be lower in 1938 and 1963 for the provinces Utrecht, Noordholland, Zuidholland than for other provinces. This was especially pronounced for Catholics and Re-Reformed Protestants in 1938, although the dip does not take place for the Re-Reformed Protestants in 1963 or 1983. There is an unusually high rate of inmarriage for Re-Reformed Protestants in Limburg in 1963, presumably due to random factors, since the Re-Reformed group there is very small.

As for outmarriage, figure 5 shows that the combinations Reformed:Catholic and other:Catholic were relatively infrequent in the northern, Protestant provinces Groningen, Friesland, Drenthe, Overijssel in 1938 and 1963. These combinations were relatively high in provinces with a Catholic majority Noordbrabant and Limburg. The outmarriage parameter for the combination Re-Reformed:Catholic fluctuates somewhat more erratically, but tended to be relatively high in Utrecht, Noordholland and Zuidholland, and relatively low elsewhere.

Figure 5
Religious assortative marriage per Dutch province,
for the years 1938, 1963 and 1983

Parameters of a quasi-symmetry model using the deviation contrast and
restricted to six levels of outmarriage

Utrecht, Noordholland and Zuidholland have in common a relatively high rate of spatial mobility, indicating that this could be a factor which negatively influences inmarriage tendencies. They are also relatively urbanized and industrialized, which could contribute to mobility or affect inmarriage independently. It is interesting to note that inmarriage rates in Flevoland in 1983 also have the low rate found in Utrecht, Noordholland and Zuidholland. Flevoland has an agricultural economic base, but as a new province on recently reclaimed land, there is of course a very high degree of spatial mobility. This shows that disaggregation can bring to light contextual factors such as spacial mobility, urbanization, industrialization, that affect inmarriage rates. Hypotheses on the effects of these factors will be explicitly tested in future analyses.

Conclusions

In this paper we took religious outmarriage as an indicator of a more peripheral place of religion in social life, and examined whether a trend towards less religious inmarriage was present from the end of the 1930s until the early 1980s in the Netherlands. A theoretical examination of the causes of assortative marriage led to the conclusion that on the one hand, inmarriage is the result of barriers between denominational groups. Individual preferences for partners with similar attitudes influence the formation of homogenous groups. In such groups with a religious identity, differences in sub-culture can develop into an us/them mentality and into norms encouraging inmarriage and discouraging or forbidding outmarriage. Besides barriers between denominational groups, a second group of factors influencing inmarriage can be supply factors: size and regional concentration. Research on religious assortative marriage in the past often failed to deal properly with these supply factors and were therefore unable to show the strength of barriers to outmarriage.

Loglinear models are able to eliminate the influence of supply factors such as size and spatial dispersion, and provide parameters relating to both inmarriage and outmarriage rates. The results provided qualified support for a long-term trend to the levelling of barriers against religious outmarriage in the Netherlands. For members of the Roman Catholic and orthodox Protestant Re-Reformed churches, inmarriage rates fell strongly from the 1960s on. However, there was no trend discernable from 1938 to 1958. There was also no trend toward less inmarriage for members of the liberal Protestant Dutch Reformed church or in the category "no denomination". Inmarriage for the category "other denominations" rose strongly in the 1970s, probably due to an increase in the number of members of non-Christian denominations such as Islamics in this category. This limits any hypothesis about persistent trends.

The decline in inmarriage for Re-Reformed Protestants closely followed that for Catholics. It is interesting that for the latter denomination, with historically more strict church norms and sanctions, relative outmarriage turned out to be more widespread than for the former denomination. The fact that the trends run parallel indicates that a common factor broke down the ingroup orientation of both Catholics and Re-Reformed Protestants.

The trend toward lower inmarriage rates for Roman Catholics and Re-Reformed Protestants held for the whole of the Netherlands as well as for its provinces. The provinces with the lowest rates of inmarriage were the western ones. This finding gives impetus to applying loglinear models explicitly including such factors as urbanization.

The limited evidence of a trend toward less inmarriage does not square with earlier findings on other countries, such as those for Canada (Heer 1962), Australia (Mol 1973), and the

United States (Glenn 1982). The importance of distinguishing orthodox Protestants from liberal Protestants found by McCutcheon (1988) was confirmed, although interestingly McCutcheon found no change in outmarriage for conservative Protestants and more outmarriage among liberal Protestant denominations. This finding that gross outmarriage was lower for Catholics than for Re-Reformed Protestants and relative outmarriage higher, indicates that the technical possibility of misleading results can indeed occur. Re-analysis of the data for other countries could show whether the Netherlands is indeed a deviant case with respect to the trend in assortative marriage. This places questions about differences between countries with respect to trends in religious assortative marriage high on the agenda of those interested in secularization.

Notes

¹ Estimation of models such as this require a program such as GLIM or SPSS LOGLINEAR, that use a design matrix, rather than the iterative proportional fitting algorithm (IPF) used by SPSS HILOGLINEAR, ECTA, BMDP4F. In general, an equality constraint can be imposed on parameters by adding the column of the design matrix for one parameter to that of the other. A difficulty when deviation contrast parameters are used is that certain parameters are redundant: they are not estimated directly but can be calculated afterwards, since the product over the parameters equals 1. It is possible to impose restrictions on redundant parameters, but these manipulations are rather arduous.

We circumvented this problem by defining the parameters on the diagonal as the redundant parameters for the symmetrical interaction effects, since we were primarily interested in imposing constraints on outmarriage parameters. We used SAS PROC IML to generate the design matrix for symmetrical interaction and GLIM to estimate the models. The data and programs used in our analyses are available from John Hendrickx, Department of Sociology, University of Nijmegen, Postbox 9108, 6500 HK Nijmegen, The Netherlands (E-mail u211310@hnykun11.urc.kun.nl).

Chapter 3

Modernization and Religious Assortative Marriage: Explanatory Models for Regional Variations in the Netherlands, 1938-1986

Abstract

In this chapter, religious assortative marriage in the Netherlands will be analyzed by province and by size of the municipality in which the marriage takes place. This will make it possible to address two questions:

- 1 How does the spatial dispersion of religious denominations in the Netherlands affect religious assortative marriage?*
- 2 How do different explanations for the varying propensities to religious assortative marriage fair in empirical tests?*

It has been argued that measures of relative homogamy should control for effects of group size on absolute homogamy rates. However, if the dispersion of the groups over different regions is uneven, then the size effects as determined at an aggregate level will not accurately represent the marriage market at different regional levels. For this reason, an analysis of religious inmarriage by province could give very different results compared to an analysis at the national level only.

Question 1 therefore relates to the accurate description of patterns and trends of religious assortative marriage. Question 2 moves on to the sociologically more interesting problem of explaining variations in religious assortative marriage. An earlier analysis in chapter 2 showed that religious assortative marriage varies by province, and it was hypothesized that aspects of modernization, such as urbanization, spatial mobility, economic structure, could explain these differences. By using aspects of modernization as covariates in loglinear models, it is possible to test to whether modernization can indeed explain differences in religious assortative marriage between provinces and through time. The availability of data on religious assortative marriage by municipal size allows for an even more powerful test of the effects of urbanization on marriage patterns.

The results show that parameters for religious assortative marriage, controlling for province, are nearly identical to parameters for an analysis on national level data only. Religious inmarriage varies with time and province, but the social proximities between denominations are constant for both. Three explanatory variables performed well at explaining differences between provinces (conditional on year of marriage) in inmarriage propensity:

- *Migration, relative to the land area of the provinces. Particularly migration to and from the province had the strongest effects; immigration from, or emigration to a foreign country were of secondary importance.*
- *The occupational structure of provinces.*
- *The mean income per capita.*

As predicted, religious inmarriage was lower for provinces where migration is higher. There was some evidence that religious inmarriage was higher where agricultural occupations were prominent, and lower where service occupations were prominent. The effects of occupational structure on religious inmarriage were relatively complex and difficult to interpret, however. A higher mean income in provinces is also associated with lower religious inmarriage.

A test was also made to determine whether these covariates also affected changes in inmarriage through time. Migration, occupational structure, and mean income all performed equally well at explaining inmarriage by table, i.e. by both province and time. Tests were also run to determine how well the covariates performed at explaining only variations through time only, and for explaining only variations by province (the effects of the covariates on variations by province were now constant through time, whereas in the earlier analysis the effects were conditional per year). Migration performed rather poorly at explaining variations of inmarriage through time only, although it did well at explaining variations by province. Occupational structure was the best explanatory variable for variations by province and through time separately. Mean income performed poorly at explaining variations by province, and intermediately at explaining the trend of religious inmarriage.

Although the covariates for urbanization and population density did not perform well at explaining variations by province in inmarriage propensity, the analysis of religious assortative marriage by municipal size showed strong effects. The social proximities between denominations were constant for time and size, but inmarriage propensities varied with time, size and time/size combination. Religious inmarriage becomes lower as the municipality in which it takes place is larger. Catholic inmarriage was especially strongly affected by municipal size during the early years of the time series.

Introduction

In previous work (Hendrickx, Lammers, Ultee 1989 and chapter 2), it was found that religious assortative marriage in the Netherlands was strong, but that it had decreased sharply in the 1960s and 1970s, and had still not reached a stable level during the 1980s. The interpretation of this trend was that aspects of modernization, such as industrialization, urbanization, spatial mobility, had caused a weakening of the barriers between religious denominations. There was also some evidence to back up this interpretation. In chapter 2 it was shown that religious inmarriage in the Netherlands was lower in the provinces Noordholland, Zuidholland and Utrecht, which are characterized by high degrees of industrialization, spatial mobility, and urbanization.

In this chapter, explicit tests will be used to ascertain whether certain aspects of modernization can indeed explain the differences in inmarriage propensity between provinces. This will be done through the use of covariates for spatial mobility, occupational structure, urbanization, prosperity, mean level of education, and religious composition of provinces. Ultee and Luijkx (1990) used explanatory variables as covariates in models of educational assorta-

tive marriage and occupational mobility, and Ganzeboom, Luijkx, Treiman (1989) made use of explanatory variables in occupational mobility models. In addition, an analysis of religious assortative marriage by municipal size (5 categories) by year of marriage will provide an even more powerful test of the influence of this factor.

Before dealing with the explanatory models however, the problem of spatial dispersion is to be addressed in a more adequate fashion than was done in chapter 2. At that point, tests showed that that religious assortative marriage did indeed vary by province, but it was argued that these variations were not so strong as to make results found at the national level invalid. However, what ought to be determined is whether the parameters from an analysis at the national level differ strongly for those found in an analysis at the provincial level. For this reason, this chapter will begin with an analysis of the trend in religious assortative marriage at the national level. This can then be used as a base of comparison for models at the provincial level and for the analysis per category of municipal size.

In summary, the outline of this chapter is as follows. It begins with a brief discussion of religious assortative marriage and the factors affecting it. After a description of the data and an outline of the modelling techniques used here, an analysis of religious assortative marriage at the national level is presented. The results from this are then compared with those of a descriptive analysis at the provincial level. Having ascertained the influence of spatial dispersion on measures of religious assortative marriage, the chapter moves on to the explanatory models. The covariates are described and hypotheses are presented on the way in which each should affect religious assortative marriage. The effects of the covariates are then tested, first for variations of religious inmarriage by province only, then on variations of inmarriage by province and through time. Since no satisfactory covariate was available for urbanization, this chapter ends with an analysis of religious assortative marriage by municipal size and year of marriage.

Studying religious assortative marriage

BACKGROUND

Religion in Dutch society

Since its independence from Spain in 1648, the Netherlands has been a predominantly Protestant nation with a large Roman Catholic segment¹. There has been a good deal of tension between the two churches, but overt conflict was infrequent. The Dutch Reformed Church came into being during the 16th century as an attempt to reform the Catholic church along Calvinist guidelines. It provided the ideological foundation for the rebellion against Spain and became the official Dutch Church after the war of independence. The Dutch Reformed church remained the State church until the Napoleonic occupation of the Netherlands from 1795 to 1813. It tended to tolerance and liberalism, although there were minority groups who felt it was becoming overly humanistic and betraying its historical roots. In the 19th century, this led to the secession of several groups to orthodox Protestant Reformed churches (Impeta 1964, Peters and Schreuder 1987).

The Roman Catholic church was outlawed after the war of independence against Spain: the Episcopal hierarchy was disbanded and Catholics were barred from office. However, freedom of religion was unofficially tolerated. The 19th century gradually brought an end to discrimi-

nation of Catholics: the French occupation in 1795 brought freedom of religion, and the Episcopal hierarchy was restored in 1853.

The restoration of the Episcopal hierarchy was the result of co-operation between the Catholics and the liberals, which culminated in the Constitutional Change of 1848. Afterwards, they became opponents and Catholics and Re-Reformed Protestants began to co-operate in a struggle for separate organizations. This began with the struggle for separate schools, but after this goal had been achieved in the constitution of 1917, the struggle went on for other separate organizations. The result was the Dutch system of pillarization, in which there were separate organizations for Catholics, orthodox Protestants, liberal Protestants, socialists and liberals, in every field imaginable.

Pillarization

Bax (1988) and Pennings (1991) contain overviews of theories on the rise of pillarization. Bax discerns four theories: emancipation, protection, social control, and consociational democracy. Pennings adds a group of modernization theories, including the one put forward by Bax. The emancipation theory contends that Catholics and members of the Re-Reformed denominations (who were recruited in large part from the lower economic strata), created the system as a path to social esteem and equality. The protection theory posits that pillarization was caused by the churches in order to protect their flocks against the forces of secularization and modernization. The social control approach sees pillarization as a means for the elites to exercise social control, by providing services such as health care, schooling, which would bind their members more closely to them. The consociational democracy theory (Lijphart 1968) holds that pillarization served to maintain the peaceful coexistence, since it separated the different groups, while contacts between the elites of each pillar allowed for the necessary coordination.

The modernization theory is a modification of the social control theory (modernization is discussed more fully below). Bax (1988) notes that a de-centralized structure with contacts between the elites was a traditional method of social control in the Republican days between the 17th and the 19th century. Loyalty was ensured by extending favours such as public offices. The growth of a centralized state and processes of modernization such as urbanization and an enlargement of scale of industry, made this untenable. After the extension of franchise following the constitutional reform of 1848, the elites became more accountable to, and dependent on, the rank and file. Given the old system of "living apart, together", binding the public to a religious (or socialist) ideology was a natural step for the new elites who arose to challenge the liberals after 1848. Modernization also provided the means for organizing the masses in new ideologically based organizations, through new developments in the realm of communication and transportation.

Bax notes that each theory has some explanatory power, and his theory of modernization combines elements of the protection theory and the social control theory. An effect of pillarization was that the masses were isolated from each other, which strengthened the barriers between religious denominations. But religious assortative marriage is also itself an aspect of pillarization at the individual level, as opposed to organizational pillarization. Kruijt (1957) treated "intranubium" (religious inmarriage) as an indicator of individual pillarization, along with other behaviors such as business relationships and friendships within the religious group. This ties in closely with the treatment in stratification theory of assortative marriage along other dimensions as an indicator of the openness of society.

The purpose of studying assortative marriage patterns is to gain information on the openness of society in some respect. The more often marriages take place between members of two groups, the more frequent contacts of a more superficial nature, such as friendship or business contacts, are likely to be. A classic example is "triple melting-pot" study, by Kennedy (1944). On the basis of marriage data, Kennedy showed that although immigrant groups did assimilate in the United States, this assimilation took place within the three religious groups: Catholicism, Protestantism, and Judaism.

Examples of other recent studies of assortative marriage are Hout (1982) and Smits, Ultee, Lammers (1993) on occupational assortative marriage, Pagnini and Morgan (1990) on ethnic assortative marriage, Sixma and Ultee (1984), Ultee and Luijkx (1990), Mare (1991), on educational assortative marriage, Johnson (1980), Hendrickx, Lammers, Ultee (1989), and Hayes (1991) on religious assortative marriage. Kalmijn (1991b) contains an interesting simultaneous analysis of religious and educational assortative marriage in the United States; Kalmijn (1991a) also contains simultaneous analyses of educational and class based assortative marriage and of educational and ethnic assortative marriage. The latter is able to address the questions raised by Kennedy in a much more satisfactory manner.

What these recent studies have in common is that they make use of special loglinear modelling techniques to derive measures of *relative* assortative marriage. These models are able to remedy certain shortcomings of earlier measures based simply on percentages. As explained in chapter 2, assortative marriage patterns are the results of "barrier factors" and of "supply factors". The latter are not related to individual selection processes and it is therefore an important advantage of loglinear techniques that they are able to separate the two.

Barrier factors comprise individual preferences, social norms and sanctions, and physical segregation of groups. Individuals tend to prefer interaction partners with similar attitudes and opinions. This is taken as a premise by Blau (1977) and Blau and Schwartz (1984); it has also been the subject of social psychological research (social comparison theory: Festinger 1947, Suls and Miller 1977).

There can also be social norms restricting interactions with members of other groups. Often these will be of an informal nature, but there are also instances of formal laws, such as the law of the Catholic church until 1966, which forbid mixed marriages. Personal preferences and group norms can influence each other: individuals can move to other groups, or a large enough group of dissidents could either bring about a change in norms or create their own new group.

The family can play an important role in the enforcement of group norms. For one thing, relationships with family members will be harder to break than other types of relationships. Parents also often provided some sort of dowry or were in other ways of material assistance in setting up a new household. In other cases, there could be an inheritance, particularly when parents had a farm or were the owners of a shop or a small enterprise. These factors provided parents with sanctions if undesirable partner choices threatened, and in any case made their wishes difficult to ignore.

A third barrier factor is the physical segregation of groups. In the Dutch case, tensions between religious denominations gave rise to a system of pillarization, with separate organizations for religious groups. Kruijt (1957) treated religious assortative marriage as an indicator of pillarization at the individual level, in contrast to pillarization at the organizational level.

These barrier factors are all related to the attitudes of individuals toward other groups. The choice of partner can also be influenced by a group of "supply factors", which are independent on feelings, prejudices, etc. toward other groups. A first supply factor is the relative sizes of the groups. If a group is relatively large, then there will be more contacts of that group with other groups, even if partners are not selected on the basis of group characteristics. A second supply factor, which receives special attention here, is spatial dispersion². If the groups are unequally distributed over different regions of a country, then an analysis at the national level will misspecify the sizes of the denominations. The solution is to analyze assortative marriage within smaller geographical units such as provinces. These units must of course not be too small, either. In that case, the group sizes per unit will not adequately reflect the marriage market either, since people will often look to other units nearby, if the ideal partner is scarce within their own geographical unit.

FACTORS AFFECTING RELIGIOUS ASSORTATIVE MARRIAGE

Secularization

The purpose of this chapter is to explain changes in religious assortative marriage which had been found in Hendrickx, Lammers, Ultee (1989) and in chapter 2. A first important factor is the secularization of Dutch society. Felling, Peters, Schreuder (1991) show religion is a complex phenomenon and that aspects of religion, such as worldview, church involvement, and salience of beliefs, are correlated, but independent. The process of secularization entails a shift away from the Christian worldview, lower degrees of church involvement, a reduced salience of beliefs. The results they present of research on secularization between 1960 and 1985 show that all these processes occurred, with the largest shifts between 1966 and 1979, and smaller changes between 1979 and 1985. Dutch society became less and less of a Christian nation, in all aspects of religiosity³.

If secularization led only to a decline in church membership, then it would relate only to changes in group size, a supply factor, and not to changes in the barriers between religious denominations. However, religious attitudes such as shifts in worldview and salience of religious beliefs also occurred for members with a high degree of church involvement, so that secularization would also weaken the barriers between religious groups.

Church involvement as an aspect of secularization has particularly interesting relationships with religious assortative marriage, since it is related to the criterion for determining the partners' denominations. The data used below incorporates a rough measure of church involvement through the use of the category "no denomination". The church involvement scale used by Felling, Peters, Schreuder (1991) sub-divides the unchurched into those of the second generation, the unchurched of the first generation who have never been members, and unchurched of the first generation who are ex-members. Church members can be sub-divided into marginal members (attend church less than once a month), modal members (attend regularly) and core members (also take part in special church activities).

It can be expected that religious assortative marriage will be different for practising members (modal and core members) than for marginal members. For marginal members, group pressures and sanctions will carry little weight, and although religion may be an important dimension of marriage partner, it will have to compete with other dimensions such as education (cf. Kalmijn 1991, and chapter 4). Unfortunately, the data used in these analyses does not allow for a distinction between practising and non-practising members. In fact, denominations

contain a large proportion of ex-members. C.B.S. (1982) showed that if a two-phase question is used in which respondents are first asked whether they have a religion, then if so, which, a much larger category "no denomination" is found than with a single-phase question, where the respondent is simply asked as to his/her denomination. The data used below is the self-reported denomination of marriage partners when applying for a marriage license, which is equivalent to a single-phase question.

Table 1
Sizes of the religious denominations between 1930 and 1985 (percentages)

year	source	Re-Reformed	Reformed	other	none	Catholic
1930	census	9.4	34.5	5.3	14.4	36.4
1947	census	9.7	31.1	3.7	17.1	38.5
1960	census	9.3	28.3	3.6	18.3	40.4
1971	census	9.4	23.5	3.1	23.6	40.4
1975	estimated [†]	9.3	24.5	4.4	23.7	39.4
1980	estimated [†]	9.0	22.5	4.6	26.3	38.8
1985	estimated [†]	8.7	20.5	4.8	29.6	37.6

† C.B.S. 1988

Table 1 shows changes in the sizes of the denominations between 1930 and 1985. It shows that there has been a strong growth in the size of the category "no denomination". This was largely to the cost of the liberal Reformed Protestants. This is due in part to low fertility in this group (C.B.S. 1988). The reduction in size of orthodox Re-Reformed Protestants and Catholics was a good deal smaller.

The growth of the category "no denomination" and the shrinking of the religious denominations relate to changes in church involvement as an aspect of secularization. Since they regard the sizes of groups, they will not affect the measures of religious assortative marriage, since these control for supply factors. However, the shrinking size of the denominations could cause the remaining members to feel that their religion is in danger, and thus lead to a greater solidarity among them. Group membership could become more salient and pressures on others to marry within the group could increase. Another possibility is that attitudes such as worldview or salience of beliefs become more important and denominational boundaries less so. However, earlier work in chapter 2 did show that inmarriage tended to be higher in provinces where the denomination was a small minority.

Changes in church involvement as a result of secularization is also indicated by a declining proportion of practising members within each denomination. Table 2 shows the decline in the percentage practising members for each denomination between 1970 and 1985. The greater the change in the percentage practising members, the greater the change in religious inmarriage can be expected to be.

Note that a comparison of percentages between denominations can be misleading, due to differences in norms with regard to church attendance. The high percentage of practising Re-Reformed Protestants suggests that for them the decline in church involvement started only after 1970. However, for Re-Reformed Protestants, the norm was attendance twice on Sunday. Dekker (1992) shows that church attendance has declined for Re-Reformed Protestants as well. On the average in 1954, 54% of the church members attended the morn-

Table 2
Percentage of the members of each denomination that attends church more than once a month

	Re-Reformed	Reformed	other	Catholic
1970	98.9	36.2	55.8	69.4
1975	84.9	35.9	61.4	60.7
1980	80.0	35.1	65.2	51.8
1985	75.9	34.1	68.8	43.4

Estimated values; see C.B.S. 1988

ing service and 49% the afternoon service. In 1969, the percentages were 47% and 33% respectively, and in 1984 they were 40% and 17%.

Table 2 shows a strong decline in the percentage practising members for Re-Reformed Protestants and for Catholics. The changes for Reformed Protestants were relatively slight. The percentage practising members for "other denominations" increased quite strongly. This category is composed of small Protestant denominations on the one hand, and of Hindus and Islamics on the other. The number of Islamics and Hindus has increased because of immigrants from (ex-) colonies and guest workers. The increase in the percentage practising members is presumably due to the influx of Islamic and Hindu guest workers and immigrants.

Depillarization

From the 1960s on, a process of depillarization set in. Religious organizations disappeared or merged with others. The organizations that remained tended not to stress their religious identities. Since religious assortative marriage is an indicator for the degree of individual pillarization, the causes of depillarization are closely tied to changes in religious assortative marriage. There are important differences, however. Organizational pillarization had a dynamic of its own. Kruijt and Goddijn (1962) found that organizational pillarization had continued to grow until 1960, but analyses of religious assortative marriage would indicate that individual pillarization started to wane in the mid 1950s (Hendrickx, Lammers, Ultee 1989 and chapter 2). Organizational depillarization will also lead to an increase in contacts between denominations and thus promote individual depillarization.

Secularization is one important cause of depillarization. As religion took an increasingly less important place in people's lives, the legitimacy of the system of pillarized organizations weakened. The democratic ideology increased in prominence during the 1960s: social control of the masses through pillarized organizations became less feasible. However, both of these processes are to some extent due to the modernization of society.

Bax (1988) argues that modernization of Dutch society, of which democratization and secularization are aspects, led to the process of depillarization. This seems paradoxical, since Bax also posited that the rise of pillarization in the 19th century was an integral part of the process of Dutch modernization. Bax explains this with an "inverted U-curve" theory: the onset of modernization at the end of the 19th century led to the rise of pillarization⁴, but an increasingly higher degrees of modernization after the Second World War led to depillarization. In any case, the key role of modernization warrants a more detailed examination.

Modernization

"Modernization" is a complex concept which entails social changes due to economic changes, resulting from technical developments (Kerr 1983). Important aspects of modernization are an increase of the scale of the economy, shifts from agricultural occupation to industrial and service occupations, higher levels of education, bureaucratization and a formalization of social relationships, greater urbanization, higher social and spatial mobility. This shows that modernization is something of a catch-all term. What these factors have in common is that they emanate from technological and economic developments, and that they widen the individual's ideological horizon and/or his autonomy from outside influences.

The often noted shift from ascription to achievement as a result of modernization can be seen as a widening of the individual's ideological horizon. The individual's autonomy was also increased, in that certain outcomes were no longer dependent on factors beyond his/her control. Evaluations based on ascribed characteristics such as family background or religion are not compatible with efficient business practises. As enterprises became larger, the necessity for formal, bureaucratic standards of evaluation became increasingly prominent. The achievement standard also tended to permeate attitudes in other areas of life. This led to a decrease in individual pillarization, and therefore also diminished the support for pillarized organizations.

Several factors related to modernization made offspring less dependent on their parents. This increased their autonomy, giving them wider scope to make their own decisions with regard to a marriage partner. This greater autonomy also made social control by pillarized organizations less tenable. Economic developments led to a decline in agricultural and small business enterprises, leading to less inheritance of family business, which increases the autonomy of the individual. An increase in social mobility shows that offspring's outcomes were less and less dependent on the parents' influence. The increase in social mobility is due to spread of mass education, which would of course also directly widen the individual's ideological horizon.

The rise of the welfare state is an important factor in reducing the individual's dependency on family and neighbourhood. This reduced the ability of the individual's social network to sanction behavior it disapproves of. The rise of the welfare state also reduced the influence of pillarized organizations, which had previously been responsible for financial assistance to the needy. An increase in per capita income also reduced dependence on primary relations.

It was noted above that education directly widened the individual's ideological horizon. Several aspects of modernization lead to an increase in contacts between members of different groups, which will indirectly widen the ideological horizon (Blau and Schwartz 1984). Greater urbanization is one of the foremost causes of an increase of the number and diversity of contacts. In addition, larger urban communities tend to be more "anonymous" than smaller towns, i.e. there is less social control in larger cities. The increase in intergenerational social mobility, alluded to above, as well as increased intragenerational social mobility, further promoted contacts between different groups. Spatial mobility would have the same effect. In addition, all forms of mobility would weaken family ties and other primary relationships and thus reduce social control.

Data

The data were unpublished tables collected by the Dutch Bureau of Statistics C.B.S. The religious denomination of bride and bridegroom were noted when they requested a marriage license. Six denominations were distinguished: (orthodox Protestant) Re-Reformed, (liberal Protestant) Dutch Reformed, other denomination, no denomination, Catholic and Jew.

A report by the C.B.S. (1982) shows that for single-phase questions such as this, a much smaller group of persons with no denomination is found, than when the respondent is asked whether he/she has a denomination, and if so, which (two-phase question). In 1981, the size of the category "none" would be 27% using a single-phase question, but 44% using a two-phase question. Apparently, many ex-members report their former religion when confronted with a single-phase question, but classify themselves as having no denomination, if this is asked explicitly in a two-phase question. Since the partners' denominations were self-reported, the data can be regarded as being based on a single-phase question.

This means that each denomination will contain a portion of ex-members as well as a portion of marginal, rarely practising members. Ideally, a distinction should be made between practising members and the loosely associated marginal members and ex-members. As it is, it is preferable that ex-members who nevertheless identify with their former religious group are treated as "members", rather than persons with no denomination. Ex-members can nevertheless have a strong propensity to inmarriage due to group identification. Future research on the impact of church involvement would be very desirable.

The marriage tables were sub-specified per province and by size of municipality, for the years 1938 to 1986 (excluding 1945). There were 11 provinces until the 1960s, when inhabitants of the land reclaimed from the sea in the "Zuidelijke IJsselmeerpolders" were included. This later became the province "Flevoland". The remaining 11 provinces are: "Groningen", "Friesland", "Drenthe", "Overijssel", "Gelderland", "Utrecht", "Noordholland", "Zuidholland", "Zeeland", "Noordbrabant", "Limburg". Seven years were selected at 8 year intervals, starting at 1938: 1938, 1946, 1954, 1962, 1970, 1978, 1986. The choice of 7 years was based on practical considerations: a larger number of years would cost a prohibitive amount of computer time.

The number of marriages in the new 12th province "Flevoland" were only substantial in the years 1970 and 1986, and therefore Flevoland was excluded from the analyses (1256 of the marriages in the selected years were in Flevoland). The Jewish category was too small to be included in an analysis by year of marriage and by province, so it was also excluded (2183 of the marriages in the selected years involved Jewish husbands, 1948 involved Jewish wives). The analyses were therefore performed on a 5 by 5 by 11 by 7 table of denomination husband by denomination wife by province by year of marriage. There were therefore 1925 cells, for a total of 649904 cases (3887 cases, or .6%, had been deleted).

Methods

It noted above that individual preferences for interaction partners with similar opinions and status, together with group norms, result in barriers to contacts between members of different groups, and that beside these "barrier" factors are "supply" factors such as relative size and spatial dispersion, which determine the gross number of contacts between groups. It has been found that loglinear models are able to incorporate the factor relative size in the main effect

parameters, so that interaction effect parameters relate to the strength of contact barriers. Furthermore, special restrictions can be imposed on the interaction effects in order to test specific hypotheses on assortative marriage patterns. A simple discussion of loglinear models can be found in chapter 2. Featherman and Hauser (1978: 141-166) discuss the shortcomings of earlier methods based on percentages and Hout (1983) gives an overview of types of special mobility designs.

SPECIAL DESIGNS

The designs for loglinear models used here differ from those typically used in mobility research, in that use is made of the "deviation contrast", i.e. the restriction that parameters sum to zero. This provides a parameter for each cell of the table, resulting in measures for each type of inmarriage and each type of outmarriage. In order to gain further insights in the nature of the associations, the interaction term can be redefined into three separate sub-terms (see chapter 8 for a technical discussion):

- 1 **Diagonal parameters.** These parameters map the space between a model of independence and a model of quasi-independence. A model of independence would imply that choice of marriage partner is made without regard to the partner's denomination. A model of quasi-independence would imply that there is a preference for a partner with the same denomination, but that in the event of a mixed marriage, there is no preference for one denomination over another. The diagonal parameters therefore indicate the propensity to inmarriage of each denomination.

Diagonal parameters are used in most types of mobility models, usually in the "quasi" versions such as quasi-independence, quasi-uniform association. As usually estimated⁵, these parameters indicate the log odds between inmarriage in that category, and outmarriage. However, the deviation contrast is used for these parameters as well, in order to keep the interpretation consistent. This results in a square table of interaction parameters, for which off-diagonal values are determined by values on the diagonal. Of course, only the diagonal "inmarriage" parameters are relevant to the interpretation.

In the results, a further distinction of diagonal parameters will sometimes be made:

- a **Overall diagonal.** Simply the average of the diagonal parameters.
 - b **Diagonal deviations.** The deviations from the overall diagonal parameter.
- 2 **Symmetric deviances.** These parameters map the space between a quasi-independence model and a quasi-symmetry model. The former model implies that in the event of outmarriage, there is no preference for one denomination over another, whereas the quasi-symmetry model implies that there are differences in preference if outmarriage takes place. The symmetric deviances therefore indicate the extra attraction/aversion between categories, in the event of outmarriage. This makes them suitable measures of social proximity. The diagonal parameters plus the symmetric deviances give the symmetric interaction parameters, using the deviation contrast.
 - 3 **Skew symmetry.** These map the space between a quasi-symmetry and a saturated model (Yamaguchi 1990, Sobel, Hout, Duncan 1985). They indicate for which cells the effects are not symmetric, providing information on male/female differences in preferences for outmarriage. Fortunately, the association in the models below is symmetric, which simplifies the interpretation.

In the analysis below, certain sub-terms can be held constant across time or province while letting others vary. In this way, it is possible both to describe the data more parsimoniously and to gain substantive insights.

A problem when analyzing large numbers is that the probability of a model, based on its L^2 and df , is almost always significant, since sample fluctuations are negligible or non-existent. A solution to this is the use of the BIC measure (Raftery, 1986):

$BIC = L^2 - df \cdot \ln(N)$, where N is the sample size.

This measure is derived from Bayesian statistics and is based on the ratio of the probabilities that two models are true, given their observed counts. In the standard situation, where the saturated model is used as baseline, BIC must be less than zero for the model to be more likely than the saturated model. In a comparison between two models, the one with the most negative BIC is preferable. BIC will be used to guide the choice of model in the analyses below.

Analyses

ANALYSES WITH TIME EFFECTS ONLY

One of the purposes of this chapter is to determine whether it could be misleading to conduct analysis at the national level only. An analysis at the national level is able to control for differences in the sizes of the religious categories at the national level, but not for their unequal dispersion over different regions. In the case of the Netherlands, the Catholics are a large majority in the two southern provinces Noordbrabant and Limburg, but are much smaller groups in other provinces. This could conceivably affect the results so strongly that analyses at a national level would provide only a distorted picture, possibly to the point of making the results misinformative.

To answer this question, religious assortative marriage will first be analyzed at the national level. The results of this analysis will be compared later to parameters from an analysis at provincial level. By comparing parameters at the national level with parameters, controlling for province, it can be determined whether controlling for spatial dispersion as well as differences in group sizes will affect the results.

Table 3

Goodness of fit statistics for models for religious assortative marriage by year of marriage, 1938 to 1986 (analysis with time effects only)

	L^2	df	BIC
1 independence	686033	112	684534
2 constant diagonal parameters, no symmetric deviances parameters	22781	107	21349
3 constant diagonal and symmetric deviances parameters	15179	102	13813
4 variable diagonal parameters, no symmetric deviances parameters	8608	77	7577
5 variable diagonal parameters, constant symmetric deviances parameters	497	72	-466
6 variable diagonal and symmetric deviances parameters	174	42	-388

Table 3 contains the goodness of fit statistics for the analysis at the national level. Model (1) is a model of conditional independence within each year in the analysis. Acceptance of this model would imply that religion is not a factor of influence in the choice of marriage partner. The large L^2 and BIC statistics show that there is a strong association between the denominations of marriage partners. Model (2) adds diagonal parameters to model (1). This would mean that religious denominations have a preference for inmarriage which did not vary during this period. However, if mixed marriages take place, there would be no preference for one denomination over the other. This results in a strong drop in L^2 , at the cost of only 5 *df*. Model (3) modifies model (2) by allowing for different social proximities between denominations. These social proximities are constant across time as well. This leads to a lower L^2 , but the BIC statistic is still strongly positive, indicating that important changes did take place.

Model (4) is a modification of model (2), allowing the inmarriage preference to vary, but not allowing for different social proximities between denominations. It is again an improvement, but the model fit remains unacceptable by the BIC criterion. Model (5) turns out to have the best fit by the BIC criterion, by allowing the inmarriage propensity to vary with time and also allowing for different social proximities between denominations, but restricting these to be constant across time. Allowing the social proximities to vary as well, as in model (6), leads to a lower L^2 , but according to the BIC criterion, this improvement does not offset the cost of *df*, since the BIC statistic increases.

Parameter estimates

The final model was model (5). It indicates that there are different social proximities between the different denominations, but that these do not vary with time. Interestingly, the social proximities between the denominations are the same for men and women. However, the inmarriage preference of the denominations does vary through time. It may seem somewhat surprising that the processes of depillarization during the 1960s and 1970s have not changed the social proximities of denominations. It must be kept in mind however, that the social proximity measures are independent of ingroup preferences, and that they are relative to one another. Changes in them would imply e.g. that Catholics came to prefer Reformed Protestants more than persons with no denomination. Shifts of this nature have evidently not been very strong. Note that because the diagonal parameters do change, that there will indeed be more outmarriage (controlling for size effects), as found in Hendrickx, Lammers, Ultee (1989) and in chapter 2. However, these changes in the relative frequency of outmarriage will be dictated by the changes in the propensities to inmarriage.

Table 4 presents the parameter estimates of this model, controlling for the time effects. Values on the diagonal of table 4 are diagonal parameters indicating inmarriage preference. The orthodox Protestant Re-Reformed denomination is the most closed group, followed by the Catholics. The liberal Protestant Reformed denomination has the greatest willingness to engage a mixed marriage, and the categories "no denomination" and "other denomination" are somewhere in between.

Values in the upper triangle of table 4 are symmetric deviances parameters, indicating the social proximities between denominations. The parameters show that when mixed marriages occur, Re-Reformed Protestants strongly prefer Reformed Protestants, are neutral with regard to marriages with members of "other denominations", have an aversion to marriages with persons with no denomination and an even stronger aversion to marriages with Catholics.

Table 4

Parameter estimates, controlling for time effects, of model 5 in table 3 (analysis with time effects only)

Husband's denomination	Wife's denomination				
	Re-Reformed	Reformed	other	none	Catholic
Re-Reformed	2.628	.501	-.039	-.172	-.289
Reformed	.067	1.101	.198	-.210	-.093
other	-.769	-.419	1.991	.118	.119
none	-.779	-.308	-.277	1.622	.293
Catholic	-1.147	-.442	-.527	-.259	2.374

Values on the diagonal are diagonal parameters (the overall diagonal parameter is 1.943)

Values in the upper triangle are symmetric deviances parameters

Values in the lower triangle are symmetric interaction parameters

The liberal Reformed Protestants also have an overwhelming preference for marriage with Re-Reformed Protestants, are only slightly adverse to marriages with Catholics with and have nearly the same aversion to marriages with persons with "other denomination" or "no denomination".

Catholics prefer marriages with persons of no denomination, followed in the second place by persons with "other denomination". As has been seen above, they have only a slight aversion to marriage with Reformed Protestants, but a strong aversion to marriages with Re-Reformed Protestants.

Members of other denominations have an equal preference for marriages with Catholics or persons with no denomination, are neutral with regard to Re-Reformed Protestants, and are adverse to marriage with Reformed Protestants. Persons with no denomination prefer to marry Catholics, with members of other denominations as second preference, are adverse to marriage with Re-Reformed Protestants, but even more strongly so to marriage with liberal Reformed Protestants.

The preferences of the category "other denominations" are somewhat remarkable. This group is composed on the one hand of small Protestant denominations other than the Calvinist Reformed and Re-Reformed denominations, and of non-Christian denominations such as Islam and Hindu on the other. Conflicting tendencies could therefore be expected to result in symmetric deviances parameter values of near zero for this category (neutral social proximity). If anything, the Protestant contingent in "other denominations" would lead to attraction to the Re-Reformed and Reformed denominations, and aversion to Catholics. The results do not bear this out, however.

The lower triangle of table 2 contains symmetric interaction parameters. These indicate the frequency of mixed marriages, controlling for size effects, but do not take into consideration to what extent mixed marriage is due to a preference for the own group and to what extent it is due to attraction or aversion between groups. These parameters are presented for the convenience of those interested. However, the symmetric deviances parameters are considered to be of greater relevance.

The final model indicated that the symmetric deviances parameters were constant through time, but that the diagonal parameters were not. Figure 1 shows the innmarriage trend through-

Figure 1
The Inmarriage trend between
1938 and 1986
National level analysis

out this period. The chart uses multiplicative parameter values, with a logarithmic axis. The use of a logarithmic axis makes an increase in parameter value by a constant factor correspond with a constant vertical distance. The vertical axis values therefore indicate how many times more frequent inmarriage in a denomination was, than expected on the basis of the size effects parameters.

Figure 1 shows that Re-Reformed and Catholic inmarriage rates started very high, but dropped strongly after 1962 in an almost parallel trend. Reformed inmarriage changed very little. Inmarriage in the category "no denomination" dropped steadily from 1938 to 1978, then rose again sharply in 1986. Inmarriage in the category "other denominations" rose to a new level after the Second World War, was stable until 1970, but began to rise sharply after that. This increase can presumably be attributed to the increase in the proportion of members of non-Christian religions, such as Islamics and Hindus (cf. C.B.S. 1982a).

The question arises of whether the changes in inmarriage preferences might be attributed to shifts within the denominations in religious attitudes. Felling, Peters, Schreuder (1991) compare results from their own surveys in 1979 and 1985 with results from earlier surveys in 1966 (Zegers, Dekker, Peters 1967) and 1979 (Goddijn, Smets, Van Tillo 1979). Catholics, Reformed Protestants, and Re-Reformed Protestants were compared with regard to church attendance, pillarization mentality and behaviour, worldview, and salience of beliefs.

A correspondence analysis showed that in 1966, Catholics were in between Re-Reformed and Reformed Protestants with regard to secularized attitudes. Catholics showed the largest shifts in attitudes between 1966 and 1979, and in 1979 they had become the most secularized of the three denominations. The Reformed and Re-Reformed denominations had shifts toward more secular attitudes of approximately the same magnitude. Shifts between 1979 and 1985

were smaller, and of a similar magnitude for the three denominations. So if changes in religious inmarriage were related solely to changes in religious attitudes, then there would have been a downward trend in religious inmarriage for Reformed Protestants, and the shift for Catholics would have been stronger and would have brought their inmarriage propensity below that of Reformed Protestants.

RELIGIOUS ASSORTATIVE MARRIAGE BY PROVINCE AND YEAR OF MARRIAGE

In this paragraph, the question to be addressed is whether religious assortative marriage varies by province as well as by year of marriage and if so, whether it varies by province/year combination as well (which would mean a four-way interaction). By comparing parameter values which control for the effects of province with the parameters from the above analysis at the national level, the impact of controlling for spatial dispersion on religious assortative marriage can also be determined.

Table 5 contains the models used for the analysis of religious assortative marriage by province and year of marriage. Models (1) to (5) did not use special designs and could therefore be estimated using SPSS HILOGLINEAR, which uses the fast "Iterative Proportional Fitting" (IPF) algorithm.

Model (1) is a model of independence of the partners' denominations, within each subtable of province and year of marriage. The fit is very poor, as may be expected. Model (2) allows for assortative marriage, but restricts it to be constant through time and across provinces. This

Table 5
Goodness of fit statistics for models of religious assortative marriage by province and year of marriage (1938-1986)

	L^2	df	BIC
1 conditional independence	502045	1232	485552
2 assortative marriage constant for time and province	31823	1216	15544
3 assortative marriage constant for province, variable with time	16807	1120	1813
4 assortative marriage constant for time, variable with province	20894	1056	6757
5 assortative marriage variable with time and province, but not with time/province combinations (no 4-way interaction)	4313	960	-8539
6 symmetric interaction, variable with time and province	4487	1062	-9731
7 symmetric deviances parameters constant for time, variable with province; diagonal parameters variable with time and province	4818	1092	-9801
8 symmetric deviances parameters constant for provinces, variable with time; diagonal parameters variable with time and province	5312	1112	-9867
9 symmetric deviances parameters constant for time and province; diagonal parameters variable with time and province	5321	1142	-9967
10 as (9), but diagonal parameters vary by province/year combination as well (4-way interaction)	1792	842	-9480

Models (1) to (5) were fitted using SPSS HILOGLINEAR (IPF algorithm)
All other models were fitted using GLIM 3 77

greatly reduces L^2 , but the model fit is still very poor. Models (3) and (4) compare the strength of the association of religious assortative marriage with year of marriage and province respectively. The considerably higher value of BIC for model (4) shows that religious assortative marriage varies more strongly by year of marriage than by province. Allowing religious assortative marriage to vary both by province and year of marriage, as in model (5), is necessary to achieve a negative BIC. The fact that BIC is negative for model (5) means that it is preferable to the saturated model, which would also allow marriage patterns to vary by year/province combination.

The remaining models in table (5) imposed special restrictions on some of the interaction effects. Model (6) shows that the restriction of symmetric interaction considerably improves the model fit, as in the analysis at the national level. In model (7), it is tested whether the social proximities were constant through time, in model (8) whether they were constant across provinces, and in model (9) whether they were constant across both. The results show that social proximities between denominations were constant across both time and province (model (9)), which considerably simplifies the interpretation of results. Model (9) had the best fit of any model and was accepted as the final model⁶.

Model (10), tested for the presence of a 4-way interaction in which homogamy also varied for each province/year combination. A 4-way interaction might be expected if processes of modernization were to remove differences between provinces in religious inmarriage. Model (5) had indicated that a 4-way interaction was not substantial by the BIC criterion, but this forms a more powerful test. It turns out that model (10) is not an improvement over model (9) in terms of BIC. There is therefore no evidence here of a process of convergence between provinces with respect to their degree of openness⁷.

Parameter estimates⁸

Model (9) indicated that the social proximities between the denominations were constant through time and across provinces. The inmarriage propensity on the other hand, did vary both by year of marriage and by province. In this paragraph, the parameter estimates of model (9) are presented and compared to the estimates from the analysis at the national level.

Table 6 contains the parameter estimates for model (9), controlling for time and province effects. A comparison with table 4 above shows that the values are all quite close. An index of dissimilarity Δ was used, defined as the sum of the absolute differences between relevant parameters, divided by their number (i.e. 10 for the symmetric deviances, 5 for the diagonal parameters). The Δ for the inmarriage parameters on the diagonal is .085. Inmarriage in the categories "no denomination" and "other denomination" was underestimated in the analysis with only time effects by .154 and .109 respectively; Catholic inmarriage was overestimated by .105. The social proximity parameters in the upper-triangle are even closer: Δ is .036 and the maximum difference is -.068, for Re-Reformed:Reformed marriages. The Δ between the symmetry parameters in the lower triangle of table 4 and those in table 6 is .047; the maximum difference is -.112, for "other": "none" marriages.

As for the homogamy trend, the Δ for the parameters for inmarriage by year of marriage was .019 between the analyses with and without province effects; the largest difference was -.070, for Catholic inmarriage in 1986. Since these differences were so small, figure 1 also gives an accurate representation of the trends of religious inmarriage, controlling for province. Generally speaking, the low Δ values both for parameters controlling for time and for trend parameters, indicate that controlling for spatial dispersion by including province in

Table 6

Parameter estimates, controlling for the effects of time and province, of model 9 in table 5

Husband's denomination	Wife's denomination				
	Re-Reformed	Reformed	other	none	Catholic
Re-Reformed	2.604	.433	-.002	-.180	-.251
Reformed	.009	1.137	-.140	-.190	-.103
other	-.747	-.396	2.100	.079	.063
none	-.816	-.337	-.389	1.776	.290
Catholic	-1.051	-.414	-.569	-.234	2.269

Values on the diagonal are diagonal parameters (the overall diagonal parameter is 1.977)

Values in the upper triangle are symmetric deviances parameters

Values in the lower triangle are symmetric interaction parameters

the analysis does not strongly alter the results. For the Netherlands, results from a national level analysis are not distorted.

A comparison of models (3) and (4) in table 5 had shown that religious assortative marriage varies more strongly with time than across provinces. However, it can also be interesting to see how inmarriage parameters per denomination are affected by the variables time and province. An appropriate measure for this is the variance⁹ of the loglinear parameters through time and across provinces, which are reported in table 7. Inmarriage in the category "other denomination" varied the most strongly through time, followed by Catholic inmarriage. Inmarriage in the category "no denomination" varied most strongly across provinces, followed by Catholic inmarriage. Reformed inmarriage barely varied at all.

By examining the variations of inmarriage by province, insights can be gained into some of the factors affecting religious assortative marriage. Table 8 presents parameters for inmarriage per province, controlling for time effects. The first column of table 8 contains the overall diagonal parameter per province, indicating how much higher or lower inmarriage was in that province, controlling for the trend in homogamy. The urbanized, industrialized provinces Noordholland, Zuidholland and Utrecht have strongly negative values for the overall diagonal parameter, indicating that inmarriage was much lower in these provinces. The overall diagonal parameter for Zeeland is also negative, which is surprising, since Zeeland has nothing in common with the three urban/industrial provinces, other than geographical proximity. Overall inmarriage tended to be higher in northern, predominantly Protestant provinces such as Groningen, Overijssel, Drenthe. On the other hand, overall inmarriage was near average in Friesland and was not much higher than aver-

Table 7

Variance of the diagonal parameters, in the analysis of religious assortative marriage by province and year of marriage

	through time	across provinces
Re-Reformed	.078	.021
Reformed	.008	.003
other	.188	.014
none	.042	.040
Catholic	.158	.027

Table 8

Parameter estimates of the effects of province on inmarriage, controlling for time

	overall diag- onal	Re- Reformed	Reformed	other	none	Catholic
Groningen	.248	.039	.147	-.017	-.141	-.028
Friesland	.080	-.314	-.017	-.047	.076	.302
Drenthe	.189	.036	-.025	.141	-.273	.121
Overijssel	.202	-.008	.008	.022	-.182	.159
Gelderland	.135	-.046	-.033	-.040	.086	.032
Utrecht	-.268	.161	-.036	.102	-.058	-.169
Noordholland	-.353	.251	-.010	-.023	-.145	-.073
Zuidholland	-.320	.074	.042	.158	-.012	-.263
Zeeland	-.107	-.054	-.090	.050	-.016	.110
Noordbrabant	.088	-.181	.036	-.054	.174	.025
Limburg	.107	.043	-.022	-.294	.490	-.216

age in Gelderland. Overall inmarriage was slightly higher than average in the southern, predominantly Catholic provinces Noordbrabant and Limburg.

Columns 2 to 6 of table 8 contain "diagonal deviation" parameters for each denomination. The parameter for a particular denomination indicates how much higher the inmarriage propensity for that denomination was compared to the overall inmarriage propensity, for each province and controlling for time effects. These parameters therefore sum to zero over the five denominations. Groningen appears to have had relatively weak effects on inmarriage per denomination. In Friesland, Catholic inmarriage was much higher, and Re-Reformed inmarriage was much lower than the overall inmarriage propensity. Drenthe and Overijssel had similar patterns: Catholic inmarriage was higher, and inmarriage in the category "none" was lower. As in chapter 2, there is evidence that Catholic inmarriage was higher in the northern, Protestant provinces, although Groningen and Friesland are exceptions.

The urban, industrial provinces Utrecht, Noordholland and Zuidholland did not affect inmarriage per denomination in the same manner. Re-Reformed inmarriage was higher in all three, but not by a substantial amount in the case of Zuidholland. Catholic inmarriage was lower, but not by a substantial amount in the case of Noordholland. Reformed inmarriage was not substantially affected in any of the three provinces. Inmarriage in the category "other" was higher in Zuidholland and Utrecht, but slightly lower in Noordholland. Inmarriage in the category "none" was substantially lower in Noordholland, but was not substantially different from the overall inmarriage parameter in Utrecht or Zuidholland.

The province Zeeland did not have a strong influence on inmarriage in any denomination. In the predominantly Catholic Noordbrabant, Re-Reformed inmarriage was lower, and inmarriage in the category "none" was higher. Re-Reformed inmarriage was not substantially higher in Limburg either, which does not accord well with the hypothesis that inmarriage will be higher in provinces where the denomination is a minority (see also the explicit test of this hypothesis in the following paragraph). Interestingly, inmarriage in the category "none" was much higher in Limburg – the strongest effect of a province on religious inmarriage. Contrary

to popular conception, which holds that people in Limburg are "more papal than the Pope", Catholic inmarriage in that province was substantially lower than average.

The effects of province on religious inmarriage per denomination can in some cases change the rank of denominations with regard to openness. In table 6, it was shown that, controlling for time and province, the Reformed Protestants had rank 1 with regard to openness. The category "none" had rank 2, the category "other" rank 3, Catholics had rank 4 and Re-Reformed Protestants had rank 5. Adding the diagonal parameters of table 6 plus the overall diagonal parameter of table 8 to the diagonal deviation parameters in columns 2 to 6 of table 8 would give the conditional diagonal parameters per province, controlling for time. It then turns out that Reformed Protestants retained rank 1 for all provinces. Catholics and Re-Reformed Protestants would switch ranks in Friesland. In Utrecht and Zuidholland on the other hand, Catholics would switch ranks with "other" making the Catholics the third most open group in these provinces. In Limburg, the category "none" would advance two places in openness, making it the second most closed group (after Re-Reformed Protestants), rather than the second most open group, as it is in all other provinces. In all the other provinces, the rank order with regard to openness would remain the same.

EXPLAINING RELIGIOUS ASSORTATIVE MARRIAGE

The analyses up to this point have been purely descriptive. In the theoretical section, it was argued that processes of secularization and modernization can explain the trend toward less religious inmarriage. This could be tested by incorporating explanatory variables related to modernization as covariates for explaining the trend. Using explanatory variables to explain a trend might entail the risk of finding spurious relationships. There have been many changes during the period under examination, and if these run more or less parallel to (or, on the contrary, are a mirror of) the trend of religious inmarriage, explanatory variables might perform well, without actually being causes of change. This danger could be reduced by examining as long a period as possible, and by a strong theoretical justification for the effect of explanatory variables.

An alternative open to us is to use explanatory variables for explaining differences in religious inmarriage between provinces, and for the trend of religious inmarriage within each province. The fact that inmarriage is lower in the provinces Noordholland, Zuidholland and Utrecht, suggests that characteristics of these provinces, such as high urbanization, an industrialized economy, a high rate of spatial mobility, will be important factors influencing religious inmarriage (cf. chapter 2). The provinces of the Netherlands show an unequal economic development, so that some provinces are in effect more "modern" than others. This provides a more powerful test for the explanatory power of covariates for modernization processes. There are more measurement points, since each year is multiplied by 11 provinces. In addition, it is less likely that explanatory variables will correspond with differences in inmarriage between provinces for spurious reasons. Some processes may just happen to run parallel to trends in religious assortative marriage, but it is unlikely that processes will just happen to correspond with variations by province.

This approach does have two disadvantages. Explanatory variables for provinces are more difficult to procure than variables at the national level. However, it was possible to procure variables for many important aspects of modernization. A second disadvantage is that aspects of modernization such as the spread of education and the rise of the welfare state are the results of intervention by the central government, as opposed to autonomously operating eco-

nomie processes. The State will treat all provinces equally, so that these explanatory variables may explain changes through time only, and perform poorly with regard to variations by province.

The covariate measures

In the following, the explanatory power of 6 groups of variables will be tested: spatial mobility, occupational structure, urbanization, prosperity, religious composition, and education. A total of 29 variables from these 6 groups were entered as covariates in loglinear models of religious assortative marriage by province. The selection of explanatory variables was by necessity dependent on which variables constituted acceptable operationalizations of aspects of modernization and were available at the provincial level.

Suitable covariates could be found for several key aspects of modernization. Aspects that could not be included were growth in the size of organizations, an increase in social mobility, the rise of the welfare state. Satisfactory measures of urbanization were also only available for the last two years in the analysis. Fortunately, this can be compensated in the following paragraph, by analyzing religious assortative marriage by municipal size and year of marriage.

Many statistics on the Dutch provinces can be found in the C.B.S. publication "*Regionaal statistisch zakboek ...*" (RSZ), published in 1972, 1974, 1977, 1980, 1982, 1984, 1986 and 1989. Information on publications related to regional data for the period before 1972 is available from "*Inventarisatie van regionaal-statistische gegevens 1946-1970*". An important source was census data, for the years 1930, 1947, 1960 and 1971 (no censuses were held after 1971). The covariate data and their sources are reported below.

Spatial mobility

Data on spatial mobility is available from 1953 to the present¹⁰. Source prior to 1972 is the C.B.S. publication "*Bevolking der gemeenten van Nederland op ...*", published annually from 1920 on. The RSZ is used for the period after 1972. Both publications report: (1) persons migrating to each province, (2) persons migrating from each province, (3) persons immigrating from a foreign country to each province, (4) persons emigrating to a foreign country from each province.

The more migration takes place, the greater the number and diversity of contacts in the population. This should lead to a widening of the individual's ideological horizon. In addition, migration weakens family ties and alters the individual's social network, which will increase his/her autonomy.

Two factors could conceivably mediate in the effects of migration on religious assortative marriage. The larger a province, the likelier it is that someone will move to it, all other things being equal. Similarly, the greater the population of a province, the more likely it is that someone will move from it. Three sets of measures based on migration were therefore constructed:

- absolute migration
 - a migration to
 - b migration from
 - c immigration
 - d emigration
- migration per km²
 - a migration to/km²
 - b migration from/km²

- c immigration/km²
- d emigration/km²
- migration per head of the population.
 - a migration to/population
 - b migration from/population
 - c immigration/population
 - d emigration/population

The four components of migration were entered into the analysis both as a single set and separately. On the one hand, the focus is on spatial mobility as such; on the other hand, it is interesting to know which component of migration is responsible for an effect. The foreign/domestic source of migration can also be used to test the hypothesis that the increase in religious heterogamy is not so much a result of increased tolerance as a shift in reference. The Netherlands after the Second World War became a multi-cultural society, with immigrants from ex-colonies and "guest" workers from southern Europe. Compared to the cultural differences with these groups, the distinctions between the religious groups may have been perceived by the Dutch as increasingly irrelevant. If groups of foreign extraction have replaced domestic religious denominations as the perceived outgroup, then immigration will be strongly related to a decrease in homogamy, but domestic migration will have a much smaller effect. If domestic migration has effects of the same magnitude or stronger than immigration, then it could be concluded that contact frequency is the causal factor.

Occupational structure

Data were available on the number of men and women working in 4 economic sectors: (1) agriculture and fishing, (2) mining, manufacturing, construction, public utilities, (3) commerce, banking, insurance, transportation, communication, (4) other services. This information was available from the censuses of 1930, 1947 and 1960, and from the RSZ from 1971 to 1984. The following measure was constructed:

- occupational structure: percentage of persons working in each sector. This introduces a linear dependency, so the effects were made to sum to zero and the value for category (1) was determined afterwards.

As an alternative operationalization, the percentage employed in each sector was also entered separately into the analysis:

- % employed in agriculture, etc.
- % employed in manufacturing, etc.
- % employed in services, etc.
- % employed in transportation, etc.

The occupational structure variable gives a complete picture of occupations in a province, whereas the "% employed" variables contrast each sector against the rest.

A shift away from agricultural occupations corresponds with a continuing shift away from a traditional society toward a modern, industrialized society. The decline of agricultural occupations is something of a general indicator of modernization, although this shift only directly affects the autonomy of the small group of farmers' offspring. The growth of the industrial sector is generally held responsible for the shift from ascription standards to achievement standards. However, the rise of service occupations can be seen as an indication of enlargement of scale. As industry becomes more efficient, it can produce more with fewer employees, and the labour market shifts toward service occupations. Enlargement of scale means that

smaller family businesses will disappear, and also entails the rise of formal, bureaucratic standards of evaluation.

Urbanization

It was difficult to find an appropriate measure of urbanization. Population density was used as an approximate measure:

- population density (persons per km²).

This was available from 1931 to 1972 in "*Bevolking der gemeenten van Nederland op ...*". The RSZ reported it after 1972. A higher population density means a larger number of contacts between individuals, which will lead to a widening of their ideological horizons.

The RSZ provided the percentage of the population living in (1) rural municipalities, (2) industrialized rural municipalities, (3) urban communities, as a measure of urbanization. This was transformed to:

- urbanization: percentage living in the three categories of urbanized municipalities. The effects were constrained to sum to zero; category (1) was treated as the redundant category.

Urbanization should affect religious inmarriage for the same reason that population density does: it leads to an increase in contacts. In addition however, there tends to be a greater amount of social control in relatively isolated rural communities. Unfortunately, information on urbanization was not available prior to 1971. However, the analysis of religious inmarriage by municipal size in the following paragraph will provide a more powerful test of the effects of urbanization on religious assortative marriage.

Mean income per capita

Income was available as measured as the average income per head of the population (or per tax-payer) per province, from the C.B.S. publication "*Inkomens verdeling ...: regionale gegevens*" for the years 1946, 1955, 1958, 1960, 1963 and 1969, and from the RSZ after 1972. In order to correct for inflation, the income statistic was divided by the consumer price index for the worker families, from the C.B.S. publication "*Negentig jaren statistiek in tijdsreeksen*". This resulted in the following measures:

- corrected income per capita: the mean income per capita per province, divided by the consumer price index for that year.

The higher the income per capita, the lower the dependence of individuals on primary relations, and hence the greater their autonomy. The mean income per capita of a province is of course a very rough measure. Effects of spatial mobility or the occupational structure will be contextual effects, that should affect the population of a province as a whole. Income per capita on the other hand, can be expected to work primarily at the individual level: a poor man living in a wealthy province will be as dependent on others as a poor man living a poor province.

Education

Information on the number of academics per province was available from the censuses of 1930, 1947, 1960 and 1971. Using these data, a measure of academics per 100000 was constructed for each province. However, this was a somewhat unsatisfactory measure, since academics can be expected to be more secular than average. Of greater interest is the percentage of the population with more than elementary education. Primary education teaches basic skills

such as reading and writing, but secondary education provides a much wider range of ideas, which can be expected to influence the individual's ideological horizon.

The censuses of 1930 and 1947 contained information on academics only. The proportion with more than elementary education was only available from the censuses of 1960 and 1971. The C.B.S. also provided us with a table of level of education by province, from the "*Arbeidskrachten telling 1985*"¹¹.

In this fashion, two measures were derived:

- academics per 100000
- percentage with more than elementary education

Religious composition

In chapter 2, it was hypothesized that homogamy might be higher for denominations in provinces where they are a minority. Denominations who form a minority might feel threatened, which would lead to heightened ingroup salience. This variable therefore differs from the others, in that it is not related to aspects of modernization.

Information on the religious composition of provinces was only available from the census of 1930, 1947, 1960 and 1971. However, information on religious composition can also be derived from the tables of religious assortative marriage. This will reflect a particular segment of the population of the province, corresponding roughly with the 20 to 29 age group. Thus, two measures were created:

- religious profiles based on population data. This contained the percentage of the province's population that was a member of each denomination. Effects were constrained to sum to zero; Catholics were used as the redundant category.
- religious profiles based on marriage tables. As above, but based on the tables data.

These measures are used to test whether the sizes of the denominations affect religious in-marriage for all denominations. As an alternative operationalization, a test was also performed for the effect of a denomination's size on the inmarriage *within that denomination only*. This was done using both population data and marriage tables data.

- size of denomination (population data). This tests whether the size of each denomination affects the religious inmarriage of that denomination.
- size of denomination (tables data). Ibid., using marriage tables.

Effects of the covariates on inmarriage by province

The procedure for using covariates as explanatory variables in a loglinear analysis is to start with a "baseline model", in which there is no variation of the inmarriage parameters by province. An interaction effect of the inmarriage parameters with the covariate is then entered and the improvement of fit noted. This fit will be better than that of the baseline model, but worse than that of a "full effects model", which simply describes the variation of inmarriage by province. The more the variations of the covariate values correspond with the variations of inmarriage by province, the better the improvement of fit will be.

A problem with the covariate data used here was that series had different first and last dates and were published at different intervals. The problem of gaps was solved by interpolating the data at a 3 year lag from the date of marriage. Most gaps were small, so this procedure should be sufficiently accurate. It was not considered useful to attempt to extrapolate the se-

ries forward or backward however. The analyses were therefore performed only for the years for which the covariate was available.

Two sets of analyses were performed using explanatory variables: first on variations in inmarriage by province only, then on variations by both province and year of marriage. Testing for the effects of covariates on variations by province could be done by fitting the model on subtables for each year for which the covariate was available (the effect of the covariate could therefore change from year to year). The fit statistics can then be added to derive the fit of the model for the period in which the covariate was available. This had the advantage that computer time was greatly reduced. Also, testing the explanatory power of covariates on provinces only would allow us to detect effects in cases where the covariate performed poorly at explaining changes through time. A disadvantage is that the models are not as parsimonious as they might be, since they must allow the symmetric deviances parameters to vary with time.

Having found covariates that performed well in explaining variations in inmarriage by province, it was then tested to what extent these could explain variations by table, i.e. variations by province, year, and province/year combination. As noted earlier, it is unlikely that a covariate will perform well at explaining variations of inmarriage by province for spurious reasons. Given that the covariate is an aspect of modernization related to variations in religious inmarriage by province, there will be no danger of finding spurious effects in a subsequent test of its effects on the trend of religious inmarriage.

Table 9 contains the goodness of fit statistics for the covariate models on the variation of inmarriage by province. Since the covariates are available for different periods, there are several different baseline models and full effects models. There are two options for evaluating the fit of the covariate models: by looking at the *improvement* in fit over that of the baseline model, or the *divergence* in fit from that of the full effects model. However, the longer the period, the greater the association of inmarriage by province, and thus the greater the room for improvement by a covariate model (see table A.1 in appendix A for fit statistics on baseline models and full effects models for the different periods). By focusing on the BIC divergence statistic, this problem can be avoided, since BIC takes differences in the number of cases and degrees of freedom for covariate models relating to different periods into account.

Table 9 reports the improvement of the covariate model's L^2 and BIC over those of the baseline model for which the covariate was available, as well as the divergence of its L^2 and BIC over those of the corresponding full effects model. The last column of table 9 reports the rank of the model's BIC divergence value. In addition to table A.1 with the baseline models and full effects models for the different periods, appendix A contains table A.2 with the L^2 values of the covariate models for each year separately, and table A.3 with the BIC values for each year.

It turned out that 7 covariate models performed so well that their BIC values were actually lower than the BIC values of the corresponding full effects models. These models, which are underlined in table 9, are migration/km² (6), "migration to/km²" (7) and "migration from/km²" (8), migration/population (11), immigration/population (14), occupational structure (16), and corrected income per capita/GNP (23). Of the 7 best fitting covariate models, 5 are related to migration. Models (7) and (8) are effects of components of migration/km² (6), and model (14) is a component of migration/population (11).

Table 9

Goodness of fit statistics for models of the effects of covariates on the variation of inmarriage by province, conditional for year of marriage

	Covariate	Period	Model			Improvement		Divergence		rank
			L^2	df	BIC	L^2	BIC	L^2	BIC	
1	migration, absolute	62-86	2563	584	-4958	-4914	-3884	1712	167	10
2	migration to (abs)	62-86	4890	644	-3404	-2587	-2330	4039	1721	21
3	migration from (abs)	62-86	4760	644	-3533	-2717	-2459	3910	1592	19
4	immigration (abs)	62-86	4301	644	-3992	-3176	-2918	3451	1133	17
5	emigration (abs)	62-86	4456	644	-3837	-3021	-2764	3605	1287	18
6	<u>migration/km²</u>	62-86	2045	584	-5476	-5433	-4402	1194	-351	2
7	<u>migration to/km²</u>	62-86	2778	644	-5515	-4699	-4442	1928	-390	1
8	<u>migration from/km²</u>	62-86	2845	644	-5448	-4632	-4374	1995	-323	3
9	<u>immigration/km²</u>	62-86	3281	644	-5012	-4196	-3938	2431	113	8
10	<u>emigration/km²</u>	62-86	3333	644	-4961	-4145	-3887	2482	164	9
11	<u>migration/population</u>	62-86	2128	584	-5392	-5349	-4318	1278	-267	5
12	migration from/pop.	62-86	6426	644	-1867	-1051	-793	5576	3258	23
13	migration to/pop.	62-86	7246	644	-1047	-231	27	6396	4078	25
14	<u>immigration/pop.</u>	62-86	2946	644	-5348	-4532	-4274	2095	-223	6
15	emigration/pop.	62-86	3473	644	-4820	-4004	-3746	2623	305	13
16	<u>occupational structure</u>	38-86	4754	1057	-9396	-12175	-10769	3165	-115	7
17	% in agriculture	38-86	6445	1127	-8643	-10484	-10016	4855	638	16
18	% in manufacturing	38-86	13653	1127	-1435	-3276	-2808	12063	7846	29
19	% in services	38-86	7462	1127	-7625	-9467	-8998	5872	1655	20
20	% in transportation	38-86	6085	1127	-9002	-10844	-10375	4496	278	12
21	population density	46-86	5569	966	-7261	-8342	-7943	4191	605	15
22	urbanization	78-86	1628	312	-2139	-925	-684	1217	251	11
23	<u>mean income per capita</u>	54-86	3744	805	-6786	-6760	-6433	2647	-296	4
24	academics per 100000	38-70	6035	805	-4490	-8341	-8014	4856	1914	22
25	% more than elementary education	70-86	2861	483	-3228	-2024	-1835	2195	493	14
26	religion (pop. data)	38-70	7578	730	-1966	-6798	-5491	6399	4438	26
27	size of denomination (population data)	38-70	10852	805	327	-3524	-3197	9673	6731	28
28	religion (tables data)	46-86	7764	876	-3870	-6146	-4552	6387	3996	24
29	size of denomination (tables data)	46-86	11621	966	-1209	-2289	-1891	10244	6658	27

Other covariate models performed less well. The models related to urbanization, population density (21) and urbanization (22) had an average explanatory power, with ranks on BIC divergence of 15 and 11 respectively. However, a comparison of the BIC values per year with the values for the full effects model in table A.3 shows that the BIC divergence for population density improved with time. The BIC divergence for population density was -66 in 1978, al-

though it rose again to 19 in 1986. The education covariates, "academics per 100000" (24) and "percentage with more than elementary education" (25) did rather poorly. However, education is affected by government policies and not so much by autonomous economic provinces, as is the case for other covariates, so this might explain the mediocre results. The religion covariates had low explanatory power compared to the other covariates in these analyses. However, table A.3 shows the fit improved strongly with time, so that the BIC divergence of model (28) was negative in 1986.

The results for the migration covariates show that taking other variables into account can strongly affect the explanatory power of a covariate. A suitable transformation might also have this effect. Therefore, the fact that a covariate does not explain much of the variation in religious inmarriage between provinces does not necessarily mean that the explanatory variable is irrelevant. The focus should be on the covariates that do perform well, rather than those that perform poorly. These models and the effect parameters will be discussed in more detail in the following.

Effects of migration

Models (1) to (15) are the alternative operationalizations of spatial mobility. A comparison of models (1), (6) and (11), in which the four components of migration are entered simultaneously, shows that migration/km² (model (6)) and migration/population (model (11)) both perform excellently, since both have negative BIC divergence values. Model (1), which uses the absolute values of migration, performs far less well.

An examination of the effects of the four components of each operationalization of spatial mobility shows that the components of migration/populations vary rather strongly with regard to their explanatory power, but that the components of absolute values of migration and migration/km² each have approximately the same L^2 . Each component of migration/km² can explain almost as much as the four components together, which shows that these covariates are strongly correlated. The L^2 of the absolute migration model (1) on the other hand, is a good deal lower than the L^2 of any of its components, models (2) to (5).

Since models (2) to (5) perform relatively poorly, it can be concluded that the area and/or population of a province are relevant co-causes of the effects of spatial mobility on religious inmarriage. It had been assumed that land area might be relevant for movement into provinces, and that population size might be relevant for movement out of provinces. An examination of the components of migration/population does not confirm these expectations however. Correcting for population size improves the fit of immigration and emigration, but leads to a much worse fit of the domestic migration variables (cf. models (12) to (15)). The situation is reversed for the components of migration/km²: the models for domestic migration variables have an excellent fit, but those for foreign migration do less well. The conclusion is that migration/km² is the optimal operationalization of spatial mobility. An explanation for the high performance of model (14), "immigration/population", might be that most immigrants arrive in western provinces, which have harbour and airport facilities. This effect is therefore substantively uninteresting.

Given that all four components of migration/km² perform well, it would be logical to interpret the parameters of model (6), in which all four components are entered together. However, due to the correlations between the components, these effects did not form a meaningful pattern. Instead, the effects of models (7) to (10), the four components of migration/km², are presented.

Figure 2

Effects of the separate components of migration per km² on
inmarriage parameters, by year of marriage

Figure 2 shows the effects of the migration to, and migration from provinces (relative to land area) on religious inmarriage. The parameters have been multiplied by 100 in order to avoid very small values. The parameters for each component of migration indicate by how much the inmarriage parameter of each denomination in a particular year would change, if that component of migration changes by a single unit. So for example, if migration to a province increased by 100 persons per km² area of that province, then in the year 1962, Catholic inmarriage in that province would have changed by $-.51$.

Migration can affect religious assortative marriage for several reasons. It promotes cross group memberships by breaking up networks in old settings and modifying others in new settings. The breaking up of old networks also implies that social control, particularly by the family, will be impeded. It was therefore expected that inmarriage would become lower as migration increases. Figure 2 confirms this for all four components of migration. The patterns of the four components of migration strongly resemble each other, except that the strengths of the relationships are stronger for domestic migration than for foreign migration.

Catholic inmarriage is most strongly affected by increasing migration (of any type), whereas Re-Reformed inmarriage is barely affected at all. Reformed inmarriage is not

strongly affected, but the effect becomes weaker, and in 1986 Reformed inmarriage would become slightly higher as migration increases. The effects of migration on inmarriage in the category “none” run parallel to those of Catholics, but are slightly weaker. The effects on the category “other” run closely parallel to the effects on Reformed Protestants.

The effects of migration on religious inmarriage tend to decrease with time in figure 2. An examination of tables A.2 and A.3 in appendix A shows that the divergence of the migration/km² covariate models from the full effects model did not get worse as time progressed. Rather, the improvement of the covariate models became less as the fit of the baseline model progressively improved. The association of inmarriage with province became steadily less as time progressed, and this is reflected in lower effects of the migration/km² covariates.

Effects of occupational structure

Model (16) tests the effects of the occupational structure of provinces on religious inmarriage. It has a negative BIC divergence and ranks 7th of the models tested. The fit of models (17) to (20), which test for effects of the percentage employed in each occupational sector, are not so good though. Of the four separate occupational sector models, model (17) of the percentage employed in agriculture might be expected to perform best, since a shift from agricultural occupations to other occupations corresponds best with the ongoing transition from a traditional society to a modern society. However, model (17) has only the second best performance of the four.

The percentage employed in transportation (model 20), has the lowest BIC deviation of the four economic sector covariates. This is probably due to the importance of the transportation sector for the western provinces, not to transportation as an important aspect of modernization (although an increase in the importance of the transportation would also reflect an increasingly mobile society). The poor performance of the percentage employed in services and especially of the percentage employed in manufacturing (lowest rank of all), is surprising. It can be concluded that a complete picture is needed of the occupational structure of a province, rather than a contrast of who works in a particular sector, versus who does not.

Figure 3 shows the variation of inmarriage by occupational sector. The relationships between the occupational sectors and religious inmarriage is not as “neat” as for migration or mean income (see below), because the effects are controlled for effects of the other sectors. It had been expected that there would be lower religious inmarriage as the agricultural sector became less important, and the manufacturing and service occupations increased in importance. Figure 3 shows that at the beginning of the time series at least, inmarriage tended to be higher where agricultural occupations were prominent. This was most strongly so for Catholics. Neither Re-Reformed or Reformed Protestants were affected much by the prominence of the agricultural sector – after 1962, Re-Reformed inmarriage would be lower where agriculture was more prominent. Inmarriage in the category “no denomination” was also negatively affected by a higher prominence of agricultural occupations in 1978 and 1986.

The prominence of the transportation and service sectors affects religious inmarriage negatively, on the whole. Interestingly, their largest effects are on inmarriage in the category “no denomination”, which until 1954 was positively affected by the prominence of the service sector and negatively affected by that of the transportation sector. Catholic and Re-Reformed inmarriage were negatively affected by the prominence of the service sector, although this effect became weaker after 1962 and became slightly positive for Re-Reformed Protestants after 1970. The prominence of the service sector had the opposite effect on Catholic and Re-

Figure 3

Effects of the occupational structure (percentage of the workforce employed in each sector) on inmarriage parameters, by year of marriage

Reformed inmarriage: the effect was slightly positive until 1954 (except for Re-Reformed Protestants in 1938), then the effect disappears.

In summary, there is some evidence that a lower prominence of the agricultural sector, and a higher prominence of service occupations lead to lower inmarriage for Catholics and Re-Reformed Protestants. The expectation that religious inmarriage would be negatively affected by the prominence of the manufacturing sector is not confirmed, however. Inmarriage tended to be slightly higher where manufacturing had greater prominence, although all effects were small. On the whole, the effects of occupational structure on religious inmarriage show a complicated structure, which is difficult to interpret.

Effects of mean income per capita

Figure 4 shows how the religious inmarriage of provinces was affected by the mean provincial income per capita, corrected for inflation. Religious inmarriage had been expected to decline with a rising income per capita, since this would diminish the individual's dependence on primary relations and thus increase his autonomy. Figure 4 shows that this expectation is, on the whole, fulfilled. The structure of the effects resemble those of mobility. Catholic in-

Figure 4
Effects of the mean provincial
income per capita, corrected for
inflation, by year of marriage

marriage is most strongly affected by increasing income per capita, although this effect becomes weaker until 1970. However, in 1986 the negative effect of income per capita on Catholic inmarriage becomes stronger again. Dutch Reformed inmarriage was negatively affected by income per capita, but this effect became weaker, and had disappeared in 1986. Re-Reformed inmarriage was barely affected by mean income per capita. The effects of income per capita on the category "none" run parallel to those on Catholics, and the effects on "other" run parallel to the effects on Dutch Reformed inmarriage.

Effects of the covariates on inmarriage by province and year of marriage

Aspects of modernization are assumed to cause changes through time, and it is only because provinces vary with respect to economic development that it was feasible to test for effects of modernization on the variation of inmarriage by province. It was found that migration relative to land area, occupational structure, and mean income per capita performed well in explaining variations by province in religious inmarriage. This raises the question of whether these explanatory variables will also explain much of the variation of inmarriage through time.

These three covariates were therefore used as explanatory variables for variations in religious inmarriage by table, i.e. by province, year of marriage, and province/year combinations. The analysis were of course only performed for the years for which the covariate was available. The baseline model restricted religious inmarriage to be constant across provinces and through time. Since the analysis of religious assortative marriage by province had shown that variations of religious inmarriage by province/year combination were not substantial by the BIC criterion, the full effects model let religious inmarriage vary by province and year, but not by province/year combinations.

Beside the question of how well a covariate can explain variations of religious inmarriage by table, it was also of interest how well they performed with regard to variations by province component, and how well with regard to variations by time component. To determine this, "partial covariate" model versions were also run in which inmarriage was allowed to vary with time and models for which it could vary by province, so that the covariate could explain only variations across provinces, or only variations through time, respectively. Corresponding

Table 10

Goodness of fit statistics for models of the effects of covariates on variations of inmarriage by province and through time

Covariate	Model			Improvement		Divergence	
	L^2	df	BIC	L^2	BIC	L^2	BIC
1 migration/km ²							
a variations by table	8317	674	-362	-5783	-5525	6002	5423
b variations by province	3356	659	-5131	-4323	-4065	1041	654
c variations through time	6335	624	-1701	-2966	-2708	4020	4084
2 occupational structure							
a variations by table	11955	1207	-4204	-19931	-19731	6633	5763
b variations by province	6318	1177	-9439	-10929	-10728	997	528
c variations through time	6777	1157	-8712	-14798	-14598	1456	1255
3 mean income per capita							
a variations by table	9904	865	-1410	-11481	-11416	6578	5728
b variations by province	5094	845	-5959	-5674	-5609	1768	1179
c variations through time	5416	815	-5245	-9500	-9435	2090	1894

“partial” baseline models were also estimated, to determine the upper limit for the L^2 of these partial covariate models. The full effects model is the same for all three models of the effects of covariates on variations by table, by province only, and through time only.

Table 10 contains the goodness of fit statistics for covariate effects on religious inmarriage by province and year of marriage. Corresponding baseline models and the full effects models for each period are reported in table A.4 in Appendix A. Table 10 shows that all three covariate models for “variations by table” have a negative BIC. Judged solely on their own merits, “occupational structure” (2a) would be the best model and “migration/km²” (1a) the worst. If the models are judged by BIC divergence values, then all three models perform more or less equally well, with model (1a) showing a slightly better performance than the other two.

All three models may perform equally at explaining variations by table, but they do show marked differences in their explanatory power with regard to variations by province, or variations through time only. It may seem surprising that all three covariate models have positive BIC divergence values for variations in religious inmarriage by province, although they had negative BIC divergence values in the previous analysis. The reason is that the effects of the covariates on variations of religious inmarriage by province are now constant through time, whereas in the previous analysis, they were allowed to vary with year of marriage.

Table 10 shows that, with regard to explaining variations in inmarriage by province only, “occupational structure” (2b) performed best. “Migration/km²” (1b) did almost as well, but model 3b (mean income) did a good deal worse. All three models were better for explaining variations across provinces, than variations through time, since the BIC divergence values for the “c” versions were higher than for the “b” versions. Model 1c (migration/km²) was the worst at explaining variations in inmarriage through time. Model 2c (occupational structure)

showed the best performance with regard to variation through time, and model 3c (mean income) was in between.

On the whole, the "occupational structure" covariates (model 2) were the most powerful explanatory variables. The model for variations by table had the lowest BIC and although its BIC divergence value was greater than that of the other two covariates, the margin was tiny. On the other hand, model 2 performed best at explaining variations in inmarriage by province and through time separately, as evidenced by its relatively low BIC divergence values. "Mean income per capita" was the second best performing covariate. The BIC value for this model was second best, and its performance at explaining variations by province and through time separately, was moderate. The components of "migration/km²" (model 1) showed mixed results. Its own BIC value was highest of the three models for explaining variations by table. It performed second best at explaining variations in inmarriage by province, but worst, by a considerable margin, at explaining variations through time.

Table 11

Parameter estimates for the effects of covariates on variations of inmarriage by both province and time

	Re-Reformed	Reformed	other	none	Catholic
migration¹/km²					
a migration to	-.099	-.096	.040	-.012	-.059
b migration from	.119	.091	-.063	-.020	.008
c immigration	-.163	-.051	.109	.047	-.047
d emigration	.026	.004	-.026	.011	.214
occupational structure					
a agriculture	.024	.010	.004	.031	.075
b manufacturing	.029	.003	-.049	-.030	.013
c transportation	.031	-.021	-.066	-.036	-.002
d service	-.083	.007	.110	.035	-.087
mean income per capita [†]	-.146	-.042	.061	-.004	-.221

† parameter estimates have been multiplied by 100

‡ parameter estimates have been multiplied by 10

Table 11 contains the effects of the three covariate models on variations of inmarriage by table. The first four rows show the effects of migration/km² on variations of inmarriage by table. The greater the migration to a province, both in comparison with other provinces and through time, the lower inmarriage was, except for the category "other denominations". Note that these covariates were entered together so that the effects control for the effects of the other covariates. The effect of migration to provinces was strongest for Re-Reformed and Reformed Protestants and somewhat weaker for Catholics. Migration from provinces had something of an opposite effect: inmarriage tended to increase as there was more migration from provinces, except for the categories "other" and (weakly) "no denomination". The effect of migration from provinces was strongest for Re-Reformed and Reformed Protestants, and did not affect Catholic inmarriage.

Immigration shows a pattern somewhat similar to that of migration to provinces. It had a strong negative effect on Re-Reformed inmarriage and weaker effects on Reformed Protestant

and Catholic inmarriage. As with migration to provinces, the effect of immigration led to higher inmarriage propensities in the category "other", but it also led to higher inmarriage in the category "none". The fourth row of table 11 shows that emigration from provinces led to higher Catholic inmarriage. Re-Reformed inmarriage and to a much lesser extent, inmarriage in the category "none" were also positively affected by emigration, whereas the category "other denominations" was negatively affected.

The effects of migration/km² on variations of inmarriage by table indicate that flow to a province (migration to and immigration) have a negative effect on the propensity to inmarriage of Re-Reformed and Reformed Protestants and Catholics, whereas flow from a province (migration from and emigration) has the opposite effect. This situation is reversed in the case of "other denominations", while the effects on inmarriage in the category "none" present a mixed picture. These effects contradict theoretical expectations that inmarriage would be lower as spatial mobility increased.

Rows 5 to 8 of table 11 show the effects of occupational structure on variations of inmarriage by table. Note that these effects sum to zero over the categories of occupational structure. The parameters in row 5 show that in conformance with theoretical expectations, inmarriage is higher as the agricultural sector has a more prominent place in the occupational structure, although the effects for Reformed Protestants and "other" denominations are minimal. A higher percentage of workers in the manufacturing field of work leads to higher Re-Reformed and (to a lesser extent) Catholic inmarriage, but lower inmarriage in the categories "other" and "none". The prominence of manufacturing does not affect Reformed inmarriage, although it was expected that a larger manufacturing sector would lead to lower religious inmarriage. The larger the transportation sector, the higher Re-Reformed inmarriage, but the lower inmarriage is in the categories "other", "none" and among Reformed Protestants. Catholic inmarriage is not affected by the prominence of the transportation sector.

The largest effects of occupational structure are those of the service sector. The larger the services sector is, the higher inmarriage in the category "other", but the lower Re-Reformed and Catholic inmarriage will be. Inmarriage in the category "none" will be only slightly higher as the service sector is more prominent, and Reformed inmarriage will not be affected. Advanced industrial societies will show a shift from occupations in industry to occupations in the service sector, and this is reflected in lower inmarriage among Catholics and Re-Reformed Protestants.

The last row of table 11 shows the effects of mean income per capita on religious inmarriage. The higher the mean income per capita, the lower Catholic and Re-Reformed inmarriage will be. Reformed inmarriage will also be slightly lower, but inmarriage in the category "other" will be somewhat higher. This confirms expectations that increasing mean income will increase individual autonomy and lead to lower religious inmarriage.

THE EFFECTS OF MUNICIPAL SIZE ON RELIGIOUS ASSORTATIVE MARRIAGE, BY YEAR OF MARRIAGE

There was no satisfactory measure of urbanization per province per year that could be used as a covariate. Fortunately, marriage tables were available per category of municipal size (five categories) as well as by province. The larger a municipality, the greater the number and the diversity of contacts will be. Larger towns and cities are characterized by a higher population density. The superior infrastructure of cities makes them attractive to the less well-to-do, since all facilities can be accessed relatively easily. The job opportunities of cities also attract

people across large distances, promoting the diversity of groups. Moreover, the occupations in smaller municipalities tend to be of an agricultural nature, whereas occupations in the cities tend to be highly skilled, with high education requirements.. Larger municipalities are of course characterized by a larger scale of organization, and by formal, bureaucratic relationships, which should promote achievement standards. On the other hand, the smaller scale of villages enables a tighter social control. Due to these factors, it can be expected that religious assortative marriage will become weaker as municipal size increases.

A table of year of marriage by municipal size by husband's denomination by wife's denomination was therefore analyzed, for the same years and denominations as used in the analyses at the national level, and for the following categories of municipal size:

- less than 20000 inhabitants¹²
- between 20000 and 50000 inhabitants
- between 50000 and 100000 inhabitants
- more than 100000 inhabitants

Table 12
Goodness of fit statistics for the models of religious assortative marriage by municipal size and year of marriage

		L^2	df	BIC
1	conditional independence	683172	448	677174
2	assortative marriage constant for time and size	41247	432	35463
3	assortative marriage constant for size, variable with time	26599	336	22101
4	assortative marriage constant for time, variable with size	21972	384	16830
5	assortative marriage variable with time and size, but no 4-way interaction	5010	288	1154
6	symmetric interaction, variable by size, time, and size/time combination (4-way interaction)	300	168	-1950
7	symmetric deviances constant for size/time combinations, diagonal parameters variable	479	258	-2975
8	symmetric deviances constant for size and time, diagonal parameters variable for size, time, and time/size combinations	1083	303	-2974
9	as (8), but diagonal parameters constant for size/time combinations	6004	393	742

Models (1) to (5) were fitted using SPSS HILOGLINEAR (IPF algorithm)

All other models were fitted using GLIM 3.77

Table 12 contains the goodness of fit statistics for the analysis of religious assortative marriage by municipal size. Models (1) to (5) were estimated using the fast SPSS HILOGLINEAR program, since they did not use special restrictions. Model 1, which lets the partners' denominations be independent of each other within each subtable of year and municipal size, has of course a very poor fit. Allowing for assortative marriage, but restricting it to be constant for year and size in model (2) strongly improves the fit, but it is far from acceptable. A comparison of models (3) and (4) shows that not allowing for size effects would lead to a worse fit than not allowing for time effects, whereas above it turned out that time effects were much more important than provincial effects. Note that a comparison of the BIC value for model (3) in table 12 with the BIC for model (3) in table 5 (effects of province) shows that the association of religious assortative marriage with municipal size is stronger

than its association with province (BIC = 22101 versus 1813 in table 5). Model (5), with all effects except the 4-way interaction, still has a positive BIC, which means that the effects of municipal size on religious assortative marriage changes with time.

Models (6) to (9) use special designs for the pattern of association between partners' denominations. Model (6) imposes only the restriction that the association between partners' denominations is symmetric, and lets it vary with time, size, and time/size combination. This leads to a strongly negative BIC. Model (7) shows that restricting the symmetric deviances parameters to be constant for size/time combinations improves the fit according to the BIC criterion. Restricting the symmetric deviances parameters to be constant for both year of marriage and municipal size in model (8) increases BIC by 1.5. The variations of the symmetric deviances parameters are therefore just barely substantial according to BIC. However, the margin was considered to be too small to warrant the complexities of interpreting such a complex model, and consequently model (8) was chosen. Finally, model (9) was used to test the strength of the 4-way interaction by restricting the diagonal parameters to be constant for size/time combinations. This had a strongly detrimental effect on BIC, so the 4-way interaction is strong indeed.

The final model was therefore model (8). This model shows that the inmarriage propensities of the denominations varied with time, municipal size, and size/time combination. The inmarriage trend will therefore be different within different categories of municipal size. Social proximities between the denominations were constant across time and categories of municipal size, however.

Parameter estimates

Table 13 presents parameters for religious assortative marriage, controlling for municipal size, time, and size/time combination. Including the variable size did not substantially alter the parameters for religious assortative marriage, controlling for other variables. A comparison of table 13 with table 4 shows that Δ , the mean absolute difference between parameters, was .067 for inmarriage parameters on the diagonal. The largest difference for the diagonal parameters was -.080, for Re-Reformed inmarriage. For the symmetric deviances parameters

Table 13
Parameter estimates, controlling for the effects of municipal size and year of marriage, of model 8 in table 11

Husband's denomination	Wife's denomination				
	Re-Reformed	Reformed	other	none	Catholic
Re-Reformed	2.547	.421	-.020	-.138	-.263
Reformed	.040	1.038	-.178	-.178	-.065
other	-.736	-.390	2.040	.093	.105
none	-.735	-.272	-.336	1.686	.223
Catholic	-1.116	-.415	-.579	-.344	2.453

Values on the diagonal are diagonal parameters (the overall diagonal parameter is 1.953)

Values in the upper triangle are symmetric deviances parameters

Values in the lower triangle are symmetric interaction parameters

Table 14

Variance of the diagonal parameters, in the analysis of religious assortative marriage by municipal size and year of marriage

	through time	across size categories	across size/year combinations
Re-Reformed	.055	.029	.008
Reformed	.021	.004	.006
other	.163	.010	.006
none	.023	.001	.004
Catholic	.178	.112	.028

in the upper triangle of table 13, Δ turned out to be .032; the maximum difference was .034, for Re-Reformed: "none" marriages. As for the off-diagonal symmetric interaction parameters in the lower triangle of table 13, Δ was .042, while the maximum difference was -.085, for Catholic: "none" marriages. On the whole, the differences between the parameters for religious assortative marriage, controlling for municipal size, time, and time size combinations, and parameters for religious assortative marriage at the national level, are fairly small, although larger than the differences between parameters of provincial level versus national level models.

Table 14 contains a comparison of the variance of the inmarriage parameters through time, across size categories, and across size/time combinations. Catholic inmarriage was the most strongly affected by both time, size, and time/size combinations. Re-Reformed inmarriage also varied strongly with municipal size, but to a far lesser extent than Catholic inmarriage, and variations across size/time combinations were fairly weak for denominations other than Catholics. Inmarriage in the category "other" varied strongly with time, as in table 7 above.

Figure 5 shows the homogamy trend, controlling for the effects of size and size/time combinations. The Δ between the diagonal deviation parameters (deviances from the overall inmarriage parameter), with and without the variable size, is .046. The largest difference is -.164 (Catholic inmarriage in 1978), followed by .126 (Catholic inmarriage in 1938). For Catholic inmarriage, Δ was .067 and for Re-Reformed and Reformed Protestants, it was .058 and .047 respectively. In an analysis at the national level, Catholic inmarriage would be under-estimated, and Re-Reformed and Reformed Protestant inmarriage overestimated, until 1962, after which the reverse situation took place. The Δ for the categories "other" and "none" were .024 and .032 respectively, with maximum differences of -.078 and .065. Altogether, the impact of controlling for municipal size on the inmarriage trend is not overly large.

The main question of this analysis is how municipal size affects religious inmarriage. Table 15 shows the overall diagonal parameter and "diagonal deviation" parameters per municipal size category, controlling for time and size/time effects. The first column of table 15 shows that overall inmarriage decreased as municipal size increased. Overall inmarriage was particularly high in the small towns (< 2000) and particularly low in large cities (> 100000).

Figure 5
The trend of homogamy between
1938 and 1986, controlling for
municipal size

Columns 2 to 6 of table 15 contain the diagonal deviation parameters, indicating how much higher inmarriage was within each denomination, compared to the overall inmarriage parameter. In the smallest towns (< 20000) Catholic inmarriage was much higher, and Re-Reformed inmarriage, Reformed inmarriage, and inmarriage in the category "other" were lower. The opposite occurred in the largest cities (> 100000), where Catholic inmarriage was much lower, and Re-Reformed inmarriage was higher. In the two intermediate size categories, 20000-50000 and 50000-100000, the effects on the diagonal deviation parameters was much less pronounced.

Table 15
Parameter estimates of the effects of municipal size on inmarriage, controlling for time and size/time combinations

	overall in-marriage	Re-Reformed	Reformed	other	none	Catholic
< 20000	.356	-.230	-.112	-.155	-.005	.502
20000-50000	.069	-.075	.041	-.016	-.001	.052
50000-100000	-.060	.083	.013	.076	-.035	-.137
> 100000	-.365	.223	.057	.095	.041	-.416

Figure 6
The trend of religious Inmarriage
per category of municipal size

The final model indicated that religious inmarriage varied with size/year combinations. Figure 6 shows the inmarriage trend per category of municipal size. The inmarriage trend for Catholics clearly varies strongly according to municipal size. In towns with less than 20000 inhabitants, Catholics chose other Catholics between 1938 and 1962 approximately 70 times more often as would be expected, if partner choice was random. In the largest cities on the other hand, Catholic inmarriage was initially much lower, but increased between 1938 and 1954. After 1962, Catholic inmarriage dropped for all categories of municipal size, but the change was especially dramatic in towns with less than 20000 inhabitants. On the other hand, Re-Reformed inmarriage was barely affected by municipal size.

Table 16

Goodness of fit statistics for conditional models per year, with and without variations in inmarriage propensity by categories of municipal size

year	model 1 [†]			model 2 [‡]			improvement	
	L^2	df	BIC	L^2	df	BIC	L^2	BIC
1938	5786	54	5187	68	39	-365	-5718	-5552
1946	6096	54	5471	168	39	-283	-5928	-5754
1954	4703	54	4088	104	39	-340	-4599	-4428
1962	4981	54	4364	128	39	-319	-4854	-4682
1970	3476	54	2842	115	39	-342	-3361	-3185
1978	1088	54	473	69	39	-376	-1019	-848
1986	653	54	39	117	39	-327	-536	-366

† symmetric interaction, constant across size categories

‡ symmetric deviances constant, diagonal parameters variable across size categories

Figure 6 indicates that some convergence is taking place, and that municipal size is become increasingly less important. To test whether this was really the case, conditional models were fitted for each year, both with and without effects of inmarriage by municipal size category. Table 16 confirms that convergence is taking place, but also shows that this only started after 1970, and that size effects were still quite strong in 1986.

That the impact of municipal size on religious inmarriage should decrease was not foreseen, but is not incomprehensible. Smaller communities have become less isolated than in the past due to improvements in transportation. Many inhabitants of small towns work in cities, which neutralizes some of the effects of municipal size. The fact that no changes occurred until 1962, and that the main changes took place between 1970 and 1978, seems to indicate that there was a time lag in the effects of these factors.

Conclusions

The main purpose of this chapter was to find and test explanations for variations in religious assortative marriage. A theoretical examination of the causes of changes in the openness of society led to the expectation that religious assortative marriage would become weaker as the "modernization" of Dutch society progressed. Aspects of modernization, such as a shift from agricultural occupations to industrial occupations, greater prosperity, higher spatial mobility, more urbanization, higher levels of education, would widen the individual's ideological horizon and/or increase the individual's autonomy. A widened ideological horizon would lead to a weaker emphasis on the religious ingroup, whereas greater autonomy would reduce the effectiveness of social pressures toward religious inmarriage.

Given the unequal economic development of provinces in the Netherlands, particularly in the past, this could be tested by using characteristics of provinces as explanatory variables in order to explain variations of religious inmarriage between provinces as well as through time. It was also possible to perform a more powerful test of the effects of municipal size on religious inmarriage, since a four-way table of partners' denominations by municipal size by year

of marriage was available. As a side issue, it was tested whether failing to control for the spatial dispersion of religious groups in analyses at the national level can lead to distorted results.

The analyses showed that religious inmarriage varied by province and year of marriage, but that the social proximities between denominations remained constant. Allowing inmarriage to vary by province/size combinations did not improve the fit of the model, but models for each year separately did show that the differences between provinces became weaker as time progressed. This indicates that provinces are converging with respect to degree of religious assortative marriage.

The results showed that there were strong variations of religious inmarriage by province. However, the inmarriage parameters by year of marriage, controlling for province were almost identical to parameters found in an analysis on national level data. It can be concluded that failure to control for spatial dispersion does not affect the results.

The analysis of the effects of covariates on variations of religious inmarriage by province, conditional on year of marriage, showed that migration relative to land area, occupational structure, and mean income per capita performed well. Surprisingly, neither urbanization nor educational level were strong explanatory variables. Religious composition of provinces also performed poorly compared to the other explanatory variables and failed to support the hypothesis that inmarriage was higher if the denomination was a minority.

It must be kept in mind that a poor fit of a covariate model does not necessarily mean that the covariate does not affect religious assortative marriage. It is possible that by using a suitable transformation of the variable, or by constructing an index together with other variables, a much better fit would be obtained. For example, models using migration values as covariates did not perform very well, but the models using migration relative to land area performed best of all.

The effects of the covariates showed that higher migration/km² in provinces was associated with lower propensities to inmarriage. This effect was particularly strong for Catholics and much lower for Reformed and Re-Reformed Protestants. These effects diminished as time progressed. The effects of occupation on religious inmarriage presented a more confused picture, due to the interrelationships between effects. Inmarriage tended to be higher where the agricultural sector was prominent, and lower where the service sector or transportation sector were prominent. The percentage working in the manufacturing sector turned out to have little influence. A higher mean income per capita also led to lower inmarriage, particularly for Catholics, and much less so for Reformed and Re-Reformed Protestants.

Given that migration relative to land area, occupational structure, and mean income could explain a considerable amount of the variation in inmarriage by province, the next step was to test whether they could explain variations both by province and through time (i.e. by table). All three covariates performed equally well at explaining variations by table. The goodness of fit statistics showed that occupational structure performed best both at explaining variations by province only and variations through time only. Migration/km² did well at explaining variations between provinces, but performed poorly at explaining variations through time. Mean income performed fairly well at explaining either variations between province and variations through time.

The effects of the covariates on variations by table differed from the effects on variations by province, conditional on year of marriage. Effects on inmarriage in the category "other denominations" tended to be the opposite of effects on Catholics and Protestants, since inmarriage in the category "other" increased with time, whereas Catholic and Re-Reformed inmarriage decreased. Both migration to and immigration to provinces led to lower religious in-

marriage among Catholics and particularly among Re-Reformed and Reformed Protestants, as theoretically expected. On the other hand, migration from and emigration from provinces led to higher religious inmarriage.

The effects of occupational structure showed that a larger manufacturing sector led to higher, not lower inmarriage, but that a larger service sector did lead to lower religious inmarriage among Catholics and Re-Reformed Protestants. A larger agricultural sector led to higher inmarriage, as expected. A higher mean income per capita led to lower religious inmarriage, particularly for Catholics and Re-Reformed Protestants, conform expectations.

Although the covariates did not show strong effects of urbanization on religious inmarriage, an analysis of religious assortative marriage by municipal size showed that municipal size strongly affects religious inmarriage. The association between religious assortative marriage and municipal size was larger than between religious assortative marriage and province. The analysis showed that religious inmarriage varied with time, municipal size, and size/time combination (a 4th degree effect), although the social proximities between denominations were constant for time and size. The parameters, controlling for size effects differed more strongly from values in the analysis at the national level only than parameters controlling for province had differed. Catholic inmarriage was particularly strongly affected by municipal size. Overall inmarriage decrease with increasing municipal size. Some convergence did take place: the effects of municipal size on religious inmarriage became weaker in the 1970s and 1980s. These effects were still quite strong in 1986, however.

These results show that modernization has indeed led to the deterioration of barriers between religious denominations in the Netherlands. The importance of municipal size would indicate that the weaker social control and increased contacts in larger municipalities played an important role. Shifts in occupational structure, from agricultural and manufacturing occupations to service sector occupations were also an important factor. These shifts would be incompatible with earlier ascription standards and would promote achievement standards. The expectation that greater spatial mobility would lead to lower religious inmarriage was only partially fulfilled, since flows out of provinces due to domestic migration and emigration led to higher, not lower religious inmarriage. Finally, the negative effects of mean income per capita on religious inmarriage indicates that greater financial independence from primary relationships allowed individuals greater scope in making their own choice of marriage partner.

Appendix A: Baseline models and full effects models for the analyses with covariates

Table A 1

Baseline models and full effects models for the periods used in the analysis of the effects of covariates on the variation of inmarriage by province, conditional on year of marriage

Period	baseline model			full effects model			improvement	
	L^2	df	BIC	L^2	df	BIC	L^2	BIC
1938 to 1970	14376	830	3524	1179	580	-6404	-13197	-9928
1938 to 1986	16929	1162	1373	1590	812	-9281	-15339	-10654
1946 to 1986	13910	996	682	1378	296	-7866	-12532	-8548
1954 to 1986	10504	830	-353	1097	580	-6489	-9407	-6136
1962 to 1986	7477	664	-1074	850	464	-5125	-6627	-4051
1970 to 1986	4885	498	-1393	666	348	-3721	-4219	-2328
1978 to 1986	2553	332	-1455	411	232	-2390	-2142	-935

Table A 4

Comparison models for the analysis of the effects of covariates on variations both through time and across provinces

Model	L^2	df	BIC
1 migration/km ² (1962-1986)			
a baseline for variations by table	14100	694	5163
b baseline for variations by province	7679	679	-1065
c baseline for variations through time	9301	644	1008
d full effects model	2315	629	-5785
2 occupational structure (1938-1986)			
a baseline for variations by table	31886	1222	15527
b baseline for variations by province	17247	1192	1289
c baseline for variations through time	21575	1172	5885
d full effects model	5321	1142	-9967
3 mean income per capita (1954-1986)			
a baseline for variations by table	21385	870	10006
b baseline for variations by province	10768	850	-350
c baseline for variations through time	14916	820	4190
d full effects model	3326	800	-7138

Table A 2

 L^2 statistics per year, for covariate models on the variation of inmarriage by province

covariate	1938	1946	1954	1962	1970	1978	1986	total	df table
baseline model	3019	3406	3027	2592	2332	1232	1321	16929	166
full effects model	212	280	247	184	255	174	237	1590	116
1 migration, absolute				655	756	597	555	2563	146
2 migration to (abs)				1291	1600	1009	990	4890	161
3 migration from (abs)				1273	1568	940	979	4760	161
4 immigration (abs)				1217	1373	856	855	4301	161
5 emigration (abs)				1141	1523	910	882	4456	161
6 migration/km ²				464	605	380	596	2045	146
7 migration to/km ²				621	864	531	761	2778	161
8 migration from/km ²				635	906	546	757	2845	161
9 immigration/km ²				893	987	674	728	3281	161
10 emigration/km ²				828	1117	654	734	3333	161
11 migration/population				459	582	365	723	2128	146
12 migration from/pop				2420	2150	736	1120	6426	161
13 migration to/pop				2564	2313	1175	1194	7246	161
14 immigration/pop.				609	840	638	859	2946	161
15 emigration/pop				594	1225	753	901	3473	161
16 occupational structure	634	1018	710	568	626	400	799	4754	151
17 % in agriculture	886	1203	1034	828	930	593	970	6445	161
18 % in manufacturing	2951	3118	2928	2094	1130	522	911	13653	161
19 % in services	1181	1437	904	1034	908	830	1168	7462	161
20 % in transportation	838	1258	1062	899	712	459	858	6085	161
21 population density		1260	997	873	1051	621	767	5569	161
22 urbanization						727	900	1628	156
23 mean income per capita			1027	676	733	441	867	3744	161
24 academics per 100000	1557	1513	979	865	1121			6035	161
25 % more than elementary education					932	760	1169	2861	161
26 religion (pop data)	1288	1694	1957	1440	1199			7578	146
27 size of denomination (population data)	2069	2644	2485	2025	1629			10852	161
28 religion (tables data)		1694	2055	1630	1307	559	519	7764	146
29 size of denomination (tables data)		2964	2740	2197	1827	917	976	11621	161
Number of cases per year									
	1938	1946	1954	1962	1970	1978	1986	total	
	65659	106673	87925	92980	123352	88694	86394	651677	

Table A 3

BIC statistics per year, for covariate models on the variation of inmarriage by province

	covariate	1938	1946	1954	1962	1970	1978	1986	total	df
	baseline model	1178	1484	1137	693	386	-659	-566	1373	1162
	full effects model	-1074	-1063	-1074	-1143	-1104	-1147	-1082	-9281	812
1	migration, absolute				-1015	-956	-1066	-1105	-4958	584
2	migration to (abs)				-551	-288	-825	-840	-3404	644
3	migration from (abs)				-569	-320	-894	-851	-3533	644
4	immigration (abs)				-625	-514	-978	-975	-3992	644
5	emigration (abs)				-701	-364	-924	-948	-3837	644
6	migration/km ²				-1206	-1106	-1283	-1064	-5476	584
7	migration to/km ²				-1220	-1023	-1303	-1069	-5515	644
8	migration from/km ²				-1207	-981	-1288	-1073	-5448	644
9	immigration/km ²				-949	-901	-1160	-1102	-5012	644
10	emigration/km ²				-1014	-770	-1181	-1096	-4961	644
11	migration/population				-1212	-1130	-1298	-937	-5392	584
12	migration from/pop				579	262	-1099	-710	-1867	644
13	migration to/pop				722	426	-659	-636	-1047	644
14	immigration/pop				-1233	-1048	-1196	-971	-5348	644
15	emigration/pop				-1247	-663	-1081	-929	-4820	644
16	occupational structure	-1041	-730	-1009	-1160	-1144	-1321	-917	-9396	1057
17	% in agriculture	-900	-661	-799	-1014	-957	-1241	-860	-8643	1127
18	% in manufacturing	1166	1254	1095	252	-758	-1312	-920	-1435	1127
19	% in services	-605	-427	-929	-808	-980	-1004	-662	-7625	1127
20	% in transportation	-948	-606	-771	-943	-1176	-1375	-972	-9002	1127
21	population density		-604	-836	-969	-837	-1213	-1063	-7261	966
22	urbanization						-1050	-873	-2139	312
23	mean income per capita			-806	-1166	-1154	-1394	-963	-6786	805
24	academics per 100000	-229	-351	-854	-977	-766			-4490	805
25	% more than elementary education					-956	-1074	-661	-3228	483
26	religion (pop data)	-331	3	295	-231	-513			-1966	730
27	size of denomination (population data)	284	780	652	183	-258			327	805
28	religion (tables data)		4	393	-40	-404	-1104	-1141	-3870	876
29	size of denomination (tables data)		1100	907	355	-60	-917	-854	-1209	966

¹ A synopsis of the history of religion in the Netherlands can be found in Thurlings (1978: 58-132) Peters and Schreuder (1987: 31-83), Bax (1988: 73-96).

² The supply factor "spatial dispersion" can be similar to the barrier factor "physical segregation". The distinction is that in the case of spatial dispersion, there are no obstacles to moving to another region, whereas in the case of physical segregation access to certain areas or organizations is restricted. So the concentration of blacks in the homelands of South Africa is an example of physical segregation, but the concentration of Catholics in the southern provinces of the Netherlands is an example of spatial dispersion.

³ The fact that religious attitudes and beliefs, as well as church membership declined since the 1960s, belies Goddijn's (1973) argument that stagnation in the process of modernizing the organization of the Catholic Church was an important cause of secularization. If discontent with ecclesiastical structures were the only problem, then membership might decline, but the decline in religious attitudes would not keep pace. Hout and Greeley (1987) show that dissatisfaction with Catholic church teachings led to a reduction in church attendance in the United States, but that this decline stabilized after 1975. Dekker (1992) describes important changes in the organization of the Re-Reformed churches, but shows that these were also affected by declining church attendance.

⁴ In my opinion, Bax's argument that pillarization was "an integral part of the process of Dutch modernization" is rather weak. Modernization and in particular the extension of franchise necessitated a new power structure in the second half of the 19th century, but does not explain why religious ideologies should play a role. Modernization certainly affected the means at the disposal of the new elites, and they used these readily. However, the goals of the new religious elites, in particular of the Re-Reformed Protestants, were to protect their flocks against the secularizing influences of modernization and later socialism.

⁵ Diagonal parameters will usually be estimated by creating dummy variables for the diagonal cells. The dummy variable for a certain category will have with the value of 1 for the diagonal cell of that category, and 0 otherwise. This is equivalent to a contrast of the diagonal cell with the mean of the off-diagonal cells, so the parameters will be equal to the log odds of inmarriage versus outmarriage.

⁶ A side question to be addressed here is whether variations of assortative marriage by province can be simplified to variations by a smaller number of regions. For this purpose, a C.B.S. grouping of provinces into 5 regions is used, based on proximity of the provinces and the nature of their social-economic activities:

North	Groningen Friesland Drenthe
East	Overijssel Gelderland
West	Utrecht Noordholland Zuidholland
Southwest	Zeeland

Table 5a contains goodness of fit statistics for models that let religious assortative marriage vary by region rather than by province. A comparison of the BIC values of these models with those in table 5 shows that model 5a has a slightly better fit, but that the fit of the remaining models is somewhat worse. An examination of figure 5 in chapter 2 does not point to groups of provinces with strongly similar patterns of assortative marriage: the pattern in each province is different. Since this is a minor point, it was decided not to pursue the regrouping of provinces into regions any further.

Table 5a

Goodness of fit statistics for models of religious assortative marriage by region (5 categories) and year of marriage (1938-1986)

	L^2	df	BIC
5a assortative marriage variable with time and region, but not with time/region combinations (no 4-way interaction)	5572	1056	-8565
6a symmetric interaction, variable with time and region	5726	1122	-9295
8a symmetric deviances parameters constant for regions, variable with time; diagonal parameters variable with time and region	6044	1142	-9245
9a symmetric deviances parameters constant for time and region, diagonal parameters variable with time and region	6338	1172	-9351

⁷ Conditional models per year for the analysis in the following section did provide evidence of convergence. Regard the fit statistics per year of the "baseline model" and "full effects model" in tables A.2 and A.3 in appendix A. The baseline model restricts the symmetric deviances and diagonal parameters to be constant across provinces, while the full effects model lets the diagonal parameters vary. Table A.3 shows that allowing inmarriage to vary by province improves the BIC for each year, but that the improvement gets progressively smaller.

⁸ GLIM 3.77 is an efficient program for large tables, but cannot directly estimate the types of parametrizations desired here. GLIM was used to derive the fitted values of the final model with 9 decimal points accuracy. Subsequently, %GLIMMAT, a series of SAS macros using PROC IML, was used to build the design matrix and determined the parameter estimates on the basis of the log fitted values. Chapter 9 contains a description of the GLIMMAT macros.

⁹ Calculating variance of loglinear parameters over the categories of province or of year of marriage does not take their standard errors into account. A better measure would be the loss of fit if each parameter were held constant for time or province, but this would cost a great deal of time and would probably not result in different conclusions.

¹⁰ For 1938, 1945 and 1946, the net change in population due to migration was available. From 1947 to 1952, the net inflow and outflow due to migration and immigration/emigration

were reported for each province. However, these data obscure a great deal of the movement of persons and were therefore not considered useful.

¹¹ The table from the "*Arbeidskrachtentelling 1985*" did not make the distinction between "semi-hoger niveau" and "hoger niveau", as did the census of 1971. It therefore could not be used to extend the range of the "academics per 100000" variable.

¹² The data did distinguish between municipalities with less than 5000 inhabitants, and with 5000 to 20000 inhabitants. However, since the second category is often composed of a group of small villages that have been grouped into a single administrative unit, this distinction was considered somewhat artificial. It was found that merging these two categories barely affected the L^2 of models, which indicates that the patterns of association within the two categories are virtually the same. Merging them therefore simplified the interpretation, without any substantial loss of information.

Chapter 4

Religion and Education as Dimensions of the Choice of Marriage Partner: Single Trait and Dual Trait Analyses

Abstract

Research on assortative marriage patterns has become an accepted method for drawing inferences on the extent of closure between different groups in a society. Research on religious assortative marriage has shown a trend toward more intermarriage in the Netherlands (Hendrickx, Lammers, Ultee 1989, chapter 2). Results on educational assortative marriage also seemed to indicate a trend to greater openness, although recent work in the United States (Mare 1990, Kalmijn 1991a,b) show a trend to greater closure.

However, partner choice is a multi-dimensional process and with exception of Kalmijn (1991a,b), these analyses consider only one dimension of partner choice at a time. Following his lead, we analyze a five-way table taken from the 1971 Dutch census, of husband's denomination by wife's denomination by husband's education by wife's education by marriage cohort. This will allow us to address the following questions:

- (a) Is there evidence of double homogamy, i.e. of a special effort to obtain a spouse with the same denomination and the same education.*
- (b) How does religion affect educational assortative marriage, and how does education affect religious assortative marriage?*
- (c) Does an analysis with two dimensions of partner choice yield different results than separate analyses for each dimension.*
- (d) How does time affect the relative strengths of religion and education as dimensions of partner choice?*

The results do not indicate a tendency to double homogamy. Religious homogamy is stronger than educational homogamy, but shows a strong downward trend in the 1960s, whereas there is an upward trend toward more educational homogamy. Inmarriage parameters in the dual trait analyses were lower than in the single trait analyses, due to controlling for the association between religion and education. Educational homogamy is affected by the wife's denomination and is lower for wives of the Re-Reformed Protestant and "other" denominations. Religious homogamy is affected by the educations of both partners. Educational inmarriage decreases with increasing education of the wife. However, husband's education affects religious homogamy only for the category "other denomination", whose inmarriage is lower for higher education of husband.

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Introduction

Assortative marriage informs us about the social distance between groups. A marriage is an intimate bond between two persons, and the extent with which members of different groups marry is a good indicator of the extent of less intimate relationships such as friendship, or simply tolerance. Hout (1982) analyzed occupational homogamy in the United States. Studies on educational assortative marriage have been done by Mare (1991) for the United States, by Sixma and Ultee (1983) for the Netherlands, while Ultee and Luijkx (1990) did an important international comparison of educational homogamy in 23 industrial nations. Religious Assortative Marriage has been studied by Johnson (1980) for the USA and by Hendrickx, Lammers, Ultee (1989) and in chapter 2 for the Netherlands. These analyses have in common the use of loglinear designs such as used in mobility models, which can test for specific patterns of assortative marriage, while cancelling out the influence of group size. Some studies such as Heer (1962) and McCutcheon (1988) used the percentage of inmarrying persons, which confuses size factors and relative homogamy factors.

These homogamy studies also examine only one dimension of homogamy at a time, although theory indicates that partner choice is a multi-dimensional phenomenon. Kalmijn (1991a,b) conducted multivariate loglinear analyses, using two dimensions of assortative marriage simultaneously. Following his lead, we will analyze religious homogamy and educational assortative marriage together in one analysis, for six marriage cohorts from before 1949 up to 1970. This simultaneous analysis allows us to test whether double homogamy takes place and to control for the association between denomination and education when determining the association between the denominations and the educations of marriage partners. We are able to test whether education affects religious homogamy (e.g. because persons with higher status conform to norms more than persons of lower status) and/or whether religion affects educational homogamy (e.g. that a religiously mixed marriage is more acceptable if the partner has a high status). The use of the dimensions education and religious denomination makes it possible to draw inferences on the divisive strengths of a vertical and a horizontal stratification dimension. The case of the Netherlands is particularly interesting, since religious cleavages in Dutch society have been strong – religious differences were considered to be of greater importance than class differences.

In the following paragraph, we discuss the background of social distance between groups, followed by a description of the Dutch situation. This is preceded by a description of the data and methods we use in this paper. We then discuss hypotheses on the associations that will be found in the table, and their implications for the type of loglinear model or pattern of association. The results are presented of single trait analyses of education and religion, followed by the results of a dual trait analysis. In this way, we are able to evaluate the impact of including two dimensions of partner choice in a single analysis.

Theoretical background

Individuals tend to choose interaction partners with a similar status and similar opinions. This proposition can be treated as a premise, as is done by Blau (1977; 1984). It has been the object of social psychological research in laboratory experiments (social comparison research: Festinger 1947; Suls & Miller 1977). The deeper reasons for this preference for similar others are open to question. It is pleasant to hear one's opinions be confirmed, but on the other hand

it can be useful and interesting to hear deviant views. As for status, the best choice would arguably be a partner with different, complementary resources that are equally valued (Becker, 1981).

Given the choice of interaction partners of all individuals in a society at a particular point in time, it would be possible to describe the group structures of that society. In many cases, there will be clusters of small face to face groups with many cross memberships, while the clusters themselves are relatively isolated. Such clusters will tend to be homogenous with respect to certain characteristics that are important to that society. In other words, the structure of society is to a certain extent the unintended result of individual preferences.

In any group that exists for more than a very short period, a group identity will evolve, stressing common characteristics and common interests and in doing so opposing them to characteristics and interests of other groups. The groups can develop formal and informal norms to promote group homogeneity. This can lead to a simpler, more rigidly defined structure than would emerge purely on the basis of individual preferences.

Individual preferences and group norms will lead to pressures to uniformity within groups. This raises the question along which dimensions the major divisions will crystallize. Resources and ideas related to the distribution of power and wealth, such as education, occupation, ownership (of the means of production) are obvious causes of division in society. People with influence will also tend to seek and maintain contacts, regardless of the precise nature of their power bases, since these contacts affect the range of their influence. In the realm of ideas, political notions on the distribution of wealth can be expected to be important.

Religious ideas are also strongly divisive in many societies, although by rational criteria, the evidence and argumentation in support of them would seldom be considered valid if applied to other areas. The fact that people support these ideas to the point of acting aggressively or violently if they are gainsaid, seems to indicate, next to material needs, a need for sense of security with respect to the ultimate meaning of life and the manner in which it should be lived. This point has been touched by Durkheim with his concept of egoism and the lack of social integration: the lower the sense of security a religion can provide for its members, the higher the suicide rate turns out to be. Religion is of course also to some extent intertwined with the economic and political interests of certain groups. It is rarely used in a conscious, cynical manner toward such goals however, and it cannot be reduced to them.

There are pressures to group homogeneity, but evidently there is also some tolerance for deviations within groups and contacts between groups. For purely utilitarian ends, the tolerance can be boundless (e.g. the alliance of Capitalist and Communist countries in the second World War). Contacts of the more personal type are usually restricted to other group members. Blau & Schwarz (1984) posited that one factor that could influence tolerance is the extent of cross-cutting memberships of groups, i.e. whether there is a strong association between dimensions such as religion and education. If the association is weak, then there will tend to be contacts between members of each religious category with groups of different mean educational level (and vice versa), and this would promote tolerance of both religious and educational differences. The existence of cross-cutting memberships necessitates the reconciliation of group subcultures, which tends to weaken ingroup tendencies. Isolationism of groups tends to have the opposite effect, the strengthening of ingroup tendencies.

An interesting contrasting view to that of Blau is the "pillarization" theory of Lijphart (1968). He posited that social heterogeneity in itself would only lead to trouble. Cross cutting cleavages would allow the separate development of groups in a "living apart, together" situa-

tion. In such a consociational society, groups are separated, thus avoiding conflicts, while contacts among the groups' elites allow for the necessary coordination.

Blau is of course aware that contacts between groups are not sufficient to enhance tolerance. Contacts can also lead to conflict, in cases where the social distance between groups is too large, either because of strong ideological differences, or because of strong differences in the distribution of resources. A consociational society might then be a useful intermediate situation, "drawing lines" and suppressing abrasive casual contacts while allowing contacts of a more utilitarian nature. Blau's theory would still seem to indicate that such an arrangement would have a detrimental effect and over time would increase the social distance between groups, while according to Lijphart, peace would be maintained in the only feasible way.

Whatever the tolerance of contacts between groups, it applies less strongly to contacts of a superficial, utilitarian nature, such as working together or using the services of business enterprises, and more so to contacts of the intimate, affective kind such as friendships and marriage. For this reason, the amount of homogamy can be used as an indicator of the social distance between groups – if many people choose partners from other groups, then there will be even more friendships and superficial contacts between the groups.

However, the amount of homogamy is not just determined by the "barriers" to contacts between two types of groups. "Supply" factors also affect the extent of "gross homogamy": there are more opportunities for contacts with members of a large group than with members of a smaller group (chapter 2). The spatial dispersion of groups is a second example of a supply factor. The disturbing influence of the size factor can be cancelled out by using appropriate methods, such as calculating odds-ratios or using loglinear analysis.

THE DUTCH SITUATION: THE CATEGORIES OF RELIGIOUS CLEAVAGES

The theory of Lijphart on consociational societies was devised in order to contribute to an explanation of the so called "pillarization" system in the Netherlands. Dutch society until the 1960s was strongly divided along religious lines, with separate organizations in the field of politics, unions, schools, charities, broadcasting associations – almost every organization imaginable had a Catholic, Protestant, liberal/neutral and socialist variation. This evokes the image of a society divided horizontally into "pillars", rather than vertically as in the class struggle scheme. Pillarization theorists consider religious cleavages to be of greater significance in Dutch society than class based cleavages. According to some, pillarization inhibited class based voting, which is low in the Netherlands compared to other countries (De Graaf and Ultee, 1990). From the 1960s on, the system of pillarization has gradually deteriorated. Many denominational organizations have merged into a single Christian organization, most notably in the case of political parties, where the Catholic KVP merged with the Protestant parties CHU and ARP to form the Christian CDA. Other religious organizations have dismantled through lack of support. Schools and media organizations are still pillarized in name, but the practical effect on everyday functioning is often small. However, the political parties continue to some extent to support pillarized organizations.

The Netherlands is a country where Calvinist Protestantism has been the dominant religion from the Reformation in the 16th century onward, but with a large Catholic segment. The Dutch Reformed church, which had provided the ideological foundation for the Dutch war of independence against Spain, was the State Church until the Napoleonic occupation of the Netherlands from 1795 to 1813. Until 1848, the Catholic hierarchy was banned and although there was considerable tolerance, there was of course also officially sanctioned discrimination

(Bax, 1988). During the next hundred years, Catholics became steadily more emancipated, moving upwards to higher income and occupational levels. Some theorists (e.g. Thurlings, 1971) treat the emancipation of the Catholics as an explanation for the rise (and after the emancipation of Catholics had been largely achieved, the subsequent decline) of the system of pillarization in the Netherlands.

However, the initial impulse for the system of pillarization was given by members of the (orthodox Protestant) Re-Reformed church. Several religious groups split from the main Dutch Reformed church at the end of the 19th century, because of dissatisfaction with the liberalism of that church. A famous preacher/politician of their ranks, Abraham Kuyper, initiated the system of pillarization by successfully fighting for separate Protestant and Catholic schools, in addition to the officially neutral state schools. The Catholics assisted him in his struggle by forming a grand coalition. During the first half of the 20th century, Catholic, Protestant (in some cases orthodox Protestant and liberal Protestant), liberal/neutral and socialist counterparts were formed or split off from the main organisation in other fields than education.

The major role of the Re-Reformed church at the instigation of the system of pillarization would suggest that ideological differences, not social and economic differences, were the main forces at work. Some aspects of the Calvinist Protestant religion reject compromise in favour of purity (Post, 1990). However, the members of the Re-Reformed church were largely recruited from lower economic strata (Kruijt, 1954) and we noted above that Catholics had an under-privileged position. The cleavages between religions could have been affected by material factors, either as the root cause of the conflict for which ideological differences were only a rationalization, or as a factor heightening the salience of the ingroup and its ideas. Such a mixture is often seen in cases of ideological conflicts, which bars overstressing the differences of ideas as the sole cause of tensions.

In the following analyses, we will test to a limited extent the salience of ideological differences (as indicated by religious homogeneity) vs. the salience of status differences (as indicated by educational homogeneity). Since we also have access to marriage cohort, we will also be able to track the development of association through time, from before the second World War, when the system of pillarization was being consolidated, up to 1970, when the process of depillarization was in full force. A description of the data we used follows, after which we discuss hypotheses, before proceeding to the analyses.

Data

The data was from the 1971 Dutch census, collected by the Dutch Bureau of Statistics C.B.S. We had access to the frequency tables based on a 10% sample, for husband's religious denomination by wife's religious denomination by husband's educational achievement by wife's educational achievement by marriage cohort. Five categories were distinguished for religious denomination, thirteen categories were distinguished for educational achievement, and 6 categories were distinguished for marriage cohort. The data therefore had 5 by 5 by 13 by 13 by 6 = 25350 cells, for a total of 2815519 cases.

The categories for religious denomination were:

- (1) Catholic
- (2) Dutch Reformed (liberal Protestant)
- (3) Re-Reformed (orthodox Protestant)

- (4) other denominations (predominantly liberal Protestant)
- (5) no denomination

The census used single-phase question, as opposed two-phase questions such as "Do you consider yourself a member of a church or religious group? If so, which one?" The latter type of question prompts marginal members to a negative response ((C.B.S. 1988, chapter 2). The one-phase question is suitable for our purposes, since it is an indicator of group identification.

There were 13 categories of education, so recoding to a smaller number of categories was necessary. The categories were recoded to the following categories:

- (1) elementary school only
- (2) level 2: compulsory lower secondary and extended lower vocational
- (3) level 3: extended lower general and intermediate vocational
- (4) level 4: intermediate general and college
- (5) university education

The justification for this recoding is discussed more fully in Appendix A.

The categories for marriage cohort were:

- (1) married before 1949
- (2) married between 1950 and 1954
- (3) married between 1955 and 1959
- (4) married between 1960 and 1964
- (5) married between 1965 and 1969
- (6) married in 1970

This covers a large period, from before the Second World War, when the system of pillarization was being built and consolidated, until 1970, when it was in full decline. In the analyses, we must of course assume that disturbing factors such as selective mortality or selective divorce do not have too great an effect. Results for the earliest cohorts will have to be interpreted with caution.

Methods

We noted above that individual preferences for interaction partners with similar opinions and status, together with group norms, result in barriers to contacts between members of different groups, and that beside these "demand" factors are "supply" factors such as relative size and spatial dispersion, which determine the gross number of contacts between groups. It has been found that loglinear models are able to incorporate the factor relative size in the main effects, so that interaction effect parameters indicate the strength of contact barriers. A simple discussion of these models is included in chapter 2. Featherman and Hauser (1978: 141-166) discuss the shortcomings of earlier methods based on percentages and Hout (1983) gives an overview of types of mobility designs.

Because we are using a five-way table, parameters for homogamy/heterogamy will be relative in an even stronger sense. For example, educational homogamy will be independent of the relative sizes of the categories and the unequal distributions of education for men and women, but also of the association between religion and education and religious homogamy. Possibly, some effects that would be found in a two-way table are partially spurious and will not be found in the four-way tables.

A problem when analyzing large numbers is that the probability of a model is almost always significant, since sample fluctuations are negligible or non-existent. A solution to this is the use of the BIC measure (Raftery, 1986)¹. This measure is derived from Bayesian statistics and is based on the ratio of the probabilities that two models are true, given their observed counts. In the standard situation, where the saturated model is used as baseline, BIC must be less than zero for the model to be more likely than the saturated model. We will use BIC to guide the choice of model in the analyses below.

SPECIAL DESIGNS

Our designs for assortative marriage patterns differ from those typically used in mobility research, in that we make use of the “deviation contrast”, the restriction that parameters sum to zero. This provides a parameter for each cell of the table, providing us with measures of each type of inmarriage and each type of outmarriage. In order to gain insights in the nature of the associations, we split the interaction parameters into three sub-terms:

- 1 **Diagonal parameters.** These are used in most types of mobility models, usually in the “quasi” versions. These parameters typically indicate the log odds between inmarriage in a particular category, and outmarriage. However, we also use the deviation contrast for these parameters, to keep the interpretation consistent. This results in a square table of interaction parameters, for which off-diagonal values are determined by values on the diagonal. We refer to the complete set as the “homogamy pattern” parameters, but only interpret the values on the diagonal, which are referred to as “inmarriage” parameters. The values of inmarriage parameters are between .6 and .8 the value of “typical” diagonal parameters.
 - a **Overall diagonal.** Simply the average of the diagonal parameters.
 - b **Diagonal deviances.** The deviances from the overall diagonal parameter.
- 2 **Symmetric deviances.** These parameters map the space between a quasi-independence model and a quasi-symmetry model. The former model implies that there is a preference for inmarriage, but that outmarriage parameters are directly determined by the inmarriage preferences. The symmetric deviances therefore indicate the extra attraction/aversion between categories, if a mixed marriage takes place. We therefore refer to them as social proximity parameters. The homogamy pattern parameters plus the symmetric deviances give the symmetric deviation contrast parameters.
- 3 **Skew symmetry.** These map the space between a quasi-symmetry and a saturated model (Yamaguchi 1990, Sobel, Hout, Duncan 1985). They indicate for which cells the effects are not symmetric, providing information on male/female differences in preferences for outmarriage.

These redefinitions are used as a first step toward obtaining a parsimonious model using deviation contrast parameters. By restricting the symmetric deviances parameters to be constant through time, a hybrid model between quasi-independence and quasi-symmetry can be used (as in Hendrickx, Lammers, Ultee 1989). This can be very useful in a five-way table, where assortative marriage parameters can vary with several variables. Chapter 8 contains a more complete discussion of these restrictions.

Further parsimony could be achieved by setting specific skew symmetry or symmetric deviances parameters to zero. For example, the category “other denomination” is heterogeneous, and conflicting tendencies could therefore result in neutrality with regard to partner, in the event of outmarriage (this was not the case however). We used two special restrictions of a

more general type: the "hollow" restriction for skew symmetry parameters, and the "mirror" restriction for symmetric deviances.

Table 1a
The "hollow" skew symmetry design

0				
a	0			
b	0	0		
c	0	0	0	
-a-b-c	c	b	a	0

Skew symmetry parameters on the diagonal are zero by definition, and $v_j = -v_j$.

As table 1a shows, the "hollow" restriction tests whether the skew symmetry is due only to preferences in the extreme categories (the categories therefore need not be fully ordered). For example, women with elementary or with university education might be extra status conscious, and therefore have different preferences for outmarriage categories than men do. For the middle categories this might not be the case. The number of parameters to be estimated is reduced from 6 to 3 (for a 5 by 5 table).

Table 1b shows the design of the mirror contrast, so called because the parameters are symmetric across the lower left to upper right diagonal, as well as across the upper left to lower right diagonal. The preferences of the highest category therefore mirror those of the lowest category, e.g. the social proximity between the lowest and second lowest is the same as between the highest and second highest, etc. The middle category is strictly neutral with regard to partner choice. The number of parameters to be estimated is thus reduced from 5 to 2. The "mirror" restriction assumes ordered categories.

Table 1b
The "mirror" symmetric deviances design

0	A	0	B	-A-B
	0	0	-A-B	B
		0	0	0
			0	A
				0

Symmetric deviances parameters on the diagonal are zero by definition, and $\omega_j = \omega_j$.

In several cases, we used the polynomial contrast for trend smoothing. Since the cohorts are not equally spaced, the values {40 52 57 62 67 70} were used as a metric. The choice of 1940 as the midpoint of the first cohort ("before 1949") was somewhat arbitrary, but experimentation showed that other values did not strongly affect the results². A full set of deviation contrast parameters can be derived from the polynomial contrast parameters, either by deleting 1st degree and 2nd degree terms from the log fitted values to derive the 3rd degree pa-

rameters (for a 3-way table) or by using the contrast matrix. We used both methods in order to minimize the chance of mistakes.

Hypotheses

THE SINGLE TRAIT ANALYSIS

The 1960s were a period of depillarization and secularization. On the basis of earlier research on religious assortative marriage (Hendrickx, Lammers, Ultee 1989, chapter 2), we can predict stability in religious inmarriage for cohorts prior to 1960, followed by a decrease in religious homogamy for Catholics and Re-Reformed Protestants in the last three cohorts (the *de-pillarization* hypothesis). Furthermore, the association can be predicted to be symmetric; a model with constant symmetric deviances parameters, but diagonal parameters which vary with time, should have the best fit. It is perhaps interesting to note that although we can predict symmetric association between the partners' denominations, there are theoretical arguments in favor of asymmetrical association. Religion tends to be more salient for women and we might therefore expect the social distance to be larger if the wife has a religion but the husband does not, than if the wife has no denomination but the husband does. However, this is not confirmed by research.

Industrialized societies are expected to show a general trend toward more openness. Mobility research by Ganzeboom and De Graaf (1983) and by Ganzeboom et al. (1987) showed that intergenerational mobility increased in the Netherlands, and research by Sixma and Ultee (1983) and Ultee and Luijkx (1990) showed that educational inmarriage decreased. The *class equality* hypothesis predicts a decline in educational inmarriage³.

An earlier analysis showed that the association between the partners' educations was asymmetric. On the one hand, this is not confirmed by other analyses, although these do not make explicit tests and use other goodness of fit measures than BIC. On the other hand, the strong flow of women into higher categories of education makes an asymmetric association between partners' educations plausible. Women with a higher education might tend to be more status conscious and therefore to have a strong aversion to marrying beneath their educational level (their preference for a partner with the same education would also partially explain an increase in educational inmarriage). We will refer to the hypothesis that increased salience of education for women will lead to asymmetric association and higher inmarriage as the *feminism factor*.

THE DUAL TRAIT ANALYSES

For some of these hypotheses, we found that it was useful to think in terms of a two-way, 25 by 25 table of the religion by education combinations for husbands and wives, rather than a four-way table. The dual trait analysis should show lower inmarriage parameters for both religious and educational assortative marriage, compared to the single trait analysis. The association between religion and education will make religiously homogamous marriages somewhat more likely, even if the partner is selected on the basis of education, and vice-versa. We will refer to this as the *spurious homogamy* hypothesis.

The *conformism* hypothesis predicts that, since there are norms prescribing both educational and religious inmarriage, people will do their best to conform to both. This means that

there will be a 4th degree effect of $ed_h * ed_w * rel_h * rel_w$. A restricted model would also have to show that the 4th degree effect is due to high values on the diagonal of the two-way, 25 by 25 table.

Blau (1977) would predict that this conformism hypothesis will be falsified, since it is simply impractical to achieve multi-dimensional heterogamy. For a Re-Reformed university graduate to find either another Re-Reformed partner or another university graduate is hard enough, since both the Re-Reformed and university educated categories are fairly small. But even if contact opportunities are frequent for larger groups, people are likely to concentrate on one dimension or the other. Blau's theory leads us to a *limited opportunities* hypothesis: the opportunities for contacts with other group members will constrain people to choose for one dimension of inmarriage or the other: double homogamy will not be feasible. The four-way interaction will therefore not be significant.

Another hypothesis is called the *pillarization* hypothesis. The theory of pillarization contends that in Dutch society, religious differences are more important than class differences. This would mean that double homogamy would be attempted. In cases of failure, achieving religious homogamy would have priority. In a strict form, educational assortative marriage would not occur outside the four-way interaction (which implies a non-hierarchical model). The three-way interactions $ed_h * ed_w * rel_h$ and $ed_h * ed_w * rel_w$ would therefore be zero.

This strict form of the pillarization hypothesis assumes that pillarization has equal salience for all denominations, which is not very realistic. Pillarization is (was) salient for Catholics and (Re-Reformed) Protestants, but not for persons with no denomination and perhaps not for Dutch Reformed Protestants and "other" liberal Protestants. We could expect that if pillarization is salient, religious homogamy will have priority, but if it is not, that educational homogamy has priority. This would mean that the conditional educational homogamy term $ed_h * ed_w$ for both Re-Reformed and Catholic husbands and wives would be considerably lower than for the remaining denominations.

In its weakest form, the phenomenon of pillarization would imply that religious homogamy is stronger than educational homogamy, and that educational homogamy is weaker, given that husband or wife is Re-Reformed or Catholic.

As religious inmarriage decreases, the choice of priority between religious and educational homogamy will shift in favour of the latter. The *shifting priorities* hypothesis predicts that double homogamy, if present, will decrease and possibly disappear, religious homogamy will decrease, and educational homogamy would, all things being equal, increase (Kalmijn 1991b).

The next hypothesis relates to the influence of education on religious homogamy. The *noblesse oblige* hypothesis posits that those with a higher status must set a good example by showing greater conformism. Therefore, religious assortative marriage should be contingent on educational status, with greater religious homogamy for higher levels of education. The three-way interactions $ed_h * rel_h * rel_w$ and $ed_w * rel_h * rel_w$ should be significant and should show stronger association between the denominations of the spouses for higher categories of education.

Opposed to the noblesse oblige hypothesis is the *avant garde* hypothesis. Those with the highest education will reject homogamy of either type more than those with lower education. Those with highest status will define the norms, under the assumption that norms of tolerance and openness are becoming increasingly important. Educational homogamy should therefore be lower in the higher educational categories. The interactions $ed_h * rel_h * rel_w$ and

$ed_w * rel_h * rel_w$ should also be significant, but religious homogamy should be lower for higher categories of education.

The noblesse oblige hypothesis (the elite tends to conform to norms) and the avant garde hypothesis (the elite tends to break norms first) are in conflict with each other. The latter hypothesis becomes more likely as time progresses and the system of pillarization is more and more widely perceived as out-dated. The conformism hypothesis is quite likely in earlier cohorts however, particularly in the first two.

A variation of the avant garde hypothesis is the *Trojan horse* hypothesis. This focuses on education as a (subversive) secularizing force, rather than as a status dimension. As in the avant garde hypothesis, it predicts that the lower salience of religion among persons with higher education will lead to lower religious homogamy than for persons with lower education (McCutcheon, 1988). However, educational homogamy would not be lower in the higher categories of education; indeed, it might be higher, since the norm of educational homogamy could be preferred over the norm of religious homogamy.

THE RELATIONSHIPS BETWEEN EDUCATION AND RELIGION

Women's education began catching up with that of men throughout this period. Sixma and Ultee (1983) found a reduction in the differences between the distributions of education for men and women between 1959 and 1971, although these differences did not disappear. We expect that differences between the association of variables for men and women to decrease as time progresses.

The relationship between education and religion will be affected by education as a secularizing force on the one hand, and differences between denominations in the salience of education on the other. Religious children attending higher education might lose their faith, or the salience of religion might at least become less for them. This would lead to an over-representation of the category "no denomination" in higher levels of education (and an under-representation at lower levels). From the point of view of religion as a cause of education, we might expect the "heteronomous", conformist values of Catholics to lead to a lower educational attainment (Lenski 1961). The Calvinist Re-Reformed and Reformed denominations on the other hand should be well represented at higher levels.

The relationship between religion and education is also expected to change. Catholics were an under-privileged group in the 19th century and this motivated their cooperation with Re-Reformed Protestants in bringing into being the system of pillarization (Thurlings 1970). Re-Reformed Protestants also tended to consist of "kleine luyden", economically under-privileged persons (Kruijt 1954). An *emancipation* hypothesis predicts that the educational attainment of these groups will be low initially, but will move toward the average as time progresses.

In a four way analysis, the matter of structural heterogamy becomes more complicated. The second order effects $ed * rel$ plus the first order effects ed and rel would form the marginal parameters of a square 25 by 25 table. Structural heterogamy can therefore be split up into structural educational heterogamy, structural religious heterogamy and structural double heterogamy. There will be structural educational heterogamy to the extent that ed_h is unequal to ed_w , structural religious heterogamy to the extent that rel_h is unequal to rel_w , and structural double heterogamy to the extent that $ed_h * rel_h$ is unequal to $ed_w * rel_w$. Structural double heterogamy therefore depends on the differences in the association of education and religious denomination for men and women.

Analyses

Before discussing the dual trait analysis, we present single trait analyses of educational and religious assortative marriage. On the smaller tables used in these analyses, parsimonious designs could be used that were not available for the dual trait analyses. The single trait analyses can therefore present a simpler picture of the patterns of religious and educational assortative marriage. In the dual trait analysis, we will compare the results of the simultaneous analysis with parameters from a corresponding single trait model (without some of the refinements of the models discussed below). This will provide insights on the impact of controlling for the association between education and religion.

SINGLE TRAIT ANALYSIS OF EDUCATIONAL ASSORTATIVE MARRIAGE

For the single trait analysis of educational assortative marriage, we analyzed a 3-way table of partners' education (5 categories) by cohort (6 categories). Because some cells were sparse, we added .5 to all cell values. The table turned out to have very few regularities. Table 2 shows the models we estimated.

In model (1), we discovered that the association between partners' education is not only asymmetric, but that the skew symmetry effects change with time. This is in line with the *feminism factor* hypothesis. Interpreting the skew symmetry trend would be something of a problem, since many of the cells are sparse. In order to smooth out large, but meaningless

Table 2
Models for the single trait analyses of Educational Assortative Marriage

nr	model	L^2	df	BIC
1	no skew symmetry trend	912	30	474
2	linear trend of skew symmetry	246	24	-5
3	2nd degree polynomial trend skew symmetry	244	18	-19
4	3rd degree polynomial trend skew symmetry	186	12	11
5	As (3), with linear trend symmetric deviances	662	38	107
6	As (3), with 2nd degree trend symmetric deviances	594	33	112
7	As (3), with 3rd degree polynomial trend symmetric deviances	452	28	43
8	As (3), with "hollow" restriction on trend skew symmetry	332	24	-18
9	As (8), with "hollow" restriction on skew symmetry	540	27	146
10	As (3), with "mirror" restriction on trend symmetric deviances	377	33	-105
11	As (10), with "mirror" restriction on symmetric deviances	1242	36	717
12	As (10), with linear trend on diagonal deviances	795	49	80
13	As (10), with 2nd degree polynomial trend on diagonal deviances	617	45	-40
14	As (10), with 3rd degree polynomial trend on diagonal deviances	579	41	-20
15	As (10), with no trend overall homogamy	509	38	-46
16	As (10), with linear trend overall homogamy	390	37	-150
17	As (10), with 2nd degree polynomial trend overall homogamy	390	36	-136
18	As (10), with 3rd degree polynomial trend overall homogamy	388	35	-123

fluctuations, we applied the polynomial contrast to cohort effects. We tested for a linear, 2nd degree polynomial, and 3rd degree polynomial trend; we felt that a 4th degree polynomial would provide too little parsimony to be worthwhile. The results of models (2), (3) and (4) indicate that a 2nd degree polynomial best describes the skew symmetry trend.

In models (5), (6) and (7), we tried to find a simple trend for the symmetric deviances, given a 2nd degree polynomial trend for skew symmetry. The fit of models with a linear, 2nd degree and 3rd degree polynomial trend is poor. Our tentative model remained model (3) with no restrictions on the trend of symmetric deviances.

In models (8) and (9), we attempted to describe skew symmetry more parsimoniously. This was done with a “hollow” skew symmetry design, in which all parameters but those for the first/last row or the first/last column are set to zero. The reasoning for this model is that asymmetries occur for combinations of the two extreme status values with each other or some of the other status values, but that the association between the middle section is symmetric. In model (8), we tested whether this “hollow” restriction could be applied to the skew symmetry trend. The BIC value for this model was only slightly higher than for model (3). The fit of model (9), which applies the “hollow” restriction to the skew symmetry term as well, is clearly poor. We decided to retain model (3) as our tentative model, although model (8) might be considered marginally acceptable.

In models (10) and (11), we focused on the symmetric deviances parameters. Model (10), which only imposes the “mirror” restriction on the 3rd degree symmetric deviances by cohort parameters, fits very well. However when the “mirror” restriction is imposed on the 2nd degree symmetric deviances term in model (11), the fit becomes unacceptable. We decided to accept model (10) as our tentative model.

Our next step was to see whether parsimony could be achieved in describing the trends of educational homogamy. In models (12) to (14), we tested whether the trend of diagonal deviances could be described by a linear, a 2nd degree polynomial, or a 3rd degree polynomial trend. None of these models was an improvement over the tentative model (10). We proceeded to test whether the overall homogamy trend could be described more simply. Model (15), which allows for no overall homogamy trend has a worse fit than model (10), although it would be an acceptable model in itself. A model with a linear trend has the best fit of models so far. Relaxing the restriction to 2nd or 3rd degree polynomial barely affects L^2 at all.

Our final model is therefore model (16). This model specifies that skew symmetry changes with time by a 2nd degree polynomial trend. A “mirror” restriction can describe the changes in social proximities but the “mirror” restriction cannot be applied to social proximities, controlling for time effects. Overall homogamy changes with a linear trend but that the trend for category specific homogamy cannot be described with a simple polynomial.

Parameter estimates

Table 3 contains the 2nd degree loglinear parameters for Educational Assortative Marriage. These are deviation contrast interaction parameters; values on the diagonal correspond with diagonal parameters, off-diagonal values are equal to homogamy pattern parameters, plus symmetric deviances, plus skew symmetry. The values on the diagonal show a wide range of inmarriage propensities. The university educated group has by far the strongest tendency to inmarriage, followed by elementary. This definitely contradicts the *avant garde* hypothesis! The inmarriage in level 3 and level 4 is quite low – outmarriages between level 4 and university are more frequent (controlling for size), than inmarriage in level 4 and outmarriages be-

Table 3

Interaction effect parameters for Educational Assortative Marriage, controlling for marriage cohort

Husband's education	Wife's education				
	elementary	level 2	level 3	level 4	university
elementary	2.661	.916	-.387	-.821	-2.369
level 2	1.253	1.022	.174	-.707	-1.742
level 3	.014	.257	.389	-.109	-.551
level 4	-1.136	-.545	.081	.702	.898
university	-2.793	-1.650	-.256	.935	3.764

tween level 3 and level 2 are almost as frequent as inmarriage in level 3. This pattern also appears for level 2: it has a fairly high tendency to inmarriage, but relative outmarriage frequencies with elementary are just as high.

Table 4 shows the symmetric deviances and skew symmetry parameters for educational assortative marriage, controlling for cohort effects. The symmetric deviances parameters in the upper triangle show a strong attraction between the lowest and second lowest, and between the highest and second highest categories. The social distance between the highest and lowest levels of education is greatest. Note that the attraction between elementary and level 2 is greater than between level 2 and level 3. Likewise, there is attraction between level 3 and university, but aversion between level 3 and level 4. There is only a partial tendency for social proximity parameters to become lower at greater as the number of steps a marriage involves increases.

Table 4

Symmetric deviances (upper triangle) and skew symmetry parameters (lower triangle) for Educational Assortative Marriage, controlling for marriage cohort

Husband's education	Wife's education				
	elementary	level 2	level 3	level 4	university
elementary		1.601	.119	-.569	-1.151
level 2	.168		-.026	.763	.812
level 3	.201	.042		-.362	.269
level 4	-.158	.081	.095		1.694
university	-.212	.046	.148	.018	

The skew symmetry values in the lower triangle of table 4 relate to downward marrying men/upward marrying women. The *feminism factor* hypothesis predicts that women, being more status conscious, eschew downward marriages with a large status distance, so parameters at several removes from the diagonal should be strongly positive (the corresponding value in the upper triangle will then be negative). Correspondingly, women should prefer short distance downward marriage (given that upward marriage or homogamy is not possi-

ble), so values near the diagonal should be negative. The skew symmetry parameters show an opposite tendency: men, rather than women have a greater propensity to marry downward over a short distance, and a lower propensity to marry downward over a long distance.

The strongest skew symmetry effects all involve elementary education. Men with level 2 or level 3 education often marry downward to women with elementary education, while men with level 4 or university education rarely marry downward with elementary educated women. The strongest skew symmetry parameter that does not involve elementary education is between university and level 3, where down-marrying husbands are more common than down-marrying wives. All other skew symmetry parameters are rather weak, but positive in the lower triangle, indicating that downmarrying husbands are on the whole more common than upmarrying husbands.

Figure 1
The trend of Educational Inmarriage
Based on the Single Trait Analyses

Figure 1 shows the trend for educational inmarriage. The chart uses parameter values conditional on cohort, i.e. the 2nd degree inmarriage parameters have been added to the 3rd degree inmarriage by cohort parameters. Multiplicative parameter values are used in conjunction with a logarithmic vertical axis. Legend entries are ranked by the 2nd degree inmarriage parameter values.

The overall inmarriage parameter increased slightly at a linear rate throughout this period (the yearly increase of the loglinear parameter value was .005). This confirms our expectation based on an earlier analysis. This could mean that education, as it becomes increasingly important for determining occupation and income, also becomes more important as the guiding force in group formation, that informal contacts between persons with different educations are becoming more infrequent. A second explanation would be that the increase in educational inmarriage is due to the increased salience of education for women, whereas the salience for

men has instead decreased (the *feminism factor*). A third explanation could be that the propensity to inmarriage has not changed or has perhaps decreased, but that a decline in the salience of religion for the process of partner selection allows persons to follow this inclination more often than before (the *shifting priorities hypothesis*). These three factors do not preclude each other and we cannot test for one over the other. On the other hand, the shifting priorities explanation does seem more plausible.

Educational inmarriage did not increase uniformly in all categories. University inmarriage was slightly lower in the first cohort and fairly stable after that. Elementary inmarriage dipped slightly after the first cohort, then climbed slowly. Level 2 inmarriage grew very slightly until the fourth cohort, after which it stabilized. Inmarriage in level 4 increased, while inmarriage in level 3, already the lowest rate, decreased until the fourth cohort, after which it also stabilized.

Figure 2 shows the trend of symmetric deviance parameters. A "mirror" restriction had been placed on the 3rd degree parameters, which results in parallel lines between certain conditional parameters in figure 2. The attraction between university and level 4 and between elementary and level 2 increased until the third cohort, after which it dropped slightly. The aversion between elementary and level 4 and between university and level 2 increased until the fourth cohort, after which it started to increase again. The trend for elementary: university and for level 2 and level 4 shows a very slight decline up to the third cohort, a sudden jump in the fourth cohort, and a decline in the last two cohorts to slightly below the initial value (the difference is .01).

Figure 3 shows the trend of skew symmetry parameters. Please note that the unit length of the vertical axis has been doubled compared to other graphs. The skew symmetry by cohort

Figure 3
The trend of Educational Skew Symmetry
Based on the Single Trait Analyses

effects had a 2nd degree polynomial trend. There appears to be convergence to symmetric interaction in 1970 - the 2nd degree polynomial allows the first cohort to be a deviant case. Exceptions to this seem to be serie c (university: level 3) and serie f (university: level 2), which reached minimum values around the third cohort, and then increase.

SINGLE TRAIT ANALYSIS OF RELIGIOUS ASSORTATIVE MARRIAGE

This section contains the result of the single trait analysis of religious assortative marriage. In addition to determining the patterns of religious assortative marriage for comparison with dual trait analysis values, we tested whether a dichotomous “education unknown” variable affects religious assortative marriage. This is discussed more fully in appendix B. We found that “education unknown” did affect religious inmarriage parameters, but not the social proximity or skew symmetry effects.

The analysis therefore took place on a four-way table, of husband’s denomination (5) by wife’s denomination (5) by cohort (6) by “education unknown” (2). Model (1) is our baseline model, which lets “unknown” affect the association between the partners’ denominations, but restricts this effect to be constant across cohorts. Model (2) shows that restricting skew symmetry to be constant improves the fit according to BIC, but in model (3) it turns out that omitting skew symmetry effects altogether has a detrimental effect on model fit. Theoretical arguments can support the choice of a model that has a good, but not the best fit. However as noted in the hypotheses paragraph, theory would support an asymmetric model. On the other hand, the constant skew symmetry effects turned out to be very weak. The maximum absolute value in the full set of parameters was -.104 (for husband “other”/ wife Re-Reformed), and they did not form a substantively meaningful pattern. These effects would add little extra information and would unduly complicate the already complex problem of parameter interpretation. We therefore decided to proceed on the basis of model (3).

Table 5
Models for the single trait analysis of Religious Assortative Marriage

nr	model	L^2	df	BIC
1	Effects of "unknown" on religious assortative marriage are constant across cohorts	783	80	-405
2	As (1), skew symmetry independent of cohort and "unknown"	1182	116	-541
3	As (2), association between partners' denominations is symmetric	1403	122	-409
4	As (3), plus social proximities are also independent of cohort and "unknown"	2357	152	100
5	As (3), linear polynomial on trend symmetric deviances	1707	147	-476
6	As (3), 2nd degree polynomial on trend symmetric deviances	1585	142	-524
7	As (3), 3rd degree polynomial on trend symmetric deviances	1525	137	-509
8	As (6), linear polynomial on trend diagonal deviances	2533	158	186
9	As (6), 2nd degree polynomial on trend diagonal deviances	1745	154	-542
10	As (6), 3rd degree polynomial on trend diagonal deviances	1695	150	-532
11	As (9), linear overall homogamy trend	5502	158	3156
12	As (9), 2nd degree polynomial trend overall homogamy	2140	157	-191
13	As (9), 3rd degree polynomial trend overall homogamy	1815	156	-502

In model (4), we tested our prediction that the symmetric deviances parameters would be constant across cohorts. This was not the case. This is remarkable, since these predictions were based on empirical results on data collected by the same agency, using the same categories, for the same period. This leads us to suspect that the disparities are due to the use of synthetic marriage cohorts in this analysis, versus real marriage cohorts in our previous work. The constant skew symmetry term and the variations by cohort of the symmetric deviances are likely to be due to selective attrition.

We proceeded to test whether the symmetric deviances trend could be described more parsimoniously, by applying the polynomial contrast with the metric described in the single trait analysis of educational assortative marriage. A comparison of models (5), (6) and (7) shows that the symmetric deviances follow a second degree polynomial trend. Models (8), (9) and (10) show that the diagonal deviances also follow a 2nd degree polynomial trend. However, models (11) to (13) show that the trend of overall homogamy cannot be described with a simple polynomial. We therefore chose model (9) as our final model.

Parameter estimates

Table 6 contains the parameters for religious assortative marriage, controlling for marriage cohort (all results below are conditional parameters for the category "education known"). Values on the diagonal show the inmarriage parameters of each denomination. Values in the upper triangle show the symmetric deviances parameters between denominations, while parameters in the lower triangle show the symmetric interaction parameters.

Religious inmarriage rates are on the whole higher than educational inmarriage rates: the overall parameter is 2.960 for religion versus 1.707 for education. This supports the "pillarization hypothesis". But the educational inmarriage parameters have greater variance: 1.293 versus .765 for religion. Inmarriage in the orthodox Protestant Re-Reformed denomi-

Table 6
Religious assortative marriage, controlling for marriage cohort

Husband's denomination	Wife's denomination				
	Catholic	Reformed	Re-Reformed	other	none
Catholic	3.304	.026	.038	-.124	.060
Reformed	-.551	2.201	1.54	-.092	-.068
Re-Reformed	-1.210	-.726	4.216	-.002	-.190
other	-1.073	-.674	-1.255	3.320	.218
none	-.470	-.250	-1.024	-.317	2.062

The upper triangle (excluding the diagonal) contains the symmetric deviances parameters

The lower triangle contains symmetric interaction effects, conditional on "education known"

nation is highest, followed by "other denomination", Catholics, liberal Reformed Protestants and persons with "no denomination".

The social proximity parameters for religion are also smaller than for education. The largest value in table 6 is .218, for other: none, versus 1.964 for education. The variance of the symmetric deviances parameters in the upper triangle of table 6 is .120, versus .924 in the table of educational symmetric deviances. The high social proximity parameters for education show that there are acceptable second choices and "worst case scenarios". The pattern of religious assortative marriage more closely approximates quasi-independence: if the marriage is going to be mixed, then the partner's denomination doesn't really matter much. The strongest exceptions are the afore mentioned other: none marriages, between which groups there is a relatively strong attraction, Reformed: Re-Reformed, between which the attraction is in fact relatively weak. On the negative side, there is an aversion between Re-Reformed: none and between Catholic and other. It is surprising to note that the social proximity between Catholics and Protestants is small but positive, and even slightly higher for orthodox Re-Reformed Protestants than for Reformed Protestants. The aversion of Catholics and Reformed Protestants for the category "other denominations" is also notable.

Figure 4 shows the religious inmarriage trend. Whereas educational inmarriage increased slightly during this period, the overall inmarriage parameter for religion dropped dramatically, after initially increasing between the first and second cohort. The overall religious inmarriage parameter was 2.375 in 1970, versus 1.767 for education. This supports to some extent the shifting priorities hypothesis. The relaxation of pressures toward religious homogamy allow educational inmarriage to increase.

Re-Reformed inmarriage was initially the highest by a considerable gap. It increased between the first and second cohorts, then began to drop sharply. Catholic inmarriage follows a trend that is nearly parallel to that of the Re-Reformed Protestants, but it started to decrease after the first cohort. The inmarriage trend for "other denominations" also increased after the second cohort; it peaked after the third cohort, then started to decrease, but more slowly than for Catholics and Re-Reformed Protestants. The inmarriage trend for liberal Reformed Protestants also increased slightly until the third cohort, then decreased. Inmarriage in the category "no denomination" decreased throughout the period.

Figure 4
The trend of Religious Inmarriage
Based on the Single Trait Analysis

The strong decline of Catholic and Re-Reformed inmarriage confirms our expectations, based on Hendrickx, Lammers, Ultee (1989) and chapter 2. However, all inmarriage parameters in those analyses were considerably lower. Furthermore, Reformed inmarriage ranked lowest in our earlier work, and there was also quite a gap between the inmarriage parameters for Reformed and "none". Since these data relate to existing marriages, they could be contaminated by changes of religion, especially for earlier marriage cohorts.

Figure 5 shows the trend of symmetric deviances parameters. The unit length of the vertical axis has again been doubled, due to the small range in values. The most remarkable outcome was that serie d, Catholic: Re-Reformed, seems to develop from second most popular combination to least popular combination. This is the opposite of what we had expected. As the depillarization process progressed, social proximity between Catholics and Re-Reformed Protestants could be expected to increase.

A possible explanation is that partners in Catholic: Re-Reformed marriages do not change their religions, but that this does occur in other mixed marriages involving Catholics and Re-Reformed Protestants. This would mean that there is also relatively little switching in "other: none" marriages, since the symmetric deviances parameters for serie a also decrease. Series for marriages between Catholics and Protestants on the one hand with "other" and "none" show a tendency to rise, which would mean that switching is frequent for these combinations (series c, f, i and j).

Figure 5
The trend of Religious Social Proximities
Based on the Single Trait Analyses

DUAL TRAIT ANALYSES

The data for the dual trait analysis was a table with 3750 cells. Of these, 1126 were empty, 1270 had less than 5 cases, and 1685 had less than 10 cases. This is a consequence of the strong association between partners' educations and partners' denominations, which causes some combinations to be rare, even in two-way subtables.

To start with, we used hierarchical loglinear modelling to find the best model according to the BIC criterion, without special mobility type restrictions on the assortative marriage parameters⁴. As in our earlier analysis, a preliminary run indicated that all 4 and 5 way interaction effects were zero. This means that the *conformism* hypothesis is falsified, since this hypothesis predicted double homogamy, but the interaction $ed_h * ed_w * rel_h * rel_w$ is not present. The *limited opportunities* hypothesis based on Blau's theory is therefore supported. The strictest form of the *pillarization* hypothesis is also falsified, since it also assumed the presence of the four-way interaction $ed_h * ed_w * rel_h * rel_w$. Our hypothesis that conformism might hold in earlier cohorts, and an *avant garde* effect in later cohorts is also falsified, since this assumes the presence of the four-way interactions $rel_h * rel_w * ed_h * cohort$ and/or $rel_h * rel_w * ed_w * cohort$.

Model (1) in table 7 shows that the fit of a hierarchical model with all 3-way interactions has a strongly negative BIC. The following two runs indicated that changes per cohort of the association between the own religious denomination and the partners education were not significant by the BIC criterion. Model (4) showed that differences per category of husband's religion in educational assortative marriage patterns are insubstantial. All effects were now substantial by the BIC criterion⁵. Note that the strictest form of the pillarization hypothesis predicted that educational assortative marriage patterns would be constant for all categories of both husband's religion and wife's religion. These results indicate that the latter is not insubstantial however, so this hypothesis can also be rejected.

Table 7

Models for the dual trait analysis of Religious and Educational Assortative Marriage

nr	model	L^2	df	BIC
1	All three way interactions	23212	2816	-17911
2	Removing relh*edw*cohort	23835	2896	-18456
3	Removing relw*edh*cohort	24580	2976	-18879
4	Removing relh*edh*edw	25098	3040	-19295
5	As (4), but no religious assortative marriage	4141675	3264	4094010
5	As (4), but no educational assortative marriage	823406	3200	776676
7	As (4), but religious assortative marriage is constant for cohort and the partners' educations	92766	3248	15335
8	As (4), but educational assortative marriage is constant for cohort and wife's education	34220	3184	-12277
9	As (4), but no association between religion and education	97234	3456	46765
10	Constant skew symmetry	26032	3118	-19500
11	Symmetric association of partners' religions	26158	3124	-19462
12	As (10), but constant religious heterogamy/variable homogamy parameters	27531	3189	-19039
13	Symmetric association of partners' educations	31871	3184	-14626
14	As (10), but halfway effects of education on religious assortative marriage	27199	3164	-19005
15	As (10), but halfway effects of religion on educational assortative marriage	26183	3124	-19437
16	As (10), but husband's/wife's education affects religious homogamy pattern only	26885	3164	-19320
17	As (10), but wife's religion affects educational homogamy pattern only	27976	3168	-18287

In models (5) and (6) we made a comparison of the strength of the association between partners' denominations and partners' educations respectively. The association is very strong in both cases, but the association between partners' denominations is much stronger than between partners' educations. Models (7) and (8) show, the differences in strength of association are in part due to the fact that religious assortative marriage varies more strongly by the other variables in the analysis than educational assortative marriage. But the L^2 change from constant religious assortative marriage effects to none at all is still 4048909 with 16 df (BIC = 4078675). The L^2 change for education is 789186 with 16 df, which corresponds with a BIC value of 788953. The association between the partners' religions is much stronger than between their educations, even if controlling for sources of variation. This confirms the weakest form of the pillarization hypothesis.

In model (9), we determined how large the association is between education and religion. The stronger this association, the more worthwhile it is to perform a dual trait analysis. The BIC value for a model for which education and religion are independent is 46765, which shows that the association is indeed quite strong.

The next step is to test whether patterns in religious and educational assortative marriage can be described in a more parsimonious model, by specifying special mobility type designs. Model (10) allows for a constant skew symmetry term, whereas model (11) is a model of

conditional quasi-symmetry. Model (10) has a slightly superior fit according to the BIC criterion. As in the single trait analyses, we decided to take note of the fact that a constant skew symmetry term causes a marginal improvement in fit, but to proceed on the basis of a model with symmetric interaction of the partners' denominations. In model (12), we tested whether the religious heterogamy pattern was constant across cohorts and the partners' educations. However, this restriction lead to an increase in BIC.

In model (13), we tested whether the association between partners' educations was symmetric. As could be expected on the basis of the single trait analyses, this was not the case. Model (14) tested whether the variation of religious assortative marriage patterns per category of husband's education and wife's education were equal, and model (15) tested whether the variation of the educational assortative marriage patterns were identical per category of husband's and wife's denomination (although the former effect was set to zero in earlier models). Neither restriction improved the model fit.

In models (16) and (17), we tested whether effects of the partners' educations on religious assortative marriage, and of wife's religion on educational assortative marriage, could be restricted to the homogamy pattern only. Both restrictions lead to a slightly worse model fit.

A logical step at this point would be to test whether the special restrictions applied in the single trait analyses, such as the mirror restriction and low degree polynomial trends, also applied to the dual trait analyses. Unfortunately, the software⁶ available to us would not allow the specification of all these effects. We are therefore accepted the fairly complex model (11) as our final model.

Parameter estimates

Education

The dual trait analyses showed that educational assortative marriage was constant for husband's denomination, but varied both with cohort and with wife's denomination. Further simplifications were not possible: the association was not symmetric, nor were the skew symmetric or social proximity parameters constant across cohorts or the partners' denominations.

Table 8 shows the 2nd degree parameters for educational assortative marriage, controlling for cohort and the partners' denominations. The figures in parentheses below each parameter is the difference between that parameter and the value in the corresponding single trait model (i.e. the saturated model, not the model with special restrictions from the single trait analysis). As an index of dissimilarity Δ , we used the sum of absolute differences between relevant parameters, divided by their number (16 in this case, 10 for the symmetric deviances or skew symmetry parameters below). For table 8, Δ was .266 and the maximum difference was 1.364, for cell (1.5). The overall diagonal parameter was .200 lower in the dual trait analyses; inmarriage was lower for university, elementary and (slightly) for level 2. Inmarriage was slightly higher for levels 3 and 4. The spurious homogamy hypothesis is therefore only partially confirmed for educational assortative marriage. The diagonal deviance parameters had a Δ of .230 and a maximum difference of -.564 (for university).

Table 8

Second degree parameters for Educational Assortative Marriage, controlling for marriage cohort and the partners' religious denominations

Husband's education	Wife's education				
	elementary	level 2	level 3	level 4	university
elementary	2.374 (-.375)	.660 (-.351)	-.578 (-.290)	-1.117 (-.349)	-1.340 (1.364)
level 2	1.136 (-.142)	.958 (-.097)	.148 (-.055)	-.655 (-.005)	-1.587 (.300)
level 3	.053 (.062)	.318 (.075)	.441 (.074)	-.050 (.086)	-.762 (-.297)
level 4	-1.046 (.128)	-.439 (.168)	.174 (.145)	.819 (.163)	.492 (-.603)
university	-2.518 (.327)	-1.497 (.205)	-.186 (.127)	1.003 (.105)	3.197 (-.764)

Figures in parentheses are the difference between dual trait parameters and the values of a corresponding single trait model (i.e. the saturated model)

Table 9 shows the 2nd degree symmetric deviances and skew symmetry parameters for education in the dual trait analysis. The symmetric deviances parameters had a Δ of .230 and a maximum difference of .549 for cell (1,5). Taking the association between religion and education into account tends to make matters less extreme: the extremely high social distance between elementary and university education became smaller, but the strong social proximity between level 4 and university, and between elementary and level 2, also diminished.

Table 9

Second degree symmetric deviances (upper triangle) and skew symmetry parameters (lower triangle) for Educational Assortative Marriage, controlling for marriage cohort and the partners' denominations

Husband's education	Wife's education				
	elementary	level 2	level 3	level 4	university
elementary		1.360 (-.320)	.027 (-.131)	-.666 (-.098)	-.721 (-.549)
level 2	.238 (.104)		.050 (.085)	-.604 (.186)	-.806 (.049)
level 3	.315 (.176)	.085 (.065)		.167 (.278)	.090 (-.232)
level 4	.036 (.238)	.108 (.086)	.112 (.030)		1.437 (-.366)
university	-.589 (-.519)	.045 (-.047)	.288 (.212)	.256 (.354)	

Figures in parentheses are the difference between dual trait and single trait parameter estimates

For the skew symmetry parameters, Δ was .122 and the maximum difference was .519 for cell (5,1). The dual trait values now seem to have different implications, instead of being simply less extreme. There now appears to be a rather strong difference between the genders' willingness to contract a marriage between university and level 3 or 4, education, whereas the single trait analysis pointed to neutrality. The values still do not accord with the *feminism factor* hypothesis: men, rather than women, are more likely to marry downward over a short social distance and less likely to marry downward over a longer distance.

We will move on now to the sources of variation in inmarriage. Figure 6a shows the trend of the educational inmarriage parameters. The results are broadly similar to the single trait analyses. Δ for the overall diagonal parameters was .033, with a maximum difference of .086 for 1962 (these values are based on the 3rd degree effects, not on the conditional values used in the chart). The diagonal deviance parameters had a Δ of .103. The value of Δ was somewhat higher for elementary and level 2 (.169 and .140) and 1952 had an especially large value (.203). Evidently, a dual trait analysis influences the height of inmarriage, but its influence on the trends is slight.

Figure 6b shows the variations of educational inmarriage by wife's denomination. Overall inmarriage is lower if the wife is Re-Reformed or of "other denomination". The *pillarization hypothesis* specified that educational inmarriage would be lower for Re-Reformed Protestants and Catholics, and is therefore only partially supported. The variation by wife's denomination is most pronounced for university inmarriage and considerably less so for elementary education and level 2. Levels 4 and 3 on the other hand, are almost constant.

Figure 7a shows the trend of the symmetric deviances parameters. It is more erratic than its

Figure 6a
The Trend of Educational Inmarriage,
Controlling for Wife's Denomination
Based on the Dual Trait Analyses

Figure 6b
The Variation of Educational
Inmarriage by Wife's
Denomination, Controlling for
Cohort
Based on the Dual Trait Analyses

Figure 7a
The Trend of Educational Social
Proximities, Controlling for Wife's
Religion
Based on the Dual Trait Analyses

Figure 7b
The Variation of Educational Social
Proximities by Wife's Denomination,
Controlling for Cohort
Based on the Dual Trait Analyses

single trait counterpart, partly because the restrictions that had been used there could not be applied here. However, the two charts are broadly similar. A comparison of the 3rd degree social proximity by cohort parameters with their single trait counterparts shows fairly small differences. Δ is .127, and the maximum difference is .671, for serie j in 1952. This second cohort contained the largest disparities with the single trait analyses: its Δ was .273. For the other cohorts, Δ varied from .114 to .120, except for the third cohort, which had the very low value of .019. Series i and j had the largest disparities: Δ was .296 and .224 respectively. These series relate to cells with small counts, at several removes from the diagonal, so disparities are probably random fluctuations. Series h, e and g had Δ 's of intermediate magnitude: .132, .124 and .124 respectively. For all other types of educational mixed marriages, the Δ was less than .1.

Figure 7b shows the variations of the social distance parameters with the wife's education. There is only a slight tendency for (multiplicative) parameters to move closer to 1, for Re-Reformed wives and perhaps for wives with "other" denomination. The 3rd order loglinear parameters of series i, a, b and c had the greatest variance across wife's denomination. Series d and e had particularly low variances.

Figures 8a and 8b show the trend of skew symmetry and the variation of skew symmetry by wife's denomination, respectively. The parameters clearly have a greater range and tend to fluctuate erratically. The Δ for the skew symmetry trend was .124, with a maximum value of .799. Disparities were again unusually strong in the second cohort (Δ =.276). Disparities were also stronger for serie j and serie h. This is largely due to small cell counts. There is no pattern apparent in the variations of skew symmetry by wife's denomination.

Figure 8a
The Trend of Educational Skew
Symmetry, Controlling for Wife's
Denomination
Based on the Dual Trait Analysis

Figure 8b
The Variation of Educational Skew
Symmetry by Wife's Denomination,
Controlling for Cohort
Based on the Dual Trait Analyses

Religion

The dual trait analyses confirmed the results of the single trait analyses: religious assortative marriage is symmetrical (although including a skew symmetry term that is constant for cohort and the partners' educations would slightly improve the fit) and varies per cohort. Furthermore, the dual trait analyses showed that religious assortative marriage varies with both husband's and wife's education.

Table 10 shows the 2nd degree parameters for religious assortative marriage, controlling for cohort and the partners' educations. Values on the diagonal show that inmarriage in the dual trait analysis was lower than in the single trait analysis, particularly for Re-Reformed and "other". Overall inmarriage was .180 lower, and all inmarriage parameters were at least

Table 10
Second degree symmetric deviances (upper triangle) and symmetry parameters (lower triangle) for
Religious Assortative Marriage, controlling for marriage cohort and the partners' educations

Husband's denomination	Wife's denomination				
	Catholic	Reformed	Re-Reformed	other	none
Catholic	3.241 (-.072)	-.082 (-.126)	.069 (.046)	-.047 (.068)	.060 (.012)
Reformed	-.683 (-.148)	2.117 (-.086)	.209 (.044)	-.098 (.013)	.029 (.069)
Re-Reformed	-1.136 (.087)	-.621 (.089)	3.930 (-.272)	-.051 (-.044)	-.228 (-.045)
other	-.927 (.149)	-.604 (.099)	-1.161 (.105)	2.954 (-.397)	.196 (-.037)
none	-.494 (-.015)	-.209 (.046)	-1.012 (-.005)	-.263 (.044)	1.978 (-.069)

Figures in parentheses are the difference between dual trait estimates and values for the corresponding single trait model (i.e. conditional quasi-symmetry)

slightly lower. This supports the *spurious homogamy* hypothesis. The Δ for the diagonal deviances was .125.

The symmetric deviances showed fairly small differences with their single trait counterparts. The Δ was .050 and the maximum deviation was -.126, for Catholic: Reformed.

Figure 9a shows the trend of religious inmarriage, controlling for cohort. The trends are largely the same as in the single trait analysis; Δ is .016 for the overall inmarriage trend, and .042 for the trend of diagonal deviances. No cohort or denomination showed especially strong disparities.

Figure 9b shows the variations of religious inmarriage with husband's education. "Other denomination" is clearly the most strongly affected, and decreases more or less linearly with increasing education. This is surprising, since "other" is a heterogeneous category and we would expect no strong effects on it due to conflicting tendencies. A decline of religious inmarriage as the husband's education is higher is predicted by the *avant garde* and *Trojan horse* hypotheses, but these predict a decrease of all (or most) types of religious inmarriage.

Figure 9c shows that the prediction that higher education is associated with lower religious inmarriage is fulfilled for the variations by wife's education. Religious inmarriage decreases as the wife's education increases, both overall and for each denomination separately. The decrease is especially strong when wife's education is university. There is clearly a much smaller range of inmarriage propensities when wife's education is university. What are the ramifications of these disparate influences of husband's and wife's education on religious inmarriage? Seen in the light of the Trojan horse hypothesis, it would mean that higher education makes religion less salient for women, but not for men (unless their denomination is "other"). It would be comprehensible if it were the other way around: if religious inmarriage was the same or higher as wife's education increased. This would be consistent with the *no-blesse oblige* hypothesis, that people with higher status have greater conformity, and with the higher salience of religion for women. An explanation could be that for men, pressures to conformity and decreased salience of religion work in opposite directions as education increases. Women on the other hand, are less responsible for upholding norms, and are therefore only affected by the decreased salience of religion due to higher education.

Figure 10a shows the trend of social proximities, controlling for the partners' educations. The range in values is small, necessitating an enlarged vertical axis. The differences with the single trait analysis were small: Δ is .022, with a maximum difference of -.075. The differences between the charts for the dual and single trait analyses appear greater, because trend smoothing could be used in the single trait analysis and because the small range of the vertical axis emphasizes fluctuations. The trends found in the single trait analysis can be found here too, but with difficulty. We concluded in the single trait analysis that the trends of the social proximities parameters do not reflect social processes; they are presented here so that the reader can draw his own conclusions.

Figure 10b shows the fluctuations of religious social proximity with husband's education. The range of values for the three middle categories is somewhat smaller. Figure 10c shows that the range of social proximity parameters increases with wife's education, and is large for level 4 as well as university. In general, it appears that the top two levels of education are more discrimination in their choice of partner, in the event of a religiously mixed marriage.

Figure 9a
The Trend of Religious Inmarriage,
Controlling for the Partners'
Educations
Based on the Dual Trait Analyses

Figure 9b
The Variation of Religious Inmarriage by
Husband's Education, Controlling for
Cohort and Wife's Education
Based on the Dual Trait Analyses

Figure 9c
The Variation of Religious Inmarriage
by Wife's Education, Controlling for
Cohort and Husband's Education
Based on the Dual Trait Analyses

Figure 10a
The Trend of Religious Social
Proximities, Controlling for the
Partners' Educations
Based on the Dual Trait Analyses

Figure 10b
The Variation of Religious Social
Proximities by Husband's Education,
Controlling for Cohort and Wife's
Education
Based on the Dual Trait Analyses

Figure 10c
The Variation of Religious Social
Proximities by Wife's Education,
Controlling for Cohort and Husband's
Education
Based on the Dual Trait Analyses

Religion and education

Our final model indicated that there was association between religion and education for both husbands and wives, and that this varied per cohort. There was also association between husband's education and wife's denomination, and between wife's education and husband's denomination; this was constant through time.

Table 11

The association between denomination and education, for husbands

Husband's denomination	Husband's education				
	elementary	level 2	level 3	level 4	university
Catholic	.340	.151	.003	-.163	-.331
Reformed	.066	.093	.071	-.089	-.142
Re-Reformed	.114	.099	-.012	-.073	-.129
other	-.399	-.317	-.041	.202	.555
none	-.121	-.026	-.022	.122	.047

Table 11 shows the association between religion and education for husbands. The parameters seem to indicate a ascendancy of education as a secularizing force over religion as a cause of educational achievement. The category "no denomination" is over-represented at higher levels of education, and under-represented at lower levels. This can be partially due to highly educated, non-religious parents passing on both traits to their offspring, and partly to religious students becoming non-religious. If this secularizing effect works just as strongly on all three religions, then the greater salience of educational achievement for the Calvinist Protestants would explain their higher achievements compared to Catholics. However, the high performance of the category "other" does not fit into this picture. A speculation might be that being composed of small, sect-sized denominations, this group is better proofed against secularizing effects of higher education.

Table 12

The association between denomination and education, for wives

Wife's denomination	Wife's education				
	elementary	level 2	level 3	level 4	university
Catholic	.355	.179	.122	.013	-.669
Reformed	-.054	.132	.086	.085	-.250
Re-Reformed	.134	.044	-.089	-.191	.102
other	-.305	-.450	-.147	.085	.818
none	-.129	.094	.028	.007	.000

Table 12 shows the association between denomination and education, for wives. Re-Reformed wives turn out to be over-represented in the university educated category, and Reformed wives are under-represented in the elementary category. There is an even stronger tendency for Catholics to have lower educations and for members of "other denominations"

tend to have higher educations. The association between “none” and education is weakest of all; this category is under-represented in the category “elementary”, but only slightly over-represented in the other categories.

Table 13

The association between husband's denomination and wife's education

Husband's denomination	Wife's education				
	elementary	level 2	level 3	level 4	university
Catholic	.047	.032	-.047	-.114	.082
Reformed	.163	.058	-.064	-.059	-.098
Re-Reformed	-.038	-.067	-.011	-.020	.136
other	-.117	-.134	.050	.202	-.002
none	-.054	.110	.072	-.009	-.119

Table 13 shows the association between husband's denomination and wife's education. None of the parameters is particularly large. Catholic husbands have a slight tendency to not marry wives with a low level of education, except if the wife is university educated; marriages of that type are slightly over-represented. Reformed husbands recruit from the lower levels of education, Re-Reformed husbands from the higher levels. Husband's with “other denomination” prefer wives with level 4 education (the strongest parameter value), and eschew women in the first two categories. Husbands with “no denomination” prefer the lower middle of the scale, with level 2 as first preference, then level 3, level 4, elementary, and university as least preferred.

Table 14

The association between wife's denomination and husband's education

Wife's denomination	Husband's education				
	elementary	level 2	level 3	level 4	university
Catholic	-.058	.095	.066	-.042	-.060
Reformed	.179	-.102	.059	-.029	-.106
Re-Reformed	.066	.001	-.002	-.099	.034
other	-.130	.011	-.050	.025	.143
none	-.056	-.005	-.072	.145	-.012

Table 14 shows the association between wife's denomination and husband's education. The parameters are even weaker than for the association between husband's denomination and wife's education – the largest value is .179. Catholic wives tend to be married to lower middle husbands. Reformed wives tend to have lowly educated husbands. There is not really any association to speak of for wife Re-Reformed. Wives with “other denomination” tend to have highly educated husbands (the level 2 parameter is the exception to a monotonic increase). Wives with no denomination tend to have husbands with an upper middle education, with level 4 as the most frequent type.

Figure 11
The association between religious denomination
and educational achievement per cohort,
for husbands

Figure 11 shows the trends in the association between religion and education for husbands. Several relationship appear to be getting weaker. The slight negative relationship for Re-Reformed Protestants in the first cohort turns into a slightly positive association in the last cohort. The negative relationship for Catholics gradually becomes more neutral. The strong positive relationship for "other" also moves toward neutrality. The predictions of the emancipation hypothesis have been by and large fulfilled.

Figure 12 shows the trends in the association between religion and education for wives. A relatively strong under-representation of "elementary" for wives with "other" denomination moves toward neutrality, as does the over-representation of "university" (the former relationship disappears, the latter does not). However, the three middle categories remain under-represented. The negative relationship for Catholics becomes weaker. The negative relationship for Re-Reformed wives becomes a positive relationship. Surprisingly, Reformed wives became increasingly under-represented in the highest category.

The association between religious denomination
and educational achievement per cohort,
for wives

Conclusions

Past research has examined both religious assortative marriage and educational assortative marriage, using highly suitable loglinear modelling techniques. In this paper, we analyzed both types of assortative marriage simultaneously, enabling us to test for double homogamy and for effects of religion on educational homogamy and of education on religious homogamy, while cancelling out the association between religion and education, as well as the size effects of husband's education and denomination and wife's education and denomination. Since we also had access to marriage cohort, trends from before the second World War until 1970 could also be examined.

We found that a pillarization effect was present: religious homogamy was much stronger than educational homogamy. Some small support was found for an even stronger version of this hypothesis: educational inmarriage was lower for Re-Reformed Protestants, for whom religious ingroup sentiments are especially salient. However, inmarriage was not lower for Catholics as had also been predicted, but was lower for the category "other". This could mean that the small group size causes a sect-like ingroup mentality for both denominations.

There were quite high values for educational inmarriage for the categories "university" and "elementary", which in previous work had been merged with other categories. Inmarriage in

other categories was quite low, however. Social distances between the educational categories had a larger variance than between religious categories.

A de-pillarization effect was also present: religious homogamy declined for Catholics and Re-Reformed Protestants, although parameters in 1970 were still very high. There was no trend toward class equality however: educational inmarriage rose slightly at a linear rate. This could mean that education was becoming increasingly salient for informal group formation as well as the choice of marriage partner. However, it is possible that the salience of education did not increase or even decreased, but that people could follow its promptings more often, due to the weakening of the norm of religious inmarriage. If this "shifting priorities" interpretation is correct, then educational inmarriage should start to decrease again in the 1980s, as the depillarization process levels off. This would be consistent with results found by Ultee and Luijkx (1990). However, a dual trait analysis with educational scales such as used here would provide important new insights.

We noted above that educational inmarriage varied with wife's denomination only, and was lower for the Re-Reformed and "other denomination" categories. Religious inmarriage varied by both husband's and wife's education. However, only inmarriage in the category "other denominations" was strongly affected by husband's education, and decreased strongly for higher levels of education. Religious inmarriage decreased for all denominations as the wife's education increased. This contradicts the "noblesse oblige" hypothesis. Since educational inmarriage rose, there is more support for a "Trojan horse" interpretation of the negative effect of education on religious inmarriage than or an "avant garde" interpretation, that the status elite is the first to conform to the new norm of social openness.

Appendix A: Recoding education

The original categories for education⁷ were:

- (1) elementary school only
- (2) compulsory lower level secondary education
- (3) extended lower level education of a general type
- (4) extended lower level education of a vocational type
- (5) intermediate level education of a general type
- (6) intermediate level education of a vocational type
- (7) college education
- (8) university education

Education must be recoded to a relatively small number of categories in order to be able to do a dual trait analysis at all. However, if the recoding causes strong loss of information, then the results of a dual trait analysis must be interpreted with caution. Our original intention was to recode the categories according to years of education, in the following fashion:

- (1) elementary or compulsory lower level education (categories 1 and 2)
- (2) low level secondary education (categories 3 and 4)
- (3) higher level secondary education (categories 5 and 6)
- (4) college or university education (categories 7 and 8)

The adequacy of a recoding can be tested by using the new categories for the 2nd degree effects in a loglinear analysis of the table, and the original scales for the 1st degree effects. Ideally, the L^2 of this model will not be significant, although we would be satisfied if the fit is

not extremely bad. The L^2 due to recoding can also be found by subtracting the L^2 for the association in the table found with the new scale from that found with the old scale (Goodman, 1981). This latter method can sometimes be more practical, since it can be performed using a fast table generating program.

It turned out that this 4 category recoding contained only 65% of the association in the 8 category coding: the total L^2 for the 6 tables of husband's education by wife's education went from 859075 in the 8 category coding to 558806 in the 4 category coding. This means that the L^2 for implementing the 4 category recoding is 300269 with 240 *df*. This corresponds with a BIC value of 296764: clearly an unacceptable loss of information.

We proceeded to investigate other methods of recoding. Categories can be combined only if they are independent. The basic set of odds ratios for an r by c table is an $(r-1)$ by $(c-1)$ table of all odds-ratios between adjacent categories. If categories i and $i-1$ are independent, then row i and column j of the basic set will consist of 1s.

A useful tool for discovering independent adjacent categories is the log-multiplicative row and column model II (rc2; see Goodman 1979).

$$\log(F_{ij}) = \beta^* + \beta_i^r + \beta_j^c + \mu + \rho_i + \sigma_j, \quad (1)$$

$$\text{where } \sum_{i=1}^r \rho_i = \sum_{j=1}^c \sigma_j = 0 \text{ and } \sum_{i=1}^r \rho_i^2 = \sum_{j=1}^c \sigma_j^2 = 1$$

This model estimates an overall association parameter μ , and two new normalized scale parameters row effect parameters ρ_i and column effect parameters σ_j . If the new scale values are used, the table will have a uniform log odds-ratio with the value μ . Scale values that are close together need very little alteration to have identical log odds-ratio values – the association between these categories is therefore small and merging them will cause an acceptably small loss of information.

Table A.1
Goodness of fit statistics for rc2 models of education partners (8 categories)
by cohort (6 categories)

	scales	groups	diagonal	L^2	<i>df</i>	BIC
1	equal	homogenous		62534	282	58416
2		heterogeneous		50139	216	46985
3	equal	homogenous	free	16005	234	12587
4		heterogeneous	free	10242	168	7789

The fit of the rc2 models is reported in table A.1. In order to get as simple an answer as possible to the question of which categories are close together, in model (1) we restricted the scale values ρ_i and σ_j to equal values, and also constrained them to be homogeneous across cohorts. Model (2) shows to the extent in which this is overly restrictive. Models (3) and (4) test whether freeing the diagonal improves the fit – if the differences in partner choice were due solely to different inmarriage preferences, we might decide to merge categories anyway. Interestingly, even the relatively unrestricted model (4) has an unacceptable fit. Although therefore the parameters from these analyses should not be interpreted in themselves, they can

be used as a guide to recoding the educational achievement scale, since the appropriateness of the recoding will be tested afterwards again when the categories are actually merged.

Table A.2

Parameter estimates for the equal/homogenous rc2 models for partners education (8 categories) by cohort (6 categories)

	(1) elem	(2) l.sec	(3) ext l.sec	(4) ext.l.voc	(5) int.sec	(6) int.voc	(7) college	(8) univ
model 1	-.605	-.246	-.021	-.247	.203	.035	.239	.642
model 3	-.529	-.292	-.040	-.292	.212	.039	.233	.669

Table A.2 contains the parameter estimates of the equal/homogenous versions of the rc2 models⁸, with and without a freed diagonal. Whether the diagonal is included or not, the rc2 models indicate that categories 2 and 4, categories 3 and 6, and categories 5 and 7 can be merged. The vocational school types rank lower in status than the general school types of the same level. Apparently, a general education of a general type is equivalent to a vocational education of a step higher (if a college education is regarded as a vocational type). The distance between college education and university education is surprising, as well as the very small social distance between college and intermediate secondary education.

Merging these categories results in an L^2 for the total association of 829500 with 96 *df*. This means that the 5 category coding explains 97% of the association in the 8 category coding. However, the loss of information is still quite significant by the BIC criterion: the L^2 is 29575 with 198 *df*, which corresponds with a BIC of 26684. A single trait analysis with 8 categories might still provide insights that a 5 category analysis does not.

In summary, the scale used in the analysis was:

- (1) elementary: elementary school only (1)
- (2) level 2: compulsory lower secondary and extended lower vocational (2 and 4)
- (3) level 3: extended lower general and intermediate vocational (3 and 6)
- (4) level 4: intermediate general and college (5 and 7)
- (5) university: university education (8)

Appendix B: Education unknown

A second step was to test whether the category "education unknown" could safely be deleted from the analysis. Table (B.1) shows the association between husband's or wife's education unknown, and husband's denomination, wife's denomination, and cohort. "Unknown" affects husband's and wife's denomination weakly, but significantly by the BIC criterion. The association of "unknown" with cohort on the other hand, is quite strong.

Table B.1

The association between the category "education unknown" and the other variables in the analysis

	Husband's education unknown			Wife's education unknown		
	L^2	df	BIC	L^2	df	BIC
husband's denomination	846	4	787	1615	4	1556
wife's denomination	835	4	776	1865	4	1805
cohort	50477	5	50403	47973	5	47899

We therefore decided to include the variable "education unknown" in the single trait analysis of religious assortative marriage. If it did not affect the association between the partners' religions, then it would not distort results when it was deleted in the dual trait analysis. It turned out that for 619177 marriages (22%), the education of one or both partners was unknown. This provided sufficient data for an analysis of a 4-way table, of husband's denomination by wife's denomination by cohort by education known/unknown.

Our hope was that the variable "education known/unknown" would be unrelated to the other variables in the table, or at least that there would be no high order effects of "unknown" with religious assortative marriage. We used hierarchical loglinear program HILOGLINEAR by SPSSX to determine the association of "unknown" with the other variables. Models (1), (2) and (3) in table B.2 show the fit of progressively less desirable models. Only model (3) is acceptable: "education unknown" is therefore associated with patterns of religious assortative marriage. This means that dropping the category "education unknown" will to some extent distort our parameters for religious assortative marriage in the dual trait analysis.

Table B.2

Models for the effects of education unknown/known on religious assortative marriage

nr	model	L^2	df	BIC
1	Education unknown affects only size parameters of husband's denomination, wife's denomination, and cohort.	4845	136	2825
2	Education unknown affects associations cohort and husband's and wife's denominations, but not the association between the partners' denominations	3392	96	1967
3	Education unknown affects association between partners' denominations, but this effect is constant through time	806	80	-382
3a	As (3), using different estimation method	783	80	-405
4	As (3a), skew symmetry independent of "education unknown"	863	86	-415
5	As (4), plus association between denominations is symmetric and social proximities are independent of "education unknown"	1441	127	-445
6	As (5), plus "education unknown" affects only the overall homogamy parameter	2716	131	771

Models (4), (5) and (6) specify how "unknown" affects religious assortative marriage patterns. These models were estimated with a different algorithm, using SPSSX LOGLINEAR, and which resulted in slightly different goodness of fit statistics in model (3a). The skew symmetry and social proximities terms were not affected by education "unknown", as models (4) and (5) show. "Unknown" therefore affects only the homogamy parameters. Model (6) tested whether only overall inmarriage was affected by "unknown", but this is not the case.

Table B.3 shows how much inmarriage parameters for the category "education unknown" differ from those for the category "education known". Catholic and Re-Reformed inmarriage is a good deal lower among persons whose education is unknown, Reformed inmarriage is lower and inmarriage of "other denominations" is higher. Deleting the category This qualifies somewhat the results of the dual trait analyses, for which the category "education unknown" must be deleted.

Table B.3
Effects of education unknown on religious inmarriage parameters

	Catholic	Reformed	Re-Reformed	other	none
Education unknown	-.363	-.111	-.304	.182	-.013

Parameters are in contrast to "education known"

Notes

- ¹ $BIC = L^2 - df \cdot \ln(N)$, where N is the sample size.
- ² We decided to use 1931, 40 years before the date of the 1971 census, as the lower boundary of the first cohort. Someone marrying at age 20 in that year would be 60 at the time of the census.
- ³ An earlier version of this paper was presented at the conference of the ISA Research Committee for Social Stratification in Prague, June 1991, under the title "Double homogamy: Marriages that are both educationally and religiously mixed. Trends in the Netherlands up to 1970". Using a 4 category scale for education, we found that educational inmarriage had increased rather than decreased. An explanation for the discrepancy is that the analyses by Sixma and Ultee (1983) and Ultee and Luijkx (1990) used three datasets on existing marriages at different points in time, covering a longer period. Sixma and Ultee found that overall inmarriage had dropped for existing marriages between 1959 and 1971, but that it increased between 1971 and 1977. (Ultee and Luijkx found that heterogamy as measured by a step parameter increased between 1959 and 1971 and increased even more strongly between 1959 and 1983).
- ⁴ We used SPSS HILOGLINEAR, specifying that the choice criterion was a probability of 0 (since otherwise only the saturated model would be suitable). A model search of one step only could be used, since all models had a probability of 0 and SPSS used the first model on its list. The choice of model was based on the effect with the most negative change in BIC.
- ⁵ The following table shows the changes in L^2 , df and BIC for the highest order effects in preliminary model 4. All BIC values are strongly positive. The first three terms relate to

religious homogamy/heterogamy parameters - patterns of religious assortative marriage vary per cohort and per category of education of husband and wife. Terms 4 and 5 relate to educational homogamy/heterogamy, which varies per cohort and per religious denomination of the wife. Terms 6 and 7 relate to the association between denomination and education, which varies per cohort and is different for husbands and wives.

Table I
Relative importance of effects

nr	effect	L^2 change	df	BIC change
1	rel _h *rel _w *cohort	23899	80	22731
2	rel _h *rel _w *ed _h	2654	64	1720
3	rel _h *rel _w *ed _w	2683	64	1749
4	ed _h *ed _w *cohort	6653	80	5484
5	ed _h *ed _w *rel _w	2586	64	1652
6	rel _h *ed _h *cohort	2445	80	1276
7	rel _w *ed _w *cohort	4286	80	3117

One way of discovering whether a table is so sparse that results are meaningless is to compare the L^2 value with the Pearson X^2 value. If the X^2 value is much larger, then this indicates that the table is too sparse. The Pearson X^2 for model (4) was 31587; L^2 was 25098. Although the difference is large, we do not consider it to be cause for alarm.

⁶ SPSSX was unable to allocate sufficient memory to perform the dual trait analyses. We therefore used GLIM 3.77, which is faster and has lower memory requirements. However, GLIM allows only 32 model vectors, so it was not possible to directly specify the design matrix for deviation contrast parameters. As a workaround, we wrote the fitted values of our final model to a file with 9 digits accuracy. We then used GLIMMAT, a set of SAS macros using PROC IML to create the design matrix (cf. chapter 9). With the design matrix and the log fitted values, we could determine the correct parameter estimates. A check showed that parameters in conjunction with the design matrix reproduced the log fitted values. The program used 45M memory and 28 minutes CPU time.

⁷ Category 7 contained, in addition to the "college education" category, the categories "some university education" (.3% and .1% of husbands and wives respectively) "supplemented college education" (.7% and .1%) and "still studying, non-university" (.4% and .3%). Category 8 contained, in addition to "university education", the category "still studying at a university" (.4% and .1%).

⁸ These models were estimated using ASSOC, (available from Ruud Luijkx, Department of Sociology, Tilburg University, PO BOX 90.153, 5000 LE Tilburg, The Netherlands; E-mail LUIJKX@KUB.NL).

Chapter 5

Religiously Mixed Marriages in Germany (1901-1986) and the Netherlands (1914-1986)

Abstract

This paper compares trends of religious homogamy in Germany (1901-1986) and the Netherlands (1914-1986), using four categories of religious denomination. In addition, the trend of religious homogamy in the Netherlands is analyzed for the period 1941-1986 using six categories of religious denomination. Special attention is given to the situation of the Jews in Germany in the period 1927-1936, and in the Netherlands in the period 1935-1941.

Jewish homogamy was highest of the four denominations in both Germany and the Netherlands. The differences in the propensities to homogamy of German versus Dutch Catholics and of German versus Dutch Protestants were fairly small in the period before World War II. After the Second World War, Catholic homogamy was considerably lower in Germany, and Protestant homogamy continued to decline. In the Netherlands however, both Catholic and Protestant homogamy increased. The analysis with an expanded number of categories in the Netherlands showed that the increase in Protestant homogamy was due to the high closure under the Orthodox-Reformed Protestants, and that homogamy under the liberal Reformed Protestants remained low in the period 1941-1986. Religious homogamy among Catholics and Orthodox-Reformed Protestants did not start to decline until the 1960s.

An analysis of mixed marriages in Germany in the period 1927-1936 showed that Jewish homogamy rose sharply after 1933, but remained constant until that year. Jewish homogamy in the Netherlands was also constant between 1935 and 1941. There is therefore no evidence that anti-Semitism led to higher Jewish homogamy in either country before the National-Socialists actually came to power.

Introduction

Religiously mixed marriages is a theme that has been somewhat neglected during the past decades. This is also true for countries for which the religious composition is predominantly heterogeneous: Canada, Australia, the United States, Germany, the Netherlands, and Switzerland. For example, in his bibliography of German works on the sociology of religion, Volker Drehsen (1980) reports only two contributions on this subject. The bibliography by

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Joos van Vugt and Ben van Son (1988) indicates that there has been a good deal of activity on the sociology of religion in the Netherlands, but reports only three researchers who have worked on this topic. The English language overviews by Robert de Brunkow (1983), Anthony Blasi and Michael Cuneo (1983) and Robert Homan (1986) contain many more entries, but the number of relevant papers is still small.

The available work shows that religiously mixed marriages have mainly been studied from three perspectives, as had already been remarked by Milton L. Barron (1952). The first perspective focuses on gains and losses. The researcher calculates the number of mixed marriages, monitors the growth of the phenomenon, and tries to determine causes of mixed marriages and, most important of all, their effects on the religiosity of the partners and the religious atmosphere in which they raise their children. This approach discloses a strong interest in religious institutions – the researchers are interested in the extent in which religiously mixed marriages can be harmful to religion and the church. The growth of the number of mixed marriages is used in this approach as an indicator of the ongoing process of secularization. Both American and Dutch researchers have analyzed religiously mixed marriages from this perspective (Bouma 1963, Van Leeuwen 1959). Certain Jewish sociologists followed a similar approach, with a focus on the ethnic survival of the Jewish people (Resnik 1933, Slotkin 1942, Cahnman 1963).

A strong shift in accent takes place if religiously mixed marriages are analyzed from the perspective of sociology of the family. Here, the focus is on “marital adjustment” and “marital happiness”. The role of interfaith and interdenominational marriages is determined as a cause of marital dissatisfaction and divorce (Landis 1949, Burchinal and Chancellor 1963, Hunt and King 1978, Glenn 1982, Larson and Goltz 1989). The results are used as a basis for pedagogic conclusions, e.g. the young must be warned about the risks of intercultural marriages, including religiously mixed marriages (Landis and Landis 1953, Bossard and Boll 1957, Gordon 1964).

The theme of religiously mixed marriages can also be analyzed from a third, macro-sociological perspective. The question then becomes: what can the phenomenon of religiously mixed marriages tell us about the social distances between different societal groups? Are certain groups becoming more integrated in society as a whole, or are they perhaps retreating into further isolation? In the context of American immigration, the important question was whether the ideal of a single melting pot was being realized. An analysis of mixed marriages in New Haven between 1870 and 1940 led Kennedy (1944) to the conclusion that assimilation into the American culture occurred predominately within three religious-ethnic categories. Using these results, Will Herberg (1955) formulated his remarkable essay “Protestant, Catholic, Jew”, on the division of American society into three ideological factions. On the other hand, other researchers point out – also on the basis of empirical research – that exogamy prevails and that religion as a criterion for the choice of partner is gradually disappearing, and conclude that religion is no longer the divisive force it once was¹.

However, this conclusion is contradicted if the special position of conservative and fundamentalist Protestants is examined separately (McCutcheon 1988). Kalmijn (1991) also showed that although religion became increasingly less important in the United States during the period 1920 to 1989, religious endogamy was still the rule. Between 80% and 90% of the Protestant marriages were endogamous during this period, versus 64% to 85% for Catholics and 90% for Jews. Similar results were found in Australia, another immigration country. Hayes (1991) found a strong tendency to religious homogamy, which contradicts the notion of a single melting pot. The pattern of religious homogamy is strongest among conservative

and fundamentalist Protestants, is weakest by a large margin under the Anglicans. The Catholics, liberal Protestants and those with no denominations were in between these two groups with respect to religious homogamy.

This third, macro-sociological perspective is the one chosen for this paper, although all three approaches can of course also have their uses. This preference results from an interest in developments in the openness of society, which has been the subject of several analysis in the past (Lipset and Bendix 1959, Heath 1981, Erikson and Goldthorpe 1992). In these research projects, the greater or lesser openness of society is measured on the basis of the amount of intergenerational mobility along an occupational hierarchy and within an occupational structure. In these works, a distinction is made between *absolute* and *relative* mobility, i.e. between percentages and odds of mobility (Goldthorpe 1980). In the first case, the focus is simply on the number of persons whose destination differs from their origin. In the second case, the analysis addresses the question of whether persons with a higher or lower origin categories have the same chances at achieving higher or lower destination categories.

In this approach, the openness of society can also be measured on the basis of educationally or occupationally mixed marriages. Here, a similar distinction is made between absolute and relative exogamy c.q. heterogamy. Absolute homogamy can be measured using the ratio of the number of marriages between persons with different levels of education or occupation to the total number of marriages, since the focus is only on the degree in which mixed marriages occur. For the analysis of relative homogamy, we are interested in the probability that someone will choose a partner with similar characteristics and in the order of preference for partners from other groups, in the event of a mixed marriage.

In this paper, we wish to examine the openness of society with regard to a horizontal stratification dimension, using religiously mixed marriages as an indicator. In earlier work, we have already analyzed religiously mixed marriages in the Netherlands between the 1940s and the 1980s (Hendrickx, Lammers, Ultee 1989, 1991). In this paper, we will perform a comparative analysis of religiously mixed marriages in Germany in the period 1901-1986 and for the Netherlands in the period 1914-1986. The Netherlands has experienced considerable tensions between religious groups and we found that religious homogamy among Catholics and Orthodox-Reformed Protestants had reached high levels in the past. Will religious homogamy in the Netherlands therefore be higher than religious homogamy in Germany? Religious homogamy in the Netherlands declined during the 1960s and 1970s and we hypothesized that this was due to processes of modernization in the Netherlands. Will there also be a trend to greater openness with respect to religion in Germany? Furthermore, the German churches are "*Volkskirche*", i.e. religion and national identity are closely related. The churches in the Netherlands on the other hand, have gradually acquired a voluntary character. Will religious homogamy in Germany therefore be more resistant to change than it was in the Netherlands?

In addition to answering these questions, we will also bring about improvements to our earlier work on religiously mixed marriages in the Netherlands. First, we will include the Jewish category in the analyses. This category was omitted in earlier works due to an exaggerated regard for small cell counts. Second, we will examine a longer period, by including tables for 1914 and 1935, although the period before 1938 can only be analyzed using four categories of religious denomination (Catholic, Protestant, Jewish, other). This analysis is therefore supplemented by an analysis of the period 1941-1986, using six categories of religious denomination (Catholic, Reformed, Orthodox-Reformed, other, Jewish, none). A third improvement on our earlier work on religious homogamy in the Netherlands is the use of special parameters to capture the pattern of attraction and aversion between the denomina-

tions, in the event of a mixed marriage (cf. Hendrickx 1993 for a technical description). In addition to providing important substantive insights, this results in simpler models, which are easier to interpret.

This paper starts with a theoretical discussion of the reasons for studying religiously mixed marriages and the factors affecting it, which culminates in the formulation of eight hypotheses. A description of the data is followed by an analysis of absolute religious homogamy in Germany and the Netherlands. We then proceed with an analysis of relative religious homogamy in the two countries, using loglinear models. The results are summarized and interpreted in the conclusions.

Theoretical background

THE OPEN SOCIETY

Western societies are depicted as open systems in works on sociology, both with regard to their values as with regard to their social structures. An open Western society would be characterized by cultural and intellectual pluralism, a democratic political order, a free enterprise economy which is open to all, and by unrestricted associations between individuals, beyond the borders of their own groups. The opposite end of the spectrum is formed by totalitarian ideologies, political dictatorship, economic protectionism, rigid caste or class systems.

An open society will be characterized by a good deal of intergenerational mobility. It is generally believed that this norm has been realized to a large extent, although not yet completely. This also applies to social aspects. Of course, there are still many social cleavages in Western societies. These cleavages are on the one hand related to biological traits such as age and gender, on the other hand to characteristics such as occupation, education, religious denomination, ethnicity. These divisions can differ in strength, and it is the task of social scientists to ascertain and explain such variations in international comparative research.

An area which is particularly suitable for the analysis of societal openness or closure, of social proximity or distance, is the everyday lives of individuals. It is held that the goal of an open society has been realized to the extent that persons belonging to different groups – social classes, educational categories, national or ethnic groups – have fewer difficulty in associating with each other in clubs, night clubs, friendship cliques. An even stronger indication that the goal of an open society is being realized is the extent in which people are willing to accept persons from other groups in their own family circle. The degree in which people would not object to a mixed marriage with persons from another group could therefore be seen as an item with the highest difficulty on a Bogardus scale.

Despite modern, alternative forms of co-habitation, marriage and the family remain a basic aspect of human societies. Societal openness could be measured using attitudinal instruments, in order to determine to what extent people state that they are willing to associate with persons from other groups. A step further would be to examine actual behaviors, i.e. to measure the extent in which people do in fact chose a marriage partner from another group, since it is common knowledge that declarations of tolerance and cosmopolitanism are often merely facile verbalisms. The measurement of convictions and attitudes can be very useful, in order to gain information on social norms and values and changes in these. But by examining pat-

terns of behavior, we can determine how attitudes relate to actual behavior, and to what extent the traditional barriers to mixed marriages are in fact deteriorating.

There have been several studies of occupational mobility in the Netherlands, as well as analyses of relative occupational and educational homogamy. Ganzeboom and De Graaf (1984) showed that father to son occupational mobility had increased between 1954 and 1977. Similarly, Sixma and Ultee (1984) showed that educational heterogamy had increased between 1959 and 1977. An international comparison of 23 countries by Ultee and Luijkx (1990) examined the relationship between these two results. They found that industrial nations with higher degrees of intergenerational occupational mobility also had higher degrees of educational heterogamy. For the United States on the other hand, Mare (1991) and Kalmijn (1991) both found a trend toward less, rather than more educational heterogamy. For West Germany, Ziegler (1985) found that the social distance between the highest and lowest levels of education had not changed.

These studies show that the openness of society with regard to vertical dimensions of social structure have been well mapped. In this paper, we will analyze the openness of German and Dutch societies on the horizontal dimension of religious cleavages. In order to do this, we will first discuss the place of religion in open societies.

SUPPLY AND DEMAND

In order to understand developments in marriage and the family, we must understand the factors affecting the outcome of processes of the marriage market. Blau's (1977; Blau and Schwartz 1984) macro-sociological theory of group relationships can provide useful elements for such a theory. This theory is based on two assumptions: the prevalence of social associations will be determined on the one hand by the social distances between positions in the social structure, and on the other hand by the opportunities for social contact which confront the individual. Applied to religiously mixed marriages, parameters of the social structure relating to the social distances between denominations determine the "demand" side of the marriage market. The opportunity structure, i.e. the degree in which contact with members of other denominations is physically possible, determines the "supply" side.

The supply side of the marriage market is affected by factors such as group size and spatial dispersion. The smaller a group, the fewer the contact opportunities will be. All other things being equal, members of smaller groups are therefore more likely to be involved in a mixed marriage. Spatial dispersion amounts to a refinement of the specification of group size: a denomination can be large in one area of the country, but small in others. In that case, an analysis at the national level will not properly reflect the opportunity structure of the marriage market in different regions.

The factors affecting the demand side of the marriage market are more difficult to ascertain. Four factors can be postulated which affect the social distances between groups: individual preferences, church norms, physical isolation of the groups, and the collective norms of religious reference groups. With regard to individual preferences, people prefer to associate with persons with a similar social status and similar attitudes and beliefs. This is treated as a premise by Blau (1977) and Blau and Schwartz (1984), but has also been the subject of social-psychological research in the social comparison theory (Festinger 1954, Suls and Miller 1977, Rijsman and Wilke 1980). Religion can therefore form a major barrier to religiously mixed marriages, assuming that religion has a relevant place in the lives of the individuals in question.

Whether differences in religion result in barriers to mixed marriage depends in the first place on the social climate between religious groups. The climate of hostility in the past was accompanied by discouragement of religiously mixed marriages by religious institutions. Religious norms thus form a second factor affecting the demand in the marriage market for a partner of one's own denomination, versus members of other religious groups. The *Codex Juris Canonici* of 1918 explicitly forbid Catholics to marry with other Christians (*mixta religio*) or with non-believers or adherents of other faiths, including the Jews (*disparitas cultus*). The Catholic Church would make an exception only on the conditions that the Catholic partner would promise to have all children baptized and raised in the Catholic faith and would attempt to convert the non-Catholic partner (Besanceney 1970: 115-117).

These laws were not applied everywhere with the same consistency. The interpretation of the *Codex* was more liberal in Germany than in the Netherlands, where until 1955 no dispensations were granted at all in three of the five dioceses. The orthodox-Calvinist denominations in the Netherlands also strongly discouraged mixed marriages (cf. Dekker 1965). The liberal-Calvinist in the Netherlands and Lutheran Church in Germany took more generous positions, although they recommended religious homogamy. It is not surprising that the small Jewish faith strongly discouraged mixed marriages. Anti-Semitism also formed a barrier to mixed marriages between Jews and members of other faiths.

The tensions between religious groups and the desire to minimize a damaging influence by other ideologies, led to an organizational tactic of isolationism. This is a third factor affecting demand in the marriage market. A minority and emancipation mentality within religious groups strengthened this striving for isolation. In Germany, it was the Catholics in particular who created their own organizations such as their own political party "*Zentrumspartei*" and the Catholic workers movement. Of particular relevance are the separate schools and youth organizations, which separated young Catholic, Protestant and socialist persons during the period in which they were most likely to select a marriage partner.

In the Netherlands, the creation of separate organizations based on religion went to extreme lengths. Catholics, orthodox-Calvinists and to some extent socialists created separate political parties, labor unions, organizations of employers, broadcasting organizations, hospitals, insurance companies, etc. A so-called "pillarized society" came into being, in which the leaders of different groups at the top of the different organizations made pragmatic deals with each other, according to the politics of accommodation (Lijphart 1968). The members of the different pillars obeyed their leaders in a disciplined manner. Here again, the separate youth and sport organizations are of special relevance, as well as the system of separate religious educational institutions, from nursery schools to universities. This religious and ideological "Apartheid", as it may be appropriately called, was considerably stronger in Dutch society, than it was in Germany. However, the onset of the system of pillarization was in 1917, when the right of religiously separate schools to public support became guaranteed by the Dutch constitution. It had therefore not yet reached its full growth in the period before World War II.

A fourth factor affecting the demand in the marriage market with respect to the partner's religious denomination is formed by the collective norms of reference groups. It would be wrong to assume that the climate within and between religious denominations will directly and effectively determine the behaviors of their members. Nor is their any guaranty that members will follow guidelines with regard to those religious segments of the marriage market from which they are to make a choice. Lenski (1960) showed that it is worthwhile to distinguish between "institutional involvement" and "involvement in socio-religious groups". The precepts of the religious institutions are to a large extent moderated and modified by the

reference groups which the members belong to. This process causes some elements to be stressed, others to be subdued, and some to totally ignored. This is the basis of the distinction between "formal" and "informal" religion.

An important source of information regarding informal religion are nation-wide opinion surveys. Results from such surveys in the last few decades show that the majority of Germans and Dutch oppose conflicts and confrontations between the churches: they want tolerance, mutual understanding, and cooperation. With regard to the topic of this paper, opinion research shows that people no longer reject contracting a mixed marriage, nor will they reproach persons who marry outside their faith. Indeed, people have come to believe that religion is or should be an irrelevant criterion in the choice of marriage partner. The attitude toward mixed marriages by others can be summarized by "live and let live".

Schmidtchen (1972, 1973) showed that by 1970, the majority of the West German population no longer opposed religiously mixed marriages. In 1965, 70% of the Dutch still rejected mixed marriages. This changed radically in a period of only five years, and from 1970 on reports show that up to 60% no longer has any objections to mixed marriages (cf. Sociaal en Cultureel Planbureau 1988). In 1981, only 19% of the West Germans and 24% of the Dutch considered common religious beliefs to be important for a good marriage (Noelle-Neumann and Köcher 1987, Halman et al. 1987).

Note also that people in both countries – led by the values of their reference groups – have increasingly less contacts with the churches and its representatives. Whereas in 1952 51% of the German Catholics and 13% of the German Protestants attended church services regularly, in 1982 these percentages had slunk to 32% and 6% respectively (Noelle-Neumann and Köcher 1987). Back in 1966, 52% of the adult Dutch population attended church services on a weekly basis. By 1985, this had fallen to 22% (Felling and Peters 1988). It should be stressed that there was a strong decline in observance of church rituals shortly before and after 1970, especially in the Netherlands and under Catholics and young people.

CHANGES IN RELIGIOUS ASSORTATIVE MARRIAGE

Much has changed with regard to the place of religion in the Netherlands and Germany since the Second World War, and especially since the 1960s. Theologians opened an ecumenical dialogue, there was an increase in cooperation between churches, and church leaders were able to reach agreement on several problematic issues, such as the regulations concerning religiously mixed marriages and the celebration in church of such marriages. The churches put considerable effort into being "good neighbours". The changes within the church were accompanied by structural changes. The German Catholic organizations have almost disappeared, and the Dutch system of pillarization largely collapsed during the 1960s and 1970s, with certain exceptions such as the school system and the broadcasting organizations (cf. Duffhues, Felling, Roes 1985). The decline of pillarization was accompanied by an unprecedented secularization of the Dutch Catholics.

In the English language sociological literature, it is common to associate changes such as these with concepts as the degree of industrialism, mobility, democracy, and pluralism. An industrialized economic system promotes social mobility and this mobility weakens the relationship with the group of origin and thus to the uncritical acceptance of its norms. This process results in the spread of a pluralist disposition, which not only accepts differences in others (negative tolerance), but is also sensitive to the utility of these differences (positive tolerance). Parallel to this process of growing mobility in an increasingly industrialized society is

a process of the weakening of ties with the church, a decrease in the cohesion of denominational groups, and a decline in membership of institutionally organized religion (cf. Luckmann 1963).

The theory of industrialization and modernization is often characterized as a "catch-all" phrase, which comprises a number of distinct processes. In his works on sociology of the family, Goode (1982) remarked that influence of industrialization and modernization on the resources of the individual must be clearly specified, in order to truly explain developments in marriage and the family. A first characteristic of aspects of modernization is that they are impelled by technological developments. A second characteristic is that they affect the individual by either widening his/her ideological horizon, or by reducing his/her dependence on primary relationships. A wider ideological horizon will mean that the individual is more tolerant of differences between groups and more willing to look beyond the borders of his/her own reference groups. These reference groups will therefore have less influence on decisions regarding choice of marriage partner, and the individual will have a lower preference for a fellow group members. A broader outlook of individuals will also reduce support for forms of social-religious isolationism. A reduced dependency due to modernization will render ineffective norms proscribing mixed marriages and will further reduce the influence of reference groups.

Education will of course directly affect the individual's horizon. The increasing number and diversity of contacts with members of other groups will have an indirect effect on the individual's horizon. Contacts can be of a face to face nature, brought about by increasing spatial mobility, travel, urbanization, or they can take the form of the communication of ideas and information through the mass-media, which is held to have transformed the world into a "global village". The well documented shift from ascription standards to achievement standards can be seen as an expression of widened horizons and increased tolerance in modern societies.

A number of aspects of modernization will also reduce the individual's dependence on others. Greater prosperity and the rise of the welfare state make it less necessary to rely on primary relationships for help. Modernization also reduces dependencies in less obvious ways. The decline in agricultural occupations and the expanded scale of production meant that there was less inheritance of family businesses, further reducing the dependence of offspring on their parents.

Other authors maintain that such effects can be derived to ideological and political causes. For example, Dahrendorf (1965) posits that National Socialism in Germany broke down the traditional narrow-minded loyalties to region and religion, to family and occupation. In this respect, the National Socialism helped modernize German society. The German occupation of the Netherlands also indirectly undermined the traditional system, by placing prominent intellectual and political figures together in concentration camps. This instigated an intensive communication process between adherents of different groups and gave birth to the idea of a nationwide movement ("nationale volksbeweging"), which propagated a breakthrough ("doorbraak") of the political, social, and ideological barriers. This was to result in the formation of a progressive political party based on both Christian and social democratic ideas (cf. Bank 1978). Although these plans were blocked shortly after World War II by conservative politicians, administrators, and church leaders, the diverse social groups increasingly refused to obey their leaders. Although the postwar system in the Netherlands appeared unchanged, the downfall of the old loyalties became apparent a few years later.

For our purposes here, it is not important whether one chooses the social-economic or the political-ideological perspective, since both predict the same outcome: the deterioration of traditional group ties, including those of church and religion. It can therefore be expected that there will be a decline in religious homogamy in the period between 1900 and the 1980s. Furthermore, it can be expected that there will be two breaks in the trend of religious homogamy. The first break will be between the periods before and after the Second World War. The breath-taking speed of the process of re-industrialization in the 1950s contrasts strongly with the stagnation and unemployment during the Depression. Furthermore, the long term consequences of the political-ideological processes would become apparent after 1945.

The second trend break can be predicted for the second half of the 1960s. The rise of the "affluent society", the concomitant changes in values (Klages 1985) and the political radicalization (Middendorp 1979) undermined the ties to church and religion (Noelle-Neumann and Köcher 1987, Felling and Peters 1988). This can be expected to result in an increase in religiously mixed marriages.

This is not to say that all differences have disappeared. Strong differences remain, both between the two countries and between the denominations. The two main churches in Germany still claim to be "*Volkskirche*". As conceptualized by Weber and Troelsch, this means that church membership is intertwined with personal identity: one is Catholic or Lutheran, *tertium non datur*. The churches in the Netherlands can no longer make this claim: they have become voluntary associations, i.e. denominations. Put somewhat differently: the German churches are institutions of German society, whereas the Dutch churches are merely institutions within Dutch society. Note that the small sect-like orthodox-Calvinist and neo-Calvinist churches consider a folk church or state church to be totally undesirable.

Furthermore, differences between Lutheranism and Calvinism should not be ignored. Lutherans do not really have a well defined religious doctrine. Lutherans tend to be individualists in theological matters, and their churches are rather loosely organized, with a weak ecclesiastic hierarchy. Calvinists, on the other hand, have a well defined doctrine as decreed by their General Synod. Calvinist churches are well organized and have a solid, democratically chosen hierarchy. The orthodox Calvinists remain a force to reckon with in the Netherlands, with their own schools, newspapers and broadcasting organizations, labor unions and employers organizations, and political parties.

Hypotheses

On the basis of the preceding, predictions about the trend of religious homogamy and heterogamy in Germany and the Netherlands can be derived. The above description of the historical background, similarities and differences gives rise to a number of hypotheses on developments of religious homogamy and heterogamy in Germany and the Netherlands. These are summarized below. To avoid repetition, supportive arguments have been omitted.

1. The analyses of the marriage market will have different results, depending on whether the focus is on absolute homogamy (no distinction between supply and demand factors) or on relative homogamy (only demand factors are considered relevant).
2. Homogamy and heterogamy will not be determined solely by supply factors – demand factors relating to the social distances between denominations will also be relevant.

The influence of demand factors will vary from denomination to denomination, which leads to the following hypotheses:

3. Catholics will have a higher propensity to homogamy than Protestants.
4. In the Dutch case, orthodox-Calvinists will be a more strongly closed group than liberal-Calvinists. The latter denomination will resemble the German Lutherans with regard to propensity to inmarriage.
5. In both countries, the Jews will be the most strongly closed group throughout the period being analyzed.

Finally, we have three hypotheses on the trend of religious homogamy:

6. There will be a decline in the propensity to religious homogamy throughout the period being analyzed.
7. There will be two breaks in the trend of religious homogamy. The first will be the period before and after the Second World War, the second will be the division between the 1960s and the 1970s.
8. In the period up to the 1960s, there was a stronger propensity to religious inmarriage among Dutch Catholics and Protestants than among German Catholics and Protestants. Since the 1960s however, the situation will be reversed.

Data

Official statistics on the choice of marriage partner are available for (West) Germany from 1901 to 1938 and from 1951 to 1986. These data are comprised of bivariate tables of the denomination of the bridegroom by the denomination of the bride. The data for Germany discerned 5 denominations: 1. Lutheran, 2. Catholic, 3. other Christian, 4. Jewish, 5. other (no denomination, unknown, not reported). In order to obtain comparability with data for the Netherlands, category 3 was merged with category 5. We selected three series: the period 1901-1936 at five year intervals, the period 1951-1986 at five year intervals, and the period 1927-1936 on a yearly basis. This third series was selected in order to gain insights in the situation during the rise of German National Socialism.

The data for the Netherlands is also comprised of official statistics, collected by the Dutch Bureau of Statistics C.B.S. Table are available for the year 1914 and from 1935 to 1986, with the exception of the chaotic year 1945. The categories used in these data until 1938 were: 1. Catholic, 2. Reformed, 3. Jewish, 4. other. From 1938 on, category 2 was divided into Reformed and orthodox-Reformed (orthodox-Calvinist) Protestants, and category 4 was divided into "other denomination" and "no denomination". Three series of tables were selected from the Dutch data. The first contained the years 1914 and 1935, together with tables for the period 1941 to 1986 at five year intervals. This series distinguished four denominations, in order to be comparable with German data. The second series covers the period 1941-1986 at five year intervals, but distinguishes six categories of religious denomination, in order to analyze the behavior of the orthodox-Reformed denomination. The third series covers the period 1935 to 1941 on an annual basis. Here again, the focus is the situation of the Jews prior to and during the Second World War².

Absolute homogamy

The data will first be analyzed by using percentages to determine the extent of absolute homogamy. Percentages can be calculated for both the global percentage homogamous marriages, and for the percentage homogamy per denomination. The first can be calculated by:

$$\text{global \% homogamy} = \frac{\text{number of homogamous marriages}}{\text{total number of marriages}} \cdot 100\%$$

The percentage homogamous marriages per denomination can be calculated by:

$$\% \text{ homogamy per denomination} = \frac{\text{number of homogamous marriages in that denomination}}{\text{total number of marriages in which one or both partners were members}} \cdot 100\%$$

Note that the global percentage is not the average value of the percentages homogamous marriages for each denomination.

Tables 1 and 2 show the amount of absolute religious homogamy in Germany and the Netherlands during the period of analysis. The results show that homogamy was the rule in marriages throughout the respective periods. There are no major changes between the periods before and after the Second World War. There is a trend toward greater religious heterogamy however. In the German Empire before World War I, less than 10% of the marriages were

Table 1

The percentage of homogamous marriages, globally and per religious denomination, for Germany, 1901-1986

	global	Catholic	Lutheran	Jewish	other
1901	91.2	78.6	87.2	85.5	39.1
1906	90.7	77.2	86.6	82.7	31.6
1911	90.0	76.1	85.8	77.8	28.4
1916	85.7	67.4	80.3	57.2	22.2
1921	88.3	72.5	83.9	74.8	33.5
1926	85.8	68.5	81.0	66.9	33.7
1931	83.9	67.5	78.6	63.9	31.6
1936	84.9	68.7	79.6	96.7	26.1
1951	74.6	60.9	62.0	30.3	15.4
1956	74.6	60.4	61.8	19.6	23.0
1961	74.1	59.4	61.3	18.1	22.2
1966	71.2	54.8	58.5	19.7	28.1
1971	68.2	53.1	53.5	18.9	32.2
1976	64.4	51.7	47.8	22.7	30.0
1981	63.3	51.9	45.0	24.4	33.2
1986	62.2	50.6	44.0	21.7	33.1

Legend: first column:

$$\frac{\text{Number of homogamous marriages}}{\text{Total number of marriages}}$$

other columns: $\frac{\text{Number of homogamous marriages for the denomination in question}}{\text{Total number of marriages in which one or both partners is a member of the denomination}}$

Table 2

The percentage of homogamous marriages, globally and per religious denomination, for the Netherlands, 1914-1986

	global	Catholic	Reformed	Jewish	other
1914	88.8	76.9	84.4	81.8	36.2
1935	83.7	76.3	76.6	70.2	43.5
1941	82.1	78.8	72.1	76.7	45.2
1946	81.7	78.0	72.1	54.8	47.2
1951	82.8	80.3	72.6	53.2	48.9
1956	83.8	82.5	72.1	37.4	53.0
1961	82.1	80.8	68.4	46.0	51.3
1966	80.6	78.1	65.4	37.4	51.7
1971	75.6	69.7	57.9	37.1	50.6
1976	72.6	64.7	51.9	23.7	51.2
1981	73.0	63.5	52.2	11.6	54.6
1986	74.9	62.6	50.4	20.0	63.3

Legend: see table 1

mixed. In the Weimar Republic, this had grown to 25%, while in the 1980s more than a third of the West German marriages were religiously mixed. A similar process took place in the Netherlands, but at a slower rate. When World War I broke out, the percentage of mixed marriages was approximately 10%. After World War II, this percentage had increased to approximately one-fifth, and in the mid-1980s, it reached a level of 25%.

Tables 1 and 2 can also provide information on the relationships between the different denominations. It can be seen that for Germany at the turn of the century, 87% of the Lutherans joined up with a Lutheran partner. For Catholics, this percentage was 79%. Only in the 1950s do these percentages approach similar levels: around 60% of the marriages of either denomination were now homogamous. Three decades later, we can see that there are more Protestant than Catholic mixed marriages, although the differences are small (7%). The largest change in absolute homogamy took place for the German Protestant group.

In the Netherlands, the Catholics formed the group with the highest percentage of absolute homogamy. In the 1950s, around 80% of the Catholics chose a partner with the same faith. This percentage dropped after the 1960s, but remained higher than 60%. The results for the Reformed Protestants show that whereas in the 1930s a partner with the same faith was chosen very often (approximately 75%), by the 1980s the absolute homogamy rate had dropped to 50%.

The values of absolute homogamy for the Jews are quite remarkable. Around the turn of the century, more than 80% of the Jewish marriages were homogamous. This tendency becomes weaker in both countries with the passing of time and in Germany in 1931, only 64% of the Jewish marriages were homogamous. This trend continued after the Second World War, and in the 1980s, the majority of marriages involving Jews were with a partner of a different faith.

Relative homogamy

The propensities to homogamy in an absolute sense, as determined in the analysis above, are the result not only of the social distances between denominations (the demand side of the marriage market), but also the contact opportunities which the denominations have, due to differences in group size (the supply side). The best example for this can be seen in the dramatic drop in the Jewish rate of absolute homogamy following World War II in both Germany and the Netherlands. Although this could be due to a disappearance of anti-Semitism following World War II, it is clear that the change is largely due to the much smaller size of the Jewish group, due to the Holocaust and later because of migration to Israel. Given this smaller group size, finding a Jewish partner would be increasingly difficult.

This shows the necessity of using measures of relative homogamy, which are able to separate the demand factors we are interested in from supply factors. The desirability of doing so was already apparent in the 1950s, when Karl Rother (1950) and Karl-Valentin Müller (1950) both developed a so-called "Konnuptialindex". This and other measures attempt to correct percentages of homogamy or heterogamy, using the number of mixed marriages that would be expected, if partner choice were independent of the partner's faith.

Social mobility research faced similar problems and found that the inadequacies of such corrected statistics could be solved using loglinear models (cf. Featherman and Hauser 1978). These models capture the association between the denominations of marriage partners in a so-called "interaction term", while the "main effects" capture differences in group size. Special mobility models impose added restrictions on the interaction effect, in order to be able to test for patterns in intergenerational mobility. Agresti (1990) discusses both loglinear models in general and mobility models in particular, including examples of programs using statistical software. Hout (1983) contains an overview of mobility models, and Goodman (1984) contains a number of Goodman's most important articles about mobility models.

Loglinear mobility models have been applied to the analysis of educationally mixed marriages by Sixma and Ultee (1984) and by Ultee and Luijkx (1990), whose results were discussed above. Mobility models have been used for the analysis of religiously mixed marriages by Johnson (1990), Kalmijn (1991a,b), Hendrickx, Lammers, Ultee (1989, 1991) and Hayes (1991).

A number of quite basic loglinear mobility models are used below to ascertain the nature of the association between the partners' denominations, and the changes in this association through time:

1. Independence. In this baseline model, it is assumed that there is no association between husband's denomination and wife's denomination. This means that the number of mixed marriages is the sole result of the supply of marriage candidates in the marriage market, i.e. by the sizes of the different religious groups.
2. Quasi-independence, constant through time. This model assumes that each denomination has a propensity to religious homogamy, but that this propensity does not change through time. However, in the event of outmarriage, there is no preference for one denomination over another, no special attraction between some denominations and aversion between others.
3. Quasi-symmetry, constant through time. This model goes a step further, and assumes not only that each denomination had a propensity to inmarriage, but that in the event of a mixed marriage, there are also preferences for one denomination over another. There is therefore a pattern of attraction and aversion between the different denominations.

However, both the preferences for homogamy and the pattern of attraction and aversion remain constant through time.

4. Quasi-independence, variable through time. This model drops the assumption of model 2, that the preferences for homogamy remain constant through time. Unlike model 3 however, it still assumes that in the event of a mixed marriage, there are no preferences for one denomination over another.
5. Constant symmetric deviances, variable diagonal parameters. This model combines models 3 and 4. It assumes that the propensities for homogamy does change through time, and also that there was a pattern of attraction and aversion between the denominations, in the event of a mixed marriage. However, like model 3, it still assumes that the pattern of attraction and aversion is constant through time.
6. Quasi-symmetry, variable through time. This model drops the assumption of model 5, that the pattern of attraction and aversion between the denominations is constant through time.

All of these models except model 5 are standard, basic mobility models, and are discussed in most works on loglinear modelling. Our use of them is somewhat different, in that we make use of the so-called "deviation contrast". This is the commonplace restriction that the loglinear parameters sum to zero, and the parameters will therefore be relative to the mean. A new element here is the use of so-called "symmetric deviances" parameters. These are used to map the space between a model of quasi-independence and a model of quasi-symmetry, in order to capture the pattern of attraction and aversion between denominations. These parameters indicate which denominations are the first, second, last choice, given that a mixed marriage takes place. They therefore control for the propensity to homogamy of the denominations, as well as differences in group size. A technical discussion is available on request (Hendrickx 1993).

A last note on loglinear models regards the evaluation of the goodness of fit of the models. Usually a test of the goodness of fit of a loglinear model can be done using the likelihood ratio L^2 and degrees of freedom df of the model. However, when the number of cases runs into tens of thousands for each table, rather than a sample of a few thousand cases at the most, then this goodness of fit test will almost always lead to a rejection of the model. For situations like this, Raftery (1986) developed the BIC measure. BIC can be calculated using:

$$BIC = L^2 - df \log(N)$$

where N is the number of cases. A BIC of zero or less means that the model is preferable to the saturated model. Similarly, in a comparison of any two models, the one with the most negative BIC is the most preferable.

Table 3 shows the goodness of fit statistics for the models for Germany in the period 1901-1936, Germany in the period 1951-1986, and the Netherlands between 1914 and 1986. Model 5 has the best fit according the BIC criterion in all three series. Of greater interest than simply the fact that the denominations of partners were not independent of each other (since there was little doubt on this point), is the strength of the association in model 1, and the huge improvement in fit that can be obtained by adding only 4 parameters for religious inmarriage in model 2. This shows that the partner's denomination was very important in both countries, and that there were very high propensities to religious inmarriage. Allowing the parameters for inmarriage to vary with time in model 4 also led to a strong reduction in L^2 . Indeed, for the Netherlands model 4 would be second choice, and its BIC value for Germany 1951-1986 is

Table 3

Goodness of fit statistics for loglinear models of the association between the partners' denominations

Model	L^2	df	BIC
Germany 1901-1936			
1 Independence	2917841	72	2916745
2 Quasi-independence, constant through time	20173	68	19137
3 Quasi-symmetry, constant through time	18468	66	17463
4 Quasi-independence, variable through time	2115	40	1506
5 Constant symmetrical deviations, variable diagonal parameters	283	38	-295
6 Quasi-symmetry, variable through time	166	24	-199
Germany 1951-1986			
1 Independence	1095736	72	1094651
2 Quasi-independence, constant through time	21366	68	20342
3 Quasi-symmetry, constant through time	20958	66	19965
4 Quasi-independence, variable through time	631	40	29
5 Constant symmetrical deviations, variable diagonal parameters	191	38	-381
6 Quasi-symmetry, variable through time	111	24	-250
The Netherlands, 1914-1986			
1 Independence	908178	108	906680
2 Quasi-independence, constant through time	15165	104	13722
3 Quasi-symmetry, constant through time	14982	102	13567
4 Quasi-independence, variable through time	367	60	-466
5 Constant symmetrical deviations, variable diagonal parameters	95	58	-710
6 Quasi-symmetry, variable through time	48	36	-451

only slightly positive. This shows that the pattern of attraction and aversion between denominations was not strongly pronounced.

THE ASSOCIATION BETWEEN THE DENOMINATIONS OF MARRIAGE PARTNERS

The fact that model 5 was chosen means that marriage partners had a certain propensity to religious homogamy, and that this propensity changed through time. In the event of mixed marriages, the partners' denomination was not irrelevant: there was a pattern of attraction and aversion between members of different denominations. However, this pattern remained constant throughout the periods in question. In this paragraph, we will examine this pattern of attraction and aversion, as well as the propensity to inmarriage, controlling for time.

The parameters on the diagonal of tables 4 and 5 indicate the strength of the propensities to homogamy of each denomination. The values in table 4 show that on the average, the Jews were the most closed group, both in the period 1901-1936 and 1951-1986, and table 5 shows that this was also the case in the Netherlands. The Catholics were the second most closed group in both tables. In Germany, the Lutheran Protestants were the most open group, whereas in the Netherlands the category "other" was more open than the Reformed group.

Table 4

Parameters for religiously mixed marriages in Germany, 1901-1936 and 1951-1986

1901-1936	Catholic	Lutheran	Jewish	other
Catholic	2.808	-.594	-.171	-.422
Lutheran	.242	1.777	-.423	-.171
Jewish	-1.867	-1.604	4.464	.394
other	-1.183	-.415	-.994	2.591
1951-1986				
Catholic	1.662	.440	-.079	-.361
Lutheran	.432	1.277	-.361	-.079
Jewish	-1.563	-1.652	4.228	.440
other	-.530	-.056	-1.013	1.592

Diagonal and lower triangle: symmetric interaction parameters, controlling for the effects of time

Upper triangle: social proximity parameters

The values in the upper triangles of tables 4 and 5 contain parameters relating to the pattern of attraction and aversion in the event of mixed marriages, as measures of the social proximities between the denominations. For tables with 4 categories, these parameters give three values, indicating the first, second and third choice of each denomination. For example, the values in the upper triangle of table 4 show that in the period 1901-1936, German Catholics had a first preference for marriage with Lutheran Protestants, had a mild aversion for marriages with Jews, and a strong aversion to marriages with "other". Note that attraction here does not necessarily imply a positive choice. Protestants could be the first choice of Catholics in the event of a mixed marriage only because the alternatives of marrying a Jew or an atheist or agnostic member of the category "other" are deemed worse.

This pattern is quite similar for Germany in both periods, as well as for the Netherlands. There is a attraction between Catholics and Protestants, and between Jews and the category "other". There is aversion between the Catholics and "other" and between Protestants and Jews. There is more or less neutrality between Catholics and Jews and between Protestants

Table 5

Parameters for religiously mixed marriages in the Netherlands, 1914-1986

	Catholic	Reformed	Jewish	other
Catholic	2.286	-.244	-.010	-.234
Reformed	-.216	1.845	-.234	-.010
Jewish	-1.610	-1.613	4.124	.244
other	-.460	-.016	-.901	1.377

Diagonal and lower triangle: symmetric interaction parameters, controlling for the effects of time

Upper triangle: social proximity parameters

and "other". The aversion of Catholics to the category "other" is something of a surprise. It might be expected that this would be the first choice of Catholics, over the culturally different Jews and their traditional enemies, the Protestants.

Using the diagonal parameters and the "symmetric deviances" parameters in the upper triangle of tables 4 and 5, symmetric interaction parameters, controlling for time, can be calculated (cf. Hendrickx 1993). These are presented in the lower triangles (including the diagonal) of tables 4 and 5. The values on the diagonal are equal to the estimated diagonal parameters, which have been discussed above. The off-diagonal parameters indicate the relative frequency (controlling for size effects) of the different types of outmarriage. The values in the lower triangle of table 4 show that mixed marriages in Germany occurred most frequently between Catholics and Protestants, and least frequently between Jews and either of the Christian denominations. In the Netherlands, mixed marriages between Jews and the Christian denominations also had the lowest relative frequency. Unlike Germany, marriages between Catholics and Reformed Protestants had only the second highest relative frequency, and were considerably less common than in Germany. Mixed marriages between Protestants and the category "other" had the highest relative frequency in the Netherlands.

As noted above, Dutch data made a distinction between Reformed Protestants ("hervormd") and Orthodox-Reformed Protestants ("gereformeerd") and between "other denominations" and "no denomination", from 1938 onward. The special place of the Orthodox-Reformed Protestants in Dutch society was noted in the theoretical section, and in hypothesis 4 we predicted that marriage patterns of Orthodox-Reformed Protestants would differ from those of the liberal Reformed Protestants. This was tested by repeating the analysis for the Netherlands using 6 categories of religious denomination for the period 1941 to 1986. Here again, model 5 had the best fit, with an L^2 of 722 and 181 df , which corresponded with a BIC of -1770. The parameters of this model, controlling for time effects, are presented in table 6.

The values on the diagonal of table 6 confirm that the Jews were the most closed group in the Netherlands. The Orthodox-Reformed Protestants have the second place with regard to societal closure, whereas the liberal Reformed Protestants were the most open group. In fact, the Orthodox-Reformed Protestants formed an even more closed group than the Catholics. However, the difference was not large, and the Catholics were far more closed than the liberal

Table 6
Parameters for religiously mixed marriages in the Netherlands, 1941-1986

	Catholic	Reformed	orthodox-Reformed	Jewish	other	none
Catholic	2.589	.063	-.234	.080	.042	.048
Reformed	-.157	1.445	.776	-.515	-.110	-.214
orthodox-Ref.	-.845	.450	3.010	-.284	-.018	-.240
Jewish	-1.045	-1.354	-1.515	5.063	.200	.520
other	-.354	-.220	-.520	-.815	2.147	-.113
none	-.188	-.164	-.581	-.335	-.238	1.506

Diagonal and lower triangle: symmetric interaction parameters, controlling for the effects of time
Upper triangle: social proximity parameters

Reformed Protestants. The category "no denomination" was the second most open group, with a parameter value very close to that of the liberal Reformed Protestants, and the category "other" was third with regard to openness.

The values in the upper triangle of table 6 show the pattern of attraction and aversion between the six categories of religious denomination. The values for Catholics show that this group was only averse to marriages with Orthodox-Reformed Protestants. Catholics were more or less neutral with regard to remaining categories. The pattern for Orthodox-Reformed Protestants shows much more pronounced preferences. They reciprocated the aversion of the Catholics, and had aversions of similar magnitude to marriages with Jews and the category "none". The Orthodox-Reformed Protestants were neutral with regard to the category "other", but had a strong attraction to the liberal Reformed Protestants, from which group they had split off in 1886. The liberal Reformed Protestants reciprocated the attraction to Orthodox-Reformed Protestants and were neutral with regard to Catholics. Surprisingly, the liberal Reformed Protestants had a very strong aversion to marriages with Jews. They had aversions of a somewhat lower magnitude to marriages with the category "other" and "none".

The Jews had a strong first preference for marriages with persons with no denomination, and a second preference for marriages with the category "other". As noted, Jews were neutral toward marriages with Catholics, had an aversion to marriage with Orthodox-Reformed Protestants and an even stronger aversion to marriage with liberal Reformed Protestants. The heterogeneous category "other denominations" had the most neutral pattern of attraction and aversion, as might be expected. They showed a slight preference for marriages with Jews and a slight aversion to marriages with liberal Reformed Protestants or members of the category "none". The preferences of the category "none" have already been seen, but will be summarized for the sake of completeness: strong attraction to Jews, neutrality to Catholics, weak aversion to "none", strong aversion to either liberal or orthodox Reformed Protestants.

The symmetric interaction parameters in the lower triangle of table 6 are presented for the reader's convenience. They can be interpreted along similar lines as the values in table 5.

TRENDS IN RELIGIOUS HOMOGAMY

Our models of religiously mixed marriages showed that there were trends in religious homogamy, both in Germany for either period, and in the Netherlands using either four or six categories of religious denomination. Figure 1 shows the trend in religious homogamy in Germany for the two periods analyzed here. The trend for the Jews shows the dramatic developments in German society. Although the Jews were the most closed group by a considerable margin, they were becoming more open between the turn of the century and 1931. This trend came to an abrupt end due to the rise to power of the National Socialists and the value for 1936 shows the effects of the Neurenberg Race Laws. After the Holocaust, the Jewish propensity to homogamy went back to a level slightly higher than before the Second World War. Note that this is the opposite of the conclusion based on percentages. Although Jewish mixed marriages did become more frequent after World War II as indicated by the measures of absolute homogamy in table 1, they continued to value having a Jewish partners, as indicated by the measures of relative homogamy in figure 1.

Figure 1 also shows that the Catholics were more closed than the Protestants throughout the period being analyzed. They show a slight tendency to greater openness during the first period. An exception is the year 1936, when all denominations had become more closed compared to 1931. After the Second World War, the German Catholics had a much lower

propensity to inmarriage, and this propensity continued to decline. Thus, there is some evidence that the Second World War led to a major break in the trend of Catholic inmarriage. However, there is no evidence of a second break during the 1960s.

The German Lutheran Protestants had the weakest propensity to homogamy throughout the period. There is very gradual trend toward greater openness (with the exception of 1936). However, the post World War II trend appears to be a continuation of the trend in the pre-war period, whereas for the Catholics it appeared to be a clear break with the past. There is also no evidence that the 1960s influenced the openness of German Protestants in any way.

Figure 2 shows the trend of religious homogamy in the Netherlands between 1914 and 1986. The Dutch Jews were by far the most closed group throughout the period. The Jewish propensity to religious homogamy only fluctuated until the 1960s, after which it began to decline. In 1986 however, this process came to an abrupt end.

The Dutch Catholics were more closed than the Protestants from 1914 to 1971. The propensities to homogamy of Catholics and Protestants converged in 1976, and in the last two years, the Catholics were slightly more open than the Protestants, although the difference is small. There is no evidence that the Second World War affected Catholic inmarriage. In fact there is an increase in the Catholic propensity to inmarriage between 1946 and 1956, rather than the decline propagated by proponents of the "Doorbraak" movement. The 1960s did lead to a dramatic drop in Catholic homogamy.

Protestants in the Netherlands had a relatively low propensity to homogamy at the beginning of the period. However, this propensity grew until 1966, after which it decline slightly. There is no evidence at all of a break due to World War II, and only slight evidence of any influence of the 1960s.

Figure 3 shows the trends for Germany and the Netherlands in a single graph. Both the German and Dutch Catholics in the past had a stronger propensity to homogamy than the German and Dutch Protestants. However, Catholics began increasingly to resemble Protestants and at the end of the series had the almost the same, low propensity to inmarriage. The Second World War brought about a break in the trend for the German Catholics, whereas for Dutch Catholics the 1960s were the period of greatest change. Both German and Dutch Protestants showed a relatively low propensity to homogamy throughout the period. However, the propensity decreased in Germany, whereas in the Netherlands it increased.

Several points deserve notice. For one thing, the German Protestants do not form a homogeneous group. There are mainline Lutherans and conservative Lutherans, as well as Evangelicals, both with and without a pietist tradition. To what extent these groups may differ with respect to choice of marriage partner cannot be ascertained using the available official statistics.

Secondly, there is the matter of loss of faith. In Germany until very recently, only a small number of persons reported to have no religious denomination. During the last German census in 1987, less than 10% of the Germans were registered as having no denomination (Moll and Wiegand 1993). For this reason, the official statistics merged them with other categories (unknown, not reported). So although their behavior with respect to choice of marriage partner can be expected to be strongly different, we have no data to test whether this is the case.

Figure 1
The trend of religious homogeneity. In Germany, 1901-1986

Figure 2
The trend of religious homogamy in the Netherlands,
1914-1986

Figure 3
The trend of religious homogamy in Germany
(1901-1986) and the Netherlands (1914-1986)

Fortunately, data for the Netherlands do allow for a distinction between mainline and orthodox Reformed Protestants. Figure 4 shows the trend for homogamy in the Netherlands between 1941 and 1986, using 6 categories of religious denomination. The category "none" has more or less the same, low propensity to homogamy as the liberal Reformed Protestants. This propensity remained constant for both groups throughout the period, with the exception of the year 1986 for the category "none", which suddenly became more closed. The Orthodox-Reformed Protestants were strongly oriented toward their own group, even more so than the Catholics. The 1960s had the same effect on Orthodox-Reformed Protestants as it did on Catholics, and their propensity to inmarriage declined strongly.

We would like to conclude the analyses with an examination of the position of the Jews during the rise to power of the National Socialists. The Jews were by far the most closed group in either country, although figure 3 does indicate a gradual decline in Jewish homogamy until the 1930s. Figure 5 shows that Jewish homogamy in Germany remained constant until 1933, when Hitler came to power and passed the Neurenberg Race Laws. These

Figure 4
The trend of religious homogamy in the Netherlands, 1941-1986

formally excluded the Jews from the marriage market and forced them to cling to their own group. However, figure 5 does not indicate that anti-Semitism in the later years of the Weimar Republic led to a lower relative frequency of mixed marriages with Jews, controlling for differences in group size. Nor is there evidence that Jews became more introverted, due to feelings of threat because of Nationalist Socialist agitation.

Likewise in the Netherlands, there is no evidence that the developments prior to World War II caused Jews to be excluded by the other religious groups, or that they became themselves more strongly focussed on their own group. The Dutch National Socialist Party NSB was not originally anti-Semitic, but in 1937 it adopted the policies of the German Nazis in this respect as well. On the other hand, support for the NSB began to decline after 1936. Neither development affected Jewish homogamy. Jewish homogamy also remained at the same level during the Nazi arms build-up and the onslaught of World War II. Only in 1941 did Jewish homogamy increase, as the German occupiers made mixed marriages with Jews a dangerous proposition. Deportation of Jews commenced in 1942, and mixed marriages with Jews became so infrequent as to render the analysis of relative homogamy meaningless. Jewish mixed marriages did continue to occur, even in 1944. Presumably, these were conducted in concentration camps on Dutch soil. Amazingly, the bureaucratic apparatus continued to record this, even in the midst of chaos and slaughter.

Figure 5

The trend of religious homogamy in Germany (1927-1936)
and the Netherlands (1935-1941)

Conclusions

At the end of the second section of this paper, we formulated eight hypotheses. Given the result above, we can now decide which of these hypotheses can be accepted and which must be rejected. In this interpretation we assume that religiously mixed marriages have implications for religion as a horizontal stratification dimension in Germany and the Netherlands.

First of all, the utility, even necessity of distinguishing between measures of absolute and relative homogamy was clearly evident in the results of our analyses. By using loglinear models, we were able to separate demand in the marriage market from supply. The method used provides different information and different insights. For example, the absolute homogamy rate for German Protestants would indicate that this was the least frequent type of mixed marriage throughout the period being analyzed. The results of the analyses of relative homogamy on the other hand, show that this is due to demographic factors. The Protestants in Germany formed the majority of the population, and they would encounter each other as a matter of course. The low values for relative Protestant homogamy show that they did not place a strong value on a homogamous marriage, and were in fact the most willing of any group to contract a mixed marriage. Similarly, the strong value Jews placed on homogamous marriages only becomes apparent if measures of relative homogamy are used.

Hypotheses 3, 4 and 5 concentrate on the subjective preferences of marrying couples, and assume that they do not all place the same value on religious homogamy, i.e. that the barriers between the religious groups do not all have the same strength. The results confirm these hypotheses, although with qualifications. At one end are the Jews, who are evidently highly motivated to maintain their ethnic identity by means of religious homogamy (cf. hypothesis 5). At the other end are the German Protestants, who have weak bonds with religion and church (cf. Felling, Peters, Schreuder 1987). Religion as a horizontal stratification dimension can scarcely be said to exist for German Protestants. In the Netherlands, the liberal Reformed Protestants and the category with no denomination place a similar low value on religious homogamy. The Catholics in both countries and the Orthodox-Reformed Protestants in the Netherlands are somewhere in the middle with regard to openness.

The special place of the Orthodox-Protestants in the Netherlands is especially interesting. For orthodox Christians, religion is not simply a system of dogmas, but also a system of prescribed behaviors. Religion defines the world and determines the believer's relationships to the world with regard to politics, science, marriage, the family. Religion to the orthodox believer relates to both cognitive mapping and normative behavior, and does so in all aspects of life (cf. Felling, Peters, Schreuder 1986, Peters and Schreuder 1989). Note that a similar phenomenon might be discernible among the rest of the denominations, if the data would allow a distinction to be made between orthodox and non-orthodox members.

This is not to say that either the Orthodox-Protestants, or the Jews, divide their social environment strictly into ingroup versus outgroup with no differentiations. The analyses showed a constant pattern of attraction between certain denominations and aversion between others. Of particular interest is the neutrality between Catholics and Jews: in the marriage market, they neither attract nor repulse each other. The relationship between Catholics and "other" (mostly the unchurched and members of smaller denominations) is more problematic. These relationships are reversed for the Protestants: the German Protestants and the Dutch liberal Protestants had a large social distance to the Jews, but were relatively close to the "other denominations".

A definite explanation is hard to give. We might speculate that these patterns are in large part due to choices made by the Jews. This group would value matters such as cultural traditions and religious faith. Their first choice in the event of a mixed marriage would then be ex-Jews in the category "other", their second choice would be the tradition oriented Catholics, and the last choice of all would be members of the relatively modern Protestant churches. Among the Protestants, the fervently religious and tradition oriented Orthodox-Protestants would be preferable to the members of the progressive and religiously casual liberal Protestants.

Hypotheses 6, 7 and 8 assume that the propensities to inmarriage would change in the course of time. More specifically, hypothesis 7 predicted that the Second World War and the roaring sixties would be two breakpoints in the trend. The results do not provide unqualified support for these hypotheses. Contrary to hypothesis 6, the propensity to religious homogamy among German Protestants changed very little, and among the liberal Protestants and the category "no denomination" in the Netherlands, it did not change at all. The Second World War can only be said to have affected the propensity to homogamy of German Catholics, and perhaps of German Protestants. It was business as usual after World War II, as far as religious homogamy in the Netherlands goes. The 1960s did lead to a strong decline in religious homogamy among Catholics and Orthodox-Protestants in the Netherlands, but did not noticeably accelerate the very slight trend to lower homogamy in Germany. The trends for Catholics and Orthodox-Protestants in the Netherlands run deceptively parallel. Both groups became more open, but the Catholic Church in the Netherlands had a full scale rebellion to cope with and a major loss of membership, whereas the Orthodox-Reformed Protestants did not have these problems.

The theories presented in the second section of this paper, on the influence of social-economic and political developments brought on by the Second World War and by the Cultural Revolution in the 1960s did not always lead to valid predictions in these analyses. The rapid postwar re-industrialization, the World War II "doorbraak" (breakthrough) movement in the Netherlands, the decline of separate organizations in both countries, do not seem to provide adequate explanations for the observed trends in both countries. One explanation might be that it was incorrect to expect modernization to lead to sudden accelerations in the trend toward greater openness.

Modernization is an ongoing process, which should lead to a gradual decline. Furthermore, we must take counteracting forces into consideration. The system of pillarization in the Netherlands is held to have been a reaction to processes of modernization and secularization (Righart 1986). The trends can be explained if we posit that separate religious organizations for Catholics in the Netherlands were able to successfully counteract the forces of modernization until the 1960s. At that point, the system of pillarization began to fall apart, which led to an acceleration in the decline of religious homogamy. In Germany, the collapse of separate Catholic organizations could account for the acceleration in the decline of Catholic after World War II. For the rest, modernization led to a gradual decline in religious homogamy in Germany.

This explanation fits the data, but others could be devised as well. This indicates the necessity of replacing the "grab bag" concept of modernization with well defined concepts which can be operationalized and used in empirical tests. By using variables related to aspects of modernization as exogenous variables to explain both differences between countries and trends within countries, as was done by Ultee and Luijkx (1990), we can go beyond interpre-

tation and speculation. In this way, we can gain empirical insights in the causes affecting the openness of society.

Notes

¹ The Catholics and the Mennonites form an exception, according to Bealer, Willets and Bender (1963).

² Data were available for the years 1942, 1943 and 1944 as well. However, because deportations of the Jews to concentration camps was well under way in 1942, we felt that results for that year would not be very meaningful. Mixed marriages with Jews were too infrequent to be meaningfully analyzed with loglinear methods during the last two years.

Part 2

Chapter 6

Design techniques for Equal/Unequal Main Effects and Symmetric/Asymmetric Interactions

Abstract

This paper discusses design techniques for the analysis of square tables, using occupational mobility as an example. These techniques are the same for mobility analysis on a dependent variable, as for frequency table mobility analysis, so it is useful to discuss them in the context of generalized linear models.

We begin with a discussion of the application of contrasts in order to achieve identification in models with categorical predictors, and how an existing design can be redefined/restricted using the same method. In a discussion of designs for inequality of the main effects, we compare Hope's halfway/difference model with the alternative size/marginal shift model by Sobel, Hout and Duncan, and briefly discuss Sobel's (nonlinear) diagonal reference model. This is followed by a discussion of the decomposition of interactions into symmetric and skew symmetric components, and how the contrast used can influence perception of the nature of asymmetries. We conclude with a new nonlinear model for asymmetric interaction, the proportional asymmetry model.

Keywords: *Generalized linear models, contrasts, nonlinear regression, mobility.*

The use of contrasts to achieve identification of generalized linear models with categorical independent variables

A generalized linear model (GLM) for the dependent variable y , involving n cases and m parameters, solves the equation:

$$\eta = \sum_{j=1}^m x_j \beta_j \quad (1)$$

The linear predictor η is a link function g of the predicted values of the dependent variable: $\eta = g(\mu)$, where $\mu = E(y)$. By allowing for different link functions and probability distribu-

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tions of γ , GLM's subsume many well known statistical models, such as the analysis of variance, loglinear, and logit models, into one statistical framework (McCullagh and Nelder 1983; Aitkin et al. 1989). For this reason, it is useful to discuss design techniques in the context of generalized linear models.

A saturated model for categorical variables, such as in analysis of variance or a loglinear analysis, fits parameters for the overall effect, for each category of each factor separately, and for all combinations of all factors. This model (or a subset of it) cannot be estimated without restrictions on each factor in each term. A general method of imposing restrictions is to reparametrize the model, using a contrast matrix (Finn 1974; Bock 1975; Lammers 1984). An overparametrized model containing all effects would be, using matrix notation:

$$\eta = A\theta \quad (2)$$

where η is an n by 1 matrix of the linear predictor, A is an n by q model matrix, and θ is a q by 1 matrix of model parameters ($q > m$). A contrast matrix C can be constructed that defines the β parameters to be estimated as linear combinations of these model parameters, such that $\beta = C\theta$. It must be so that $A = XC$, if equation (2) is equivalent to $\eta = X\beta$, the matrix notation of equation (1). Using $X = AC'(CC')^{-1}$, a full rank design matrix can be derived from the model matrix.

Several common types of contrasts are:

deviation contrast: The β parameters are relative to the mean θ^a of the model parameters:

for the factor a with k categories, $\beta_i^a = \theta_i^a - \theta^a$. One β parameter is redundant and can be dropped, since the sum of the parameters is zero.

simple contrast: Parameters are relative to a chosen reference category c : $\beta_i^a = \theta_i^a - \theta_c^a$, $c \neq i$.

difference contrast: Parameters are relative to the previous category: $\beta_i^a = \theta_i^a - \theta_{i-1}^a$, for $i=2$ to k . For an interaction effect, this contrast will indicate row-wise differences between column-wise differences (or vice-versa), so that in a loglinear model, the parameters are equal to the log-odds ratios in the 2 by 2 subtables of the table (the local [log] odds ratios; Agresti 1990). Many restricted designs for interaction effects, such as used in e.g. mobility research, are formulated in terms of patterns of log odds-ratios (Goodman, 1979).

orthogonal polynomial contrast: For a factor with k levels, η is described in terms of a set of $k-1$ polynomials. Furthermore, the design matrix is made to be orthogonal, so that parameter estimates are independent of each other.

The choice of contrast defines in what sense parameters are relative, and their use can be important when the focus is on the interpretation of individual parameters, rather than simply on whether certain terms in the model are significant or not. The type of contrast will not affect the goodness of fit of a model and a set of parameters can be transformed to a different contrast ex post facto by suitable transformations of the β parameters.

Contrasts are also relevant when additional restrictions are imposed. This can be done using a redefinition matrix R , which specifies a new set of redefined or restricted parameters γ as linear combinations of β parameters, such that $\gamma = R\beta$. With R , the design matrix X can be transformed to a new design matrix Z , by $Z = XR(RR')^{-1}$. An alternative method is to manipulate the design matrix. Removing a column of the design matrix fixes its parameter to zero; adding two columns of the design matrix imposes an equality constraint on the two parameters. Manipulating the design matrix will often be practical, although using a redefinition matrix can be more flexible.

Equality and differences of the main effects

Examples of redefining and restricting parameters in order to make them correspond with substantive concepts can be found in analyses using two factors with equal categories, such as intergenerational occupational mobility analysis. There are two types of mobility analysis. The analysis of variance type (ANOVA mobility analysis) tests for the effects of mobility on a dependent variable, under the hypothesis that mobility can be stressful and will therefore affect behavior. The second type analyzes frequency tables using loglinear models, in order to test for the presence and patterns of mobility.

There are strong parallels in the design considerations of both types of mobility analysis. For origin variable o and destination variable d with equal number of categories, both types use a model of main effects only, as a baseline model:

$$\eta_{ij}^{od} = \beta^* + \beta_i^o + \beta_j^d, \quad (3)$$

using an identity link and assuming a normal distribution of y for the ANOVA type of mobility analysis, and using a log link and assuming a poisson distribution for the frequency table type.

In the case of ANOVA mobility analysis, effects are partially due to the origin and destination variables themselves. The baseline model is used to control for this, so that any significant interaction effects can be attributed to combinations of origin and destination categories. For frequency tables, higher cell counts can be expected for mobility between relatively large categories. A baseline loglinear model incorporates these size effects, and interactions measure relative mobility, which is independent of the marginal distributions.

Hope (1971, 1981, 1982) felt it would be useful to redefine the main effects of equation (3). Hope's design is:

$$\eta_{ij}^{od} = \beta^* + h_i + h_j + d_i - d_j, \text{ where} \\ h_i = \frac{1}{2}(\beta_i^o + \beta_i^d) \text{ and} \\ d_i = \frac{1}{2}(\beta_i^o - \beta_i^d) \quad (4)$$

The h_i parameters are called halfway effects. For ANOVA type of mobility analysis, halfway effects indicate the effect of "occupation" itself on the dependent variable, as opposed to the separate effects of father's occupation and son's occupation. For frequency table mobility analysis, halfway effects pertain to size effects, as opposed to the separate size effects of origin and destination. The d_i parameters are difference effects. In ANOVA type mobility analysis, these effects indicate the unequal strength of the row and column factors on the dependent variable¹, thus forming a measure of loyalty to origin versus conformism to destination behavior. For frequency table mobility analysis, Hope (1981, 1982) posited that difference effects measure structural mobility: the degree to which mobility is forced by shifts in the sizes of occupational categories.

Equation (4) can be used to redefine parameters with no loss of information, using any contrast for β_i^o and β_j^d . Hope favoured the use of polynomials, in order to partition the difference effects into a linear parameter "L", which represents uniform shifts between the margins, and a residual, for the nonuniform shifts.

Sobel, Hout and Duncan (1975) made two critical notes on equating difference effects in loglinear models with structural mobility. They argued that structural mobility must be

equated with marginal heterogeneity, but showed that difference parameters will account for marginal heterogeneity only if the interaction is symmetric. A second point is that since the margins of a mobility table do not correspond with (occupational) distributions at two points in time (Duncan 1966; Sobel 1983), the measure for structural mobility should apply uniformly to all origin categories. To achieve this, they formulated the following design for size effects and structural mobility:

$$\eta_{ij}^{\text{sd}} = \lambda_i + \lambda_j + \gamma_j, \text{ where}$$

$$\lambda_i = \lambda_j, \text{ if } i = j, \text{ and} \quad (5)$$

$$\sum_{j=1}^r \gamma_j = 0,$$

using a poisson distribution and a log link for a square r by r table. The model has k size effect parameters λ_i and $k-1$ marginal shift parameters γ_j . There is no overall effect, because this is incorporated in the size effect parameters λ_i .

Although this is perhaps not directly apparent from equation (5), this design is equivalent to a main effects design. Luijkx (1985) showed that the marginal shift parameters γ_j in the SHD model are equal to $-2d_j$ in terms of Hope's model (assuming that the difference parameters use the deviation contrast). This means that the marginal shift parameters are equal to $\beta_j^o - \beta_j^d$, while the size effect parameters λ_i turn out to be equal to $\frac{1}{2}\beta^* + \beta_i^o$ (entering this in equation (5) results in the main effects model)². So in terms of a redefinition of parameters, Sobel, Hout and Duncan have achieved the opposite of their intentions: their structural mobility parameters depend on origin and destination, while their size effects parameters are dependent on origin only. Our conclusion is that the SHD model does not serve its purpose of providing a measure of structural mobility that is independent of origin category. It has no advantages over Hope's halfway/difference design, but of course no disadvantages either.

EXTENSION TO NONLINEAR DESIGNS: THE DIAGONAL REFERENCE MODEL

The designs discussed so far are linear designs. For the analysis of effects of mobility on fertility, Sobel (1981, 1985) developed a nonlinear design for use in an analysis of variance model. Sobel felt that Hope's halfway model (for analysis of variance) was on the right track, but criticized its equality restriction as unrealistic. Sobel argued that mobile persons must reconcile the conflicting pressures of their origin and destination reference groups and that the main effects are therefore unlikely to be equal. It is more plausible that they will be unequal, but proportional to each other. To test this, Sobel introduced the simple diagonal reference model³ (SDR), which specifies that:

$$\eta_{ijk} = p\mu_u + (1-p)\mu_d \quad (6)$$

For $i, j=1$ to r , the number of categories of the origin and destination variables, and for $k=1$ to n , the number of respondents, using an identity link and assuming a normal distribution of y_{ijk} . The SDR model estimates one salience parameter p , and r diagonal parameters μ_u . The SDR model combines linear and multiplicative terms, and therefore falls beyond the scope of GLM's. Estimation must be done with a program for nonlinear regression, but modern programs make this a fairly simple task⁴.

The salience parameter p compares the strength of the effects of origin and destination status on behavior. If $p > \frac{1}{2}$, then origin status has more influence on behavior than destination status; if $p < \frac{1}{2}$, then destination has greater salience. Salience of origin versus destination is also indicated by Hope's difference parameters, but the SDR model expresses it as a ratio, using a single parameter, while the difference parameters express salience as subtraction, using $r-1$ parameters. A linear or low order polynomial restriction could be placed on the difference parameters to achieve parsimony, but this may not always be appropriate, given the measurement level of the origin and destination variables. An attractive feature of the SDR model is that it makes no assumptions about the ordering of the categories of the status variables. The p parameter will often be of substantive interest when the effects of the row and column factor are being compared, as in research on effects of mobility (e.g. De Graaf and Ultee, 1990). The model can also be extended to let salience vary per origin category or destination category.

Symmetric/asymmetric interaction effects

Equation (3), or transformations derived from it, is used as a baseline model in mobility research, while the main focus is on the interaction effects of origin and destination. For ANOVA type mobility analysis, significant interactions indicate that mobility does affect behavior, controlling for the separate effects of the origin and destination variables. For frequency table type mobility analysis, significant interactions indicate the presence of relative mobility, i.e. mobility, controlling for size effects of the origin and status variables.

A following step can be to apply additional restrictions to the interaction effects, in order to test specific hypotheses, or to acquire a parsimonious description of the pattern of changes. To start with, the parameters can be restricted to be symmetric. For ANOVA type mobility analysis, symmetric interactions indicate that upward mobility has the same effects on behavior as downward mobility. For frequency table mobility analysis, symmetric interactions indicate that there is as much upward mobility as downward mobility, which corresponds with "circulation" or "exchange" mobility. Asymmetric interactions mean that there is either net upward or downward mobility. Sobel, Hout and Duncan (1985) show that this would be a second source of structural change, beside those of the difference effects.

If the interaction effects are not symmetric, insights in the nature of the asymmetries can be gained by redefining the interaction parameters β_{ij}^{od} for a square table into symmetric parameters σ_{ij} and "skew symmetric" parameters⁵ v_{ij} (Yamaguchi 1990).

$$\begin{aligned}\sigma_{ij} &= \frac{1}{2}(\beta_{ij}^{od} + \beta_{ji}^{od}) \\ v_{ij} &= \frac{1}{2}(\beta_{ij}^{od} - \beta_{ji}^{od})\end{aligned}\tag{7}$$

This definition implies that $\sigma_{ij} = \sigma_{ji}$, so $r(r-1)/2$ symmetry parameters are identifiable and the rest are redundant. Also, it follows from equation (7) that $v_{ij} = -v_{ji}$ and that $v_{ii} = 0$, so that $(r-2)(r-1)/2$ parameters are identifiable while the rest are redundant.

Sobel, Hout and Duncan (1985) first suggested redefining the full interaction effect into symmetric and skew symmetric components. Their saturated model for an r by r frequency table is:

$$\eta_{ij}^{od} = \lambda_i + \lambda_j + \gamma_j + \delta_{ij} + \zeta_{ij}, \text{ where}$$

$$\lambda_i = \lambda_j \text{ if } i = j$$

$$\sum_{j=1}^r \gamma_j = 0 \quad (8)$$

$$\delta_{ij} = \delta_{ji} \text{ if } i \neq j$$

$$\delta_{ij} = 0 \text{ if } i = j$$

$$\zeta_{ij} = 0 \text{ if } i = j$$

The size parameters λ_i and marginal shift parameters γ_j were discussed above. The symmetry parameters δ_{ij} are identifiable due to the restriction that the diagonal cells form a contrast category. In terms of a contrast, the SHD symmetry design⁶ would be:

$$\delta_{ij} = ((\theta_{ij} - \theta_{ii}) - (\theta_{ji} - \theta_{jj}))/2 \quad (9)$$

As equation (9) shows, the symmetry parameters are equal to the log odds-ratio divided by 2, based on:

- the odds of mobility versus immobility in the origin category, and
- the odds of immobility in the destination category versus mobility.

Sobel, Hout and Duncan specify that additional restrictions will be required in order to estimate the skew symmetry parameters ζ_{ij} , but do not specify what these restrictions should be. Our evaluation is that the reasoning of the SHD symmetry parameters, comparing mobile cells with immobile cells, cannot be extended to a full set of interaction parameters or a skew symmetric component. On the face of it, the SHD symmetry and skew symmetry parameters could be derived by applying equation (7) to interaction parameters based on the contrast:

$$\beta_{ij} = ((\theta_{ij} - \theta_{ii}) + (\theta_{ji} - \theta_{jj}))/2 \quad (10)$$

Under equation (10), interaction effects will be the average of the log odds of mobility to origin i to destination j versus immobility in the origin i , and the log odds of mobility from j to i versus immobility in j . Additional $r-1$ restrictions will be required for equation (10), since only r parameters on the diagonal are dropped. The symmetry component of equation (10) is equal to the δ_{ij} parameters in equation (9), so the extra restrictions must be applied to the skew symmetry component. However, this means that $\zeta_{ij} = (\theta_{ij} - \theta_{ji})/2$, i.e. skew symmetric model parameters, to which any contrast can be applied.

The contrast used for the skew symmetry parameters can influence the perception of sources of asymmetric interaction. To illustrate this, we fitted a symmetry/skew symmetry loglinear model to table 1, using the deviation contrast and using the difference contrast. These models fit perfectly. A model of quasi-symmetry for table 1 has a likelihood ratio L^2 of 27.45 with 6 df and would be inadequate by the usual standards ($\text{prob}=.00012$). However, the large L^2 for a relatively unrestricted model is related to the large number of cases. The Bayesian Information Criterion⁷ (BIC) was proposed by Raftery (1986) as an alternative measure of fit in such situations. For a quasi-symmetry model, $\text{BIC}=-31.94$, which would imply that the skew symmetric interactions are small enough to be ignored.

Table 1
Intergenerational Occupational Mobility

Father's occupation	Son's first occupation				
	Upper non-manual	Lower non-manual	Upper manual	Lower manual	Farm
Upper nonmanual	1414	521	302	643	40
Lower nonmanual	724	524	254	703	48
Upper manual	798	648	856	1676	108
Lower manual	756	914	771	3325	237
Farm	409	357	441	1611	1832

From: Featherman and Hauser (1978)

Table 2a contains symmetric/skew symmetric parameters using the deviation contrast. These show high status inheritance for category 5 (farm) and 1 (upper nonmanual), and a much lower, uniform level of status inheritance for the other occupations. There is also a good deal of single step mobility between categories 1 and 2. Relative cell densities tend to become smaller as the distance from the diagonal increases. All skew symmetric parameter values are small.

Table 2
A comparison of symmetric parameters (upper triangle) and skew symmetric parameters (lower triangle), using two types of contrasts

Table 2a					Table 2b				
Deviation contrast					Difference contrast				
1.107	.387	-.063	-.398	-1.033					
.073	.432	-.049	-.054	-.716	.675	-.032	.330	-.116	
-.021	.053	.472	.070	-.430	.147	1.003	-.379	.162	
-.070	.070	-.034	.457	-.075	.068	-.051	.790	-.033	
.018	-.050	.066	-.034	2.163	.209	.220	.133	2.770	

Table 2b uses the difference contrast, so parameters can be interpreted as log odds-ratios. Although table 2a shows no substantial asymmetries, the skew symmetry parameters in cells (5,2) and (5,3) of table 2b are fairly large. The symmetry parameters together with the skew symmetry parameters indicate that in the 2 by 2 table of father lower manual or farm by son upper nonmanual or lower nonmanual, there is a strong negative negative association (-.325), but in the counterpart table in the upper triangle, the association is negligible (.093). Similarly, in the table of father lower manual or farm by son lower nonmanual or upper manual, there is strong positive association (.382), but again negligible association in the upper triangle counterpart (-.058).

Sobel's SDR model uses a nonlinear design to test whether the main effects of a model are unequal, but proportional. We decided to extend this principle to interaction effects, letting the interaction effect parameters in upper triangle of a table be a constant value times the parameters in the lower triangle (excluding the diagonal in both cases). The specification for the interaction effects is:

$$\omega_{ij} = (1+q)\beta_{ij}^{od} + (1-q)\beta_{ji}^{od} \quad (11)$$

with $r(r-1)/2$ identifiable symmetry parameters ω_{ij} , and 1 asymmetry parameter q . Parameters in the lower triangle will be $\frac{1+q}{1-q}$ times parameters in the upper triangle of the square table of interaction effects.

With q unknown, this is not a linear design, and we used PROC NLIN from SAS to estimate the parameters⁸ in a loglinear model, using the SHD parametrization for symmetric interaction parameters as parametrization for the ω_{ij} parameters. A proportional asymmetry model applied to table 1 had an L^2 of 11.753 with 5 *df*. The model has a BIC value of -37.74, so by Bayesian criteria it is preferable to the saturated model and the quasi symmetry model (BIC=-31.94).

Table 3
Full set of ω_{ij} parameters of the proportional asymmetry model
Model fit: $L^2=11.753$ with 5 *df*; BIC=-37.74
 $q=-.466$ (s.e.=.134)

Father's occupation	Son's first occupation				
	Upper non-manual	Lower non-manual	Upper manual	Lower manual	Farm
Upper nonmanual	0	-.163	-.426	-.614	-1.333
Lower nonmanual	-.448	0	-.223	-.261	-1.092
Upper manual	-1.170	-.612	0	-.204	-.898
Lower manual	-1.685	-.716	-.560	0	-.754
Farm	-3.658	-2.998	-2.465	-2.068	0

The interaction effect parameters ω_{ij} , based on q and β_{ij} parameters using the SHD contrast, are presented in table 3. The q parameter is significant, with a value of -.465 and a standard deviation of .134. The fact that q is negative means that for table 1, downward mobility is more likely than upward mobility. Parameters in the lower triangle of table 3 are $\frac{1+q}{1-q} = 2.745$ times parameters in the upper triangle. This means that the log odds-ratios of upward types of mobility with the two referent immobility cells are 2.745 times the log odds-ratios of their downward mobility counterparts.

Notes

¹ Hope (1971, 1975) argued that (in ANOVA mobility analysis) these effects constitute a form of mobility effects that were disregarded in previous work. The disparate effects of origin and destination can be substantively interesting, but they are certainly distinct from mobility effects as measured by the interactions.

² If two models are equivalent, then their parameters $\beta_{(1)}$ and $\beta_{(2)}$ can be expressed in terms of each other using a transformation matrix T . This can be seen by:

$$\begin{cases} \beta_{(1)} = C_{(1)}\theta \\ \beta_{(2)} = C_{(2)}\theta \end{cases}$$

We can write $\theta = C'_{(1)}(C_{(1)}C'_{(1)})^{-1}\beta_{(1)}$, which means that

$$\begin{aligned} \beta_{(2)} &= C_{(2)}C'_{(1)}(C_{(1)}C'_{(1)})^{-1}\beta_{(1)} \\ \beta_{(2)} &= T\beta_{(1)} \end{aligned}$$

Where $T = C_{(2)}C'_{(1)}(C_{(1)}C'_{(1)})^{-1}$. If the models are equivalent, T can also be derived from the design matrices, since in that case:

$$\begin{aligned} X_{(1)}\beta_{(1)} &= X_{(2)}\beta_{(2)} \\ \beta_{(2)} &= (X'_{(2)}X_{(2)})^{-1}X'_{(2)}X_{(1)}\beta_{(1)} \end{aligned}$$

If the models are indeed equivalent, T will transform the parameters exactly. If the models are not equivalent but the design matrices have the same number of columns, then $T = (X'_{(2)}X_{(2)})^{-1}X'_{(2)}X_{(1)}$ can still be solved, but T will not accurately transform the parameters.

³ Sobel referred to the model as the simple diagonal mobility model. De Graaf and Ganzeboom (1990) suggested the name "diagonal reference model" to avoid confusion with Goodman's loglinear diagonal models for frequency table mobility analysis. A more extensive discussion of the SDR model is in Hendrickx et al. (1991).

⁴ We found that diagonal reference models are easy to specify using NLR by SPSS. Starting values may be arbitrary and derivative functions do not have to be specified (when a normal distribution is assumed).

⁵ The term "skew symmetry" refers to the property of a matrix that satisfies $A' = -A$ (Yamaguchi, 1990: 186). This property distinguishes skew symmetry designs from restricted designs (e.g. Goodman's 1979 RC-1 model) that are simply asymmetric.

⁶ Equation (9) generates a different design matrix from that specified in Sobel, Hout and Duncan (1985). It gives the same interaction parameters, but different overall and main effect parameters.

⁷ BIC can be approximated in large samples by $L^2\text{-}df\log(n)$. A model with a negative BIC value is preferable to the saturated model. In a comparison of several models, the model with the lowest BIC is the preferred model.

⁸ The SAS/STAT User's Guide, Volume 2: 1168-1175 and the program GLIM SAS in the SAS sample library show how to emulate the GLIM program using PROC NLIN. This makes it possible to incorporate nonlinear predictors in a model using link functions and error distributions. Chapter 11 contains a discussion of the program structure and several examples of nonlinear designs in GLM-type models.

Chapter 7

Design Matrix Techniques for Generalized Linear Models and their Applications to Mobility Models

Abstract

Restrictions must be placed on the parameters of categorical independent variables in order to achieve identification. This can be done by specifying a contrast matrix, which specifies identifiable parameters as linear combinations of model parameters. The choice of contrast determines the meaning of the parameters, i.e. in what sense they are relative. The process can be repeated with a reparametrization matrix, which expresses restricted parameters as linear combinations of present identifiable parameters. This technique enables the specification of restricted designs using generalized linear models, in order to test for patterns of effects/ association that correspond with substantive interests of the researcher.

Mobility models are examples of modelling strategies aiming at pattern seeking. Restrictions have typically been imposed using techniques that can be seen as practical shortcuts to the formal method of specifying a reparametrization matrix, but which fail if the restrictions become more complex. Also, these models often neglect to distinguish between restrictions imposed to achieve identification and restrictions imposed on substantive considerations. In some cases this results in model indeterminacy.

The first paragraph contains a discussion of contrasts in relation to generalized linear models. The following paragraph discusses mobility models, and the special aspects of design they address. This is followed by an examination of how models that are stated in terms of log odds-ratios can be interpreted in terms of restricted designs with the so-called difference contrast, and how this clarifies certain model indeterminacies. Two alternative design approaches are then presented, both based on the so-called deviation contrast (the usual restrictions). The first design approach, the levels restriction, imposes equality restrictions on interaction parameters (which still sum to zero). The second approach, the distance restriction, fixes the increase of parameters per step away from the diagonal to equal values (under the constraint that they sum to zero).

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The uses of contrasts for specifying parameters of categorical independent variables in generalized linear models

A generalized linear model for the dependent variable Y , involving n cases and m parameters, solves the equation

$$\eta = X\beta \quad (1)$$

where η is an n by 1 matrix of predicted values, X is a n by m design matrix and β is a m by 1 matrix of parameters. The expected value of Y is a function of η : $E(Y) = \mu$, the predicted value under the model, and $\eta = g(\mu)$. For example, the link function g is an identity function for an analysis of variance model, a log function for a loglinear model. Maximum likelihood estimates are found for β , under the assumption that Y has a particular distribution. An analysis of variance model is assumed to have a normal distribution, a loglinear model is assumed to have a poisson distribution (McCullagh & Nelder 1983).

The design matrix X is based on factors (categorical independent variables) and covariates (continuous independent variables) that are assumed to affect the dependent variable Y . The columns of the design matrix for covariates correspond with the values of the covariate variable and do not present any special difficulties. The design vectors for factors do give special problems however, because of the necessity of applying restrictions to the parameters pertaining to these factors in order to identify the model.

A model of the effects of two or more factors on a dependent variable contains an overall effect, a contribution to the predicted value m for each category of each factor separately, and a contribution to m for each combination of all factors. A mathematical rendition of the verbal model for the relationships between categorical independent variables and η can be written as:

$$\eta = A\theta \quad (2)$$

where A is the *model matrix* and θ is a vector of model parameters, with a parameter for an overall effect, for each category of each factor separately, and for all combinations of all factors. It stands to reason that all these effects must be in relative, rather than absolute terms¹. In order to do this, a *contrast matrix* C is specified, which expresses the identifiable parameters β as linear combinations of the original parameters θ , such that $\beta = C\theta$ (Finn 1974: 219-250; Bock 1975: 239-269; Lammers 1984: 232-252). With C known, a full rank design matrix X can be derived² from the model matrix A .

TYPES OF CONTRASTS

The most widely used contrast is the *deviation contrast*. The deviation contrast specifies that the value of an identifiable parameter β as the deviation from the average of the model parameters. For the main effects of factor a with k categories, β can be specified as:

$$\beta_i^a = \theta_i^a - \frac{1}{k} \sum_{i=1}^k \theta_i^a = \theta_i^a - \theta^a \quad (3)$$

This means that the values of β have an average of zero, so that one β parameter is redundant: it can be found afterwards by taking the negative sum of the other parameters. An arbitrarily chosen parameter is omitted in the contrast matrix and therefore in the design matrix; it can be calculated afterwards³.

For a second degree interaction⁴ effect, an identifiable parameter has the value of the model parameter, minus the average model parameters for the first factor, minus the average model parameters for the second factor, plus the overall average of the model parameters:

$$\beta_{ij}^{ab} = \theta_{ij}^{ab} - \theta_i^{ab} - \theta_j^{ab} + \theta^{ab} \quad (4)$$

For factors a and b with k and l categories respectively, $k + l - 1$ parameters are redundant.

The deviation contrast has as the desirable property that it provides information on all categories of the factors. Since parameters are made to be relative to their own average, it involves no choices of an arbitrary nature. It has the disadvantage that restrictions on any parameter(s) will affect all other parameters, and that placing restrictions on redundant parameters is relatively difficult (see also below).

Another often used contrast is the *simple contrast*. In this contrast, a particular category of the factor is chosen as a point of reference. The identifiable β parameter for a category of a factor expresses the difference between θ for that category and θ for the contrast category. So if category c of factor a is the contrast category,

$$\beta_i^a = \theta_i^a - \theta_c^a, c \neq i \quad (5)$$

The design matrix based on the simple contrast is equivalent to the design matrix based on dummy variables, where the dummy variable for a category has been dropped to achieve identification. This is often used for programming expedience when only the model fit and not the parameters themselves are the focus of interest. A simple contrast can of course also be substantively interesting in many applications. Parameters have a straightforward meaning, and restrictions can be applied without special difficulties.

The *difference contrast* compares the model parameter of a category of a factor with that of the previous (or alternatively, the next) category. It is therefore of particular interest when the factor is of ordinal measurement level, and in situations where changes are being analyzed. For the main effects of factor a , β would be specified as:

$$\beta_i^a = \theta_i^a - \theta_{i-1}^a, i = 2 \text{ to } k \quad (6)$$

The difference contrast is particularly interesting when used for an interaction effect. In that case, the contrast becomes:

$$\begin{aligned} \beta_{ij}^{ab} &= (\theta_{i+1,j+1}^{a,b} - \theta_{i+1,j}^{a,b}) - (\theta_{i,j+1}^{a,b} - \theta_{i,j}^{a,b}) \\ &= (\theta_{i+1,j+1}^{a,b} - \theta_{i,j+1}^{a,b}) - (\theta_{i+1,j}^{a,b} - \theta_{i,j}^{a,b}) \\ &= (\theta_{i,j}^{a,b} + \theta_{i+1,j+1}^{a,b}) - (\theta_{i+1,j}^{a,b} + \theta_{i,j+1}^{a,b}) \end{aligned} \quad (7)$$

Interaction effect parameters now indicate "differences between differences", i.e. the row-wise difference between the column-wise differences in consecutive model parameters or equivalently, the column-wise difference between the row-wise differences in model parameters. The attractive point about this parametrization is that when frequency data are used in a loglinear model, the interaction parameters are equal to the log odds-ratios. Many special purpose loglinear models are based on the log odds-ratio and can be seen as restricted versions of a model using the difference contrast. Because they give a measure of net change, interaction effect parameters using the difference contrast could be useful for other types of generalized linear models as well.

A final contrast type we would like to mention is the *orthogonal polynomial contrast*. This parametrization can be used when factors have a suitable interval character. The first β parameter for a factor measures a linear response, the second a quadratic response, etc. Y is described in terms of a $k-1$ order polynomial function of a factor with k levels.

A following step is to make the design matrix orthogonal, i.e. cause the column vectors to be perpendicular to each other, which means that parameter estimates will be uncorrelated. In terms of a contrast matrix, this can be done by creating a matrix in which the identifiable parameters are polynomial functions of the model parameters, then making it row-wise orthogonal. The design vectors will now not only be perpendicular to each other, they will also have a length of 1. In other cases, tables giving the orthogonal design matrices for different numbers of categories are used (e.g. Bock 1975: Appendix B). The columns of these design matrices have been multiplied by a constant so that the entries are integers, in order to facilitate their entry in computer programs.

ADDING SPECIAL RESTRICTIONS

The procedure described above, of specifying a contrast matrix in order to transform the (unidentifiable) model parameters θ into identifiable parameters β , can of course be repeated. This can be done in order to impose linear constraints among the β parameters, the most common of which will be that parameters have equal values. If γ is the q by 1 ($q \leq m$) matrix of restricted parameters, then restrictions can be imposed on the β parameters using a reparametrization matrix R , such that $\gamma = R\beta$. With R , the design matrix can be transformed to estimate γ .

An identifiable parameter can be fixed to the value of zero by simply dropping the parameter from the model: either by removing the corresponding row of the contrast matrix or by removing the corresponding column of the design matrix. An equality constraint between two identifiable parameters can be imposed by specifying a new γ parameter which has the average value of the two β parameters. An alternative method that is often more practical is to add the columns of X corresponding with the two parameters. The operation is more logical when treated in terms of a reparametrization matrix however, and this method is also more general.

Special models for square tables

A number of special models have been developed for the analysis of square tables. These occur in research on differences between identical scales, such as mobility analysis (changes in status, usually between generations), homogamy analysis (differences in status between marriage partners), endogamy analysis (different group memberships of marriage partners). There are two general types of square table analysis:

- (1) The analysis of magnitude and patterns of differences in scores on the row and column variables. The hypothesis is that social forces restrict the occurrence of certain combinations of categories of the row and column variables, and stimulate others. Whether this is the case and, if it does occur, what patterns of differences exist can be ascertained using loglinear models on square frequency tables.
- (2) The analysis of the effects of differences in scores on the row and column variables on a dependent variable, e.g. the effect of intergenerational occupational mobility on voting behavior. The hypothesis is that persons in off-diagonal "mobile" cells score substantially differently on the dependent variable than persons in diagonal "immobile" cells.

Analysis of variance on a square table of means is the most common type of model for this kind of analysis, although a logit model could also be applied.

In both types of analysis, the marginals of the table are a potentially disturbing element. In the frequency table case, the marginals contain the distributions of the row and column variables, independently of each other. The relative size of each category determines the cell frequency that can be expected, in the absence of social forces that constrain the occurrence of certain combinations. The relative sizes of the row and column variable categories are modelled in the main effects of a loglinear model. Significant interaction of the row and column variable shows that social forces are indeed present.

When a dependent variable is being used, the marginals of a square table of means contain the association of the row and column variables with the dependent variable, independently of each other. Opposed to the hypothesis that difference in scores on the row and column variables affects the dependent variable, is an explanation simply in terms of the row and column variables. An expected value for each cell can be derived from the marginals, the row-wise and column-wise average scores on the dependent variable. Again, the main effects of the analysis of variance model contains the independent, additive influence of the row and column variable, while interaction effects contain the substantively interesting surplus effects of being in different categories of the row and column variables.

Although the analysis of square frequency tables and the analysis of square means tables are two entirely different issues, the same basic modelling strategy apparently applies to both. In either case, the purpose is to prove that cell values are "special", and this is done by comparing (through the use of the interaction parameters) the observed cell value with an expected value derived from the marginals, and expressed in the main effects. Further common points of interest in the two types of square table analysis are the amount of equality/difference in the main effects, symmetry/asymmetry of the interaction effect parameters, and restricted interaction effect designs in order to express patterns of cell values.

The matters of equality/difference of the main effects and symmetry/asymmetry of interactions are discussed in chapter 6, a companion piece to this which is available on request. In the following section we will discuss special interaction effects and the relevance of specifying contrasts and reparametrizations for these designs.

RESTRICTED DESIGNS FOR THE INTERACTION EFFECT

In many analyses, the detection of association between two factors, or of a significant interaction of the effects of two factors on the dependent variable is the total purpose of the analysis. In mobility research, it is followed by an attempt to describe the association more parsimoniously. One argument for the analysis of variance case, is that interactions could also be due to measurement errors or flawed data, and that a meaningful pattern of interactions is necessary before the conclusion can be drawn that differences between row and column scores do indeed affect behavior (Duncan, 1966). For both types of analysis, the fact that the scales are ordered can be used to develop predictions on the patterns of changes, e.g. that small changes are more likely than large changes, so that possibly parameters further from the diagonal of the table can be expressed in terms of parameters closer to the main diagonal. Development of special designs for loglinear analyses has received the most attention (especially by Goodman; Goodman (1984) contains many of his most relevant articles) and has been more systematic, so the following will focus primarily on these. An overview of

these designs is given by Hout (1983). Many designs for loglinear tables could also be meaningfully used in mobility research with a dependent variable, however.

There have been subtle shifts in the strategy used by the loglinear analysis of mobility tables. The earliest models tried to explain association as an exception, e.g. by fitting structural zeros on the main diagonal of the table, in the quasi-independence model. Later models tried, if association had been found, to describe it more parsimoniously, using fewer parameters. This coincided with the availability of faster computers with greater capacities, which were able to handle programs based on a design matrix such as GLIM, rather than loglinear programs based on the iterative proportional fitting algorithm (IPF) such as ECTA. The first type of model can also be fitted using design techniques, thus increasing their flexibility. However, we are primarily interested in the second type of model, which aims to describe association in parsimonious terms, rather than explain it as exceptional⁶.

Unfortunately, contrasts, their implications, and the methods of reparametrization in order to derive restricted designs from more general ones, have been neglected in the development of mobility models. Designs are usually developed in terms of a restricted *model* matrix, which is often developed by specifying constraints for subsets of model parameters. One of the subsets is then used as a contrast category and set to zero. Thus no distinction was made between restrictions implemented on substantive grounds, and restrictions that are required for identification of the model. Because of this, the meaning of parameters is unclear and can shift with any modification of the model. Furthermore, model expansion or contraction must often stop at a certain, arbitrary point. The most important problem however is model indeterminacy: models with apparently different implications can turn out to be equivalent.

A well known example of this problem is Featherman and Hauser's (1978) loglinear levels model. They fit a model with five interaction effect model parameters (i.e. without identification restrictions) according to the pattern in table 1a. Subsets of interaction effect model parameters were restricted to equal values on the basis of empirical considerations. For the model estimation, one of the levels is made redundant, by specifying that the sum of the levels parameters is zero or by choosing a level as a contrast category. Four interaction effect parameters are estimated, compared to the sixteen possible interaction effect parameters in the saturated model.

The problem is that alternative levels models with ostensibly disparate substantial implications turn out to be mathematically equivalent models (MacDonald 1981; Pöntinen 1982; also in Hout 1983: 37-51). This is illustrated in table 1b by the alternative design given by Pöntinen, which seems to be a totally different model, but is equivalent to the design in

Table 1a
Design for Featherman &
Hauser's levels model

2	4	5	5	5
3	4	5	5	5
5	5	5	5	5
5	5	5	4	4
5	5	5	4	1

Table 1b
Alternative design by Pöntinen
(1982: 94)

2	4	4	5	5
3	4	4	5	5
5	5	4	5	5
5	5	4	4	4
5	5	4	4	1

table 1a: the predicted values and goodness of fit statistics of both designs are identical.

Goodman (1979) showed that, for row and column factors with ordered categories, the problem of equivalent models could be dealt with by restating the restricted designs for interaction effects in terms of patterns of (log) odds-ratios, thus distinguishing unique designs from equivalent ones. We noted above that if the difference contrast is used for interaction effects, the parameters are equal to the log odds-ratio of the 2 by 2 subtables that compose the frequency table. By imposing restrictions on these parameters, existing models can be derived. Two well known examples of models that can be meaningfully restated in terms of log odds-ratios are the crossings parameter model and the class of association models, such as the uniform association model and the row and column model I. In the following two paragraphs, we will discuss how treating these models as restricted designs using the difference contrast for the interaction effect parameters clarifies some paradoxical aspects of these models, and points the way to alternatives, if these models do not fit the data.

The crossings parameter model

The crossings parameter model is a restricted type of symmetrical interaction. The reasoning behind it is that, for row and column factors with ordered categories, small changes (short distance mobility) are more likely than large changes (long distance mobility). The interaction effect model parameters are therefore restricted to make them increase in a regular pattern as they progress further away from the diagonal. The restricted interaction effect parameters γ_{ij}^{ab} for the crossings parameter model are defined as:

$$\begin{aligned}\gamma_{ij}^{ab} &= 0 \text{ for } i = j \\ &= \sum_{s=j}^{i-1} v_s, \text{ for } i > j \\ &= \sum_{s=i}^{j-1} v_s, \text{ for } i < j\end{aligned}\tag{8}$$

The parameters v_s , $s = 1$ to $r-1$ are the identifiable parameters for an interaction effect with the crossings parameter model. This is a rather highly restricted model and there are of course no identification problems. A formal weakness of this modelling approach is that it has not been made clear which restrictions have been implemented in order to achieve identification and which have been implemented for substantive reasons.

Table 2a shows the interaction effect pattern imposed by the crossings parameter model.

Table 2a
Model parameters of the crossings parameter model

0	v_1	v_1+v_2	$v_1+v_2+v_3$	$v_1+v_2+v_3+v_4$
v_1	0	v_2	v_2+v_3	$v_2+v_3+v_4$
v_1+v_2	v_2	0	v_3	v_3+v_4
$v_1+v_2+v_3$	v_2+v_3	v_3	0	v_4
$v_1+v_2+v_3+v_4$	$v_2+v_3+v_4$	v_3+v_4	v_4	0

Problems occur with the crossings parameter model when it must be extended. Since it is not a restricted version of a saturated or quasi-symmetrical model, it is not possible to simply relax restrictions.

A crossings parameter model is extended to a quasi-crossings model by fitting additional parameters to the diagonal cells. The difficulty is that a full set of diagonal parameters cannot be added to the crossing parameter model, because it already exactly fits the upper left and lower right diagonal cells. The quasi crossings parameter model therefore requires extra restrictions which will often be at odds with substantive considerations. One restriction is to fit diagonal parameters for all diagonal cells except the upper left and bottom right cells (Goodman 1972):

$$\begin{aligned}
 \theta_{ij}^{ab} &= 0 \text{ for } i=j, \text{ if } i=1 \text{ or } i=r \\
 &= d_i \text{ for } i=j, \text{ if } 1 < i < r \\
 &= \sum_{s=j}^{i-1} v_s \text{ for } i > j \\
 &= \sum_{s=i}^{j-1} v_s \text{ for } i < j
 \end{aligned} \tag{9}$$

See the table 2b for this design.

Table 2b
Model parameters of a quasi crossings parameter model using equation (9)

0	v_1	v_1+v_2	$v_1+v_2+v_3$	$v_1+v_2+v_3+v_4$
v_1	d_1	v_2	v_2+v_3	$v_2+v_3+v_4$
v_1+v_2	v_2	d_2	v_3	v_3+v_4
$v_1+v_2+v_3$	v_2+v_3	v_3	d_3	v_4
$v_1+v_2+v_3+v_4$	$v_2+v_3+v_4$	v_3+v_4	v_4	0

Alternatively, restrictions could be placed on the crossings parameters and a full set of diagonal parameters can then be estimated (Haberman 1979):

$$\begin{aligned}
 \theta_{ij}^{ab} &= d_i \text{ for } i=j \\
 &= \sum_{s=j}^{i-1} v_s \text{ for } i > j \\
 &= \sum_{s=i}^{j-1} v_s \text{ for } i < j, \text{ where } v_1 = v_2 \text{ and } v_{r-1} = v_r
 \end{aligned} \tag{10}$$

The design for this model is given in table 2c.

Equation (9) and equation (10) seem to have very different substantive implications. Equation (9) implies that there is no unique immobility in the highest and lowest categories - immobility there is due to status barriers rather than intrinsic immobility. Equation (10) implies that there is intrinsic immobility in each category, but that the barriers between the highest and second highest category is equal to that between the second highest and third highest,

Table 2c
Interaction effect parameters of a quasi crossings parameter model using equation (10)

d_1	v_1	$2v_1$	$2v_1+v_2$	$2v_1+2v_2$
v_1	d_2	v_1	v_1+v_2	v_1+2v_2
$2v_1$	v_1	d_3	v_2	$2v_2$
$2v_1+v_2$	v_1+v_2	v_2	d_4	v_2
$2v_1+2v_2$	v_1+2v_2	$2v_2$	v_2	d_5

and that the barriers between the lowest and second lowest categories is also equal to that between the third lowest and second lowest - rather dubious and arbitrary restrictions.

As it turns out, equation (9) and equation (10) are equivalent models. Table 3a shows the log odds-ratios of a crossings parameter model; tables 3b and 3c contain the log odds-ratios of both quasi-crossing parameter versions. Both table 3b and table 3c contain unique values on each of the diagonal cells of the table of log odds-ratios and symmetrical values on the subdiagonals. The crossings parameter model itself contains unique values on the diagonal only.

The quasi-crossings parameter model shows even more clearly than the levels model the pitfalls of developing a model in terms of unidentifiable *model* parameters, instead of identifiable parameters using a predetermined contrast, whose meaning is therefore clear. An alternative course would be to reparametrize the design matrix for symmetrical interaction with the difference contrast, fixing all off-diagonal parameters to zero for a model equivalent to the crossing parameter model, and fixing parameters on the second and higher diagonals to zero for models equivalent to the quasi-crossings parameter models.

Seen in terms of a restricted model using the difference contrast, the CP restrictions imply that origin status affects the likelihood of status inheritance versus single step mobility. However, there is no association between origin and destination statuses at one or more removes from each other. The QCP restriction modifies this to allow for association between origin and destination statuses at a single remove from each other.

Interaction parameters with the difference contrast are relatively complex, but have a distinct meaning which is relevant for many substantive applications. Also, a model based on an interaction effect with this

Table 3a
log odds-ratios of a crossings parameter model

$-2v_1$	0	0	0
0	$-2v_2$	0	0
0	0	$-2v_3$	0
0	0	0	$-2v_4$

Table 3b
log odds-ratios of a quasi crossing parameter model using equation (9)

d_1-2v_1	$-d_1$	0	0
$-d_1$	$d_1+d_2-2v_2$	$-d_2$	0
0	$-d_2$	$d_2+d_3-2v_3$	$-d_3$
0	0	$-d_3$	d_3-2v_4

Table 3c
log odds-ratios of a quasi crossing parameter model using equation (10)

$d_1+d_2-2v_1$	$-d_2$	0	0
$-d_2$	$d_2+d_3-2v_1$	d_3	0
0	$-d_3$	$d_3+d_4-2v_2$	$-d_4$
0	0	$-d_4$	$d_4+d_5-2v_2$

contrast can be expanded or restricted at will, without ambiguity as to its interpretation. If freeing the (symmetrical) parameters of one subdiagonal does not adequately improve the model fit, then the restrictions on the parameters of the next subdiagonal can be removed, etc until the quasi-symmetry model is reached. Or alternatively, the restriction that interaction effect is symmetrical can be removed and the model can be expanded on these lines.

Association models: uniform association and the row and column model I

The uniform association model tests for linear by linear interaction. Substantively, this model is based on the hypothesis that each further step of mobility becomes increasingly difficult. The interaction effect of a uniform association model is:

$$\theta_{ij} = i \cdot j \cdot u \quad (11)$$

where i is the row variable index, j is the column variable index and u is the uniform association parameter to be estimated.

Table 4
Design of the uniform association model

u	$2u$	$3u$	$4u$	$5u$
$2u$	$4u$	$6u$	$8u$	$10u$
$3u$	$6u$	$9u$	$12u$	$15u$
$4u$	$8u$	$12u$	$16u$	$20u$
$5u$	$10u$	$15u$	$20u$	$25u$

The model design of a uniform association model is given in table 4. As table 5 shows, this results in a constant log odds-ratio for the entire table. The uniform association model can be regarded in terms of contrasts in two ways. One way of looking at it is as a model using the difference contrast for the interaction effect, with all parameters constrained to equal values. Alternatively, it can be seen as the result of an interaction term using the polynomial contrast, but with all parameters but those for first order

by first order, set to zero. This second method is of rather formal interest only, since interaction effects of higher order polynomials by higher order polynomials will be rather abstract and difficult to interpretate.

If the uniform association model does not fit the data well (and this is all too likely to be the case, since it is a highly restricted model), then an obvious way to extend it is to let the uniform association parameter vary with rows, with columns, or with both. We will discuss the latter type (row and columns effects model type I), since the rows version and columns version are submodels of this model.

The row and column effects model I (RCI) extends the notion that the uniform association model consists of linear by linear interaction. Parameters are added for linear effects within

each row category and within each column category. Restrictions are necessary however, and often the linear effect parameters of the first and last categories of rows and columns are set to zero. As was the case with Featherman & Hauser's levels model, other restrictions can be applied that result in equivalent models, but with apparently very different substantive implications (De Graaf 1985). The RC-I model is:

Table 5
log odds-ratios of the uniform association model

u	u	u	u
u	u	u	u
u	u	u	u
u	u	u	u

$$\theta_{ij}^{ab} = i \cdot j \cdot u + j \cdot v_i + i \cdot w_j, \text{ where}$$

u is the uniform association parameter,

v_i is the row effects parameter, $v_1 = v_r = 0$,

w_j is the column effects parameter, $w_1 = w_c = 0$

(12)

This model design is clarified in table 6; table 7 shows the pattern of odds-ratios that results. What appear to be arbitrary and undesirable restrictions on the row and column effects parameters in equation (12) turn out to be quite meaningful in terms of log odds-ratios in table 7. The row and column model I simply examines whether the log odds-ratios are an additive function of the row and column averages of the table of log odds-ratios. Each cell of the table of log odds-ratios is now an additive function of an overall parameter (u), a row parameter ($v_i - v_{1,i}$; $i=2$ to r , $v_1 = v_r = 0$) and a column parameter ($w_j - w_{1,j}$; $j=2$ to r , $w_1 = w_r = 0$). In terms of difference contrast parameters, the model would be reparametrized to give an overall effect, and row and column parameters with a sum of zero.

Table 6
Design of the row and column effects model I

u	$2u + w_2$	$3u + w_3$	$4u + w_4$	$5u$
$2u + v_2$	$4u + 2v_2 + 2w_2$	$6u + 3v_2 + 2w_3$	$8u + 4v_2 + 2w_4$	$10u + 5v_2$
$3u + v_3$	$6u + 2v_3 + 3w_2$	$9u + 3v_3 + 3w_3$	$12u + 4v_3 + 3w_4$	$15u + 5v_3$
$4u + v_4$	$8u + 2v_4 + 4w_2$	$12u + 3v_4 + 4w_3$	$16u + 4v_4 + 4w_4$	$20u + 5v_4$
$5u$	$10u + 5w_2$	$15u + 5w_3$	$20u + 5w_4$	$25u$

The overall parameter u indicates the average association in the table, the difference of the log odds of no change versus a one step change in two adjacent categories of the row factor on the one hand, and the log odds of no change versus one step change in two adjacent categories of the column factor on the other. The row parameter indicates how the log odds of the related one step change of column score deviates, averaged over all types of single step row score changes. Likewise, a column parameter indicates how the log odds of the related single step change of row score deviates, averaged over all types of single step column row changes. The only assumption the model makes, is that the log odds ratios are indeed additive, i.e. that the deviation from the average association of any log odds of row category change, is inde-

Table 7
log odds-ratios and their row and column averages, for the row and column effects model I

$u+v_2+w_2$	$u+v_2+(w_2-w_1)$	$u+v_2+(w_3-w_1)$	$u+v_2-w_4$	v_2
$u+(v_3-v_2)+w_2$	$u+(v_3-v_2)+(w_3-w_2)$	$u+(v_3-v_2)+(w_4-w_3)$	$u+(v_3-v_2)-w_4$	v_3-v_2
$u+(v_4-v_2)+w_2$	$u+(v_4-v_2)+(w_3-w_2)$	$u+(v_4-v_2)+(w_4-w_3)$	$u+(v_4-v_2)-w_4$	v_4-v_2
$u-v_4+w_2$	$u-v_4+(w_3-w_2)$	$u-v_4+(w_4-w_3)$	$u-v_4-w_4$	$-v_4$
w_2	w_3-w_2	w_4-w_3	$-w_4$	u

pendent from the deviation from the average of all column category changes. For example, the log odds of son being lower nonmanual versus son being a farmer might be relatively high, but the difference between this log odds for father is higher nonmanual versus lower nonmanual would be equal to the difference for father is lower nonmanual versus higher manual.

IMPOSING RESTRICTIONS ON PARAMETERS WITH THE DEVIANCE CONTRAST

The deviation contrast for a single factor lets the parameters indicate the difference between the corresponding model parameter and the average of the model parameters; in the case of an interaction effect, the parameter for cell ij corresponds with the model parameter for ij , minus the average of the model parameters for which the row factor is i , minus the average of the model parameters for which the column factor is j , plus the average of the model parameters. Because of this, the parameters have a sum of zero and one of the parameters for the factor is redundant: it can be found by taking the negative sum of the remaining parameters. Interaction parameters form a table in which all rows sum to zero and all columns sum to zero: the parameters for any row and any column can be omitted and derived from the non-redundant parameters after these have been estimated.

The deviation contrast will often be the contrast of choice, since it does not require the arbitrary omission of particular parameters and does not assume any order among categories. A full set of parameters is procured, in accordance with the original model formulation. In some cases however, it may be desirable to impose added restrictions, e.g. to restrict parameter values to zero or to impose an equality constraint on a set of parameters. The full set of interaction parameters can be too large to interpret, or differences between parameters can be too small to be considered substantial, making a more parsimonious model desirable.

As noted above, a zero value constraint can be imposed on any identifiable parameter by deleting the row corresponding with that parameter from the contrast matrix or, equivalently, by deleting the column corresponding with the parameter from the design matrix. An equality constraint between two identifiable parameters can be imposed by replacing the row of the contrast matrix corresponding with one of the parameters by the average of the two rows, and deleting the row corresponding with the other parameter. It can be shown that adding the column of the design matrix corresponding with one of the parameters to the second parameter's design vector, then deleting the first parameter's design vector, is an equivalent method.

Placing a constraint on a redundant parameter is not so straightforward however: these parameters must be manipulated by indirect means. We worked out the rules for imposing these restrictions by altering the design matrix, since this method will often be more practical than specifying a reparametrization matrix⁷. The rules for several basic types of restrictions are:

- (1) **A zero value constraint on an identifiable parameter:** Delete the design vector corresponding with that parameter.
- (2) **A zero value constraint on a redundant parameter:** The redundant parameter can be derived from a set of the identifiable parameters, since their sum is zero. Choose one of the identifiable parameters and subtract its design vector from the design vectors of the remaining parameters by which the redundant parameter is composed, then delete that design vector. The value for the parameter that was chosen can be found from the negative sum of the remaining identifiable parameters.

- (3) **An equality constraint between two identifiable parameters:** Add the design vector of one of the identifiable parameters to that of the second, then delete the first design vector.
- (4) **An equality constraint between a redundant parameter and an identifiable parameter in its composition:** Subtract $\frac{1}{2}$ times the column of the identifiable parameters design vector from the design vectors of the other parameters used to derive the redundant parameter, then delete it. The values for the constrained parameters can be found from the negative sum of the identifiable parameters, divided by 2.
- (5) **An equality constraint between a redundant parameter and an identifiable parameter that is not in its composition:** Subtract the identifiable parameter's design vector from the design vectors of the identifiable parameters that compose the redundant parameter, then delete it.
- (6) **An equality constraint between two redundant parameters:** Select an identifiable parameter that composes one of the two redundant parameters. Subtract its design vector from the design vectors of parameters used to derive that redundant parameter. Add it to the design vectors of parameters that derive the other redundant parameter, then delete it from the design matrix.

Adding multiple restrictions in this manner turns out to be a complicated task, because for each following restriction, the redundant parameters and the composing parameters have changed, and new restrictions can (partially) undo previous ones if not done properly.

A solution to this problem is to redefine the contrast matrix to let parameters on which restrictions will not be placed, be the redundant parameters whenever possible, under the rule that one parameter from each row and each column must be redundant. In chapter 2 on religious assortative marriage, we were interested in whether outmarriage rates for certain combinations of religious denominations were equal, and less so whether or not the inmarriage propensities for certain denominations were equal. We had already found that a quasi-symmetry model fitted and wished to improve it by imposing equality restrictions on off-diagonal parameters. We redefined the contrast matrix for symmetrical interaction with the deviation contrast, with the redundant parameters on the diagonal. This results in a simple design matrix with $\frac{1}{2}r(r-1)$ design vectors X_k for symmetrical interaction parameters γ_{ij}^{ab} in the upper triangle of the *row* by *col* table, such that for $i=1$ to $r-1$ and $j=i+1$ to r , the design vector

$$\begin{aligned} X_k &= 1 \text{ if } (row=i \text{ and } col=j) \text{ or } (row=j \text{ and } col=i) \\ X_k &= -1 \text{ if } (row=i \text{ and } col=i) \text{ or } (row=j \text{ and } col=j) \end{aligned} \quad (13)$$

Equality restrictions on off diagonal parameters can be imposed by adding columns of the design matrix. Ideally, these restrictions will be devised a priori on the basis of theoretical considerations. Given the purely nominal character of our scales, we were unable to make sound predictions - in this case, we wanted a more parsimonious model in order to enhance the interpretability of our results. For most of the ten tables, a pattern could be discerned from the preliminary results from which, together with theoretical considerations, a restricted design could be derived.

Table 8
Religious assortative marriage in the Netherlands in 1973

	Re-Reformed	Reformed	other	none	Catholic
Re-Reformed	5954	1995	166	703	848
Reformed	2193	12416	459	2713	4032
other denomination	170	565	1421	575	822
no denomination	996	3555	581	17456	4823
Catholic	818	3598	494	3494	36644

The table for the year 1973 (table 8) presented special difficulties however, so we imposed our restrictions on statistical criteria only. We did this by fitting a model (using GLIM), examining the standard deviations for differences between parameters, imposing an equality restriction between parameters for which the T-value for the difference was lowest⁸. We repeated this until the fit of the model according to the BIC criterion no longer improved. The smallest difference between identifiable off-diagonal interaction parameters in each step, its standard deviation and T-value, and the effect of the equality restriction on L^2 , df and BIC, are detailed in table 9. Table 10a shows the full set of symmetrical interaction parameters from the starting model, while table 10b shows the final parameter values using the levels restriction.

Table 9
Results of a stepwise search for an optimal levels restriction on off-diagonal symmetrical interaction parameters with the deviation contrast, applied to table 8

Restriction	difference	SD of difference	T-value of difference	L^2	df	BIC
Starting model quasi-symmetry	—	—	—	19	6	-51
$\gamma_{24}^{ab} = \gamma_{25}^{ab}$	- 008	017	- 431	19	7	-62
$\gamma_{14}^{ab} = \gamma_{13}^{ab}$	- 066	.049	-1.365	21	8	-72
$\gamma_{24}^{ab} = \gamma_{25}^{ab} = \gamma_{34}^{ab}$	-.054	023	-2 379	27	9	-78
$\gamma_{35}^{ab} = \gamma_{23}^{ab}$	- 102	034	-3 042	36	10	-80
$\gamma_{14}^{ab} = \gamma_{13}^{ab} = \gamma_{15}^{ab}$	- 148	019	-7 610	94	11	-33

Table 10a
Symmetrical interaction parameters for table 8
using the deviation contrast
 $L^2=19$ with 6 df; BIC=-51

2.147	.164	-.741	-.676	-.894
.164	1.007	-.558	-.303	-.310
-.741	-.558	2.103	-.354	-.451
-.676	-.303	-.354	1.497	-.164
-.894	-.310	-.451	-.164	1.818

Table 10b
Symmetrical interaction parameters for table 8
using the deviation contrast and restricted to six
levels of outmarriage
 $L^2=36$ with 10 df; BIC=-80

2.139	.152	-.715	-.715	-.863
.152	.992	-.516	-.314	-.314
-.715	-.516	2.060	-.314	-.516
-.715	-.314	-.314	1.493	-.150
-.863	-.314	-.516	-.150	1.842

APPLYING A DISTANCE RESTRICTION TO PARAMETERS WITH THE DEVIANCE CONTRAST

In an earlier paragraph, we criticized the crossings parameter model for failing to discern between restrictions imposed on interaction effect parameters for substantive reasons and restrictions that are required for identification. We suggested that it would be preferable to think in terms of an equivalent model using the difference contrast, under the restriction that off diagonal parameters are zero. The basic idea of a crossings parameter model is intriguing however: that the relative frequency of mobility changes at a regular rate per step away from the diagonal of the table. We therefore wondered whether it might be implemented as a restriction on interaction parameters using the deviance contrast, rather than as a model as such.

Table 11
Father's occupation by son's first occupation

Father's occupation	Son's first occupation				
	Upper non-manual	Lower non-manual	Upper manual	Lower manual	Farm
Upper nonmanual	1414	521	302	643	40
Lower nonmanual	724	524	254	703	48
Upper manual	798	648	856	1676	108
Lower manual	756	914	771	3325	237
Farm	409	357	441	1611	1832

From: Featherman and Hauser (1978)

The fixed horizontal distance restriction

One way of doing this would be to impose a restriction on the deviation contrast parameters such that these would increase by a fixed amount with each horizontal step from the diagonal in the upper triangle of the table, and with each vertical step from the diagonal in the lower triangle of the table. Substantively, this would mean that for a mobility table such as table 11, that the relative frequency of mobility changes at a constant rate per step of downward mobility for a given origin class, and per step of upward mobility for a given destination class.

Table 12a
Full set of symmetrical interaction effect parameters using a fixed horizontal distance restriction on parameters with the deviation contrast

.869	.435	.000	-.435	-.869
.435	.297	.027	-.244	-.514
.000	.027	.525	-.009	-.542
-.435	-.244	-.009	.659	.028
-.869	-.514	-.542	.028	1.897

Table 12b
Identifiable parameters of a fixed horizontal distance restriction

-.435				
	-.270			
		-.533		
			-.630	

Table 12a shows a full set of symmetrical interaction parameters with this "fixed horizontal distance" restriction, using the data in table 11, while table 12b shows the identifiable parameters. The values in table 12a are symmetrical and sum to zero over both the rows and the columns. The parameters in the first row increase by -.435 with each step away from the diagonal, the parameters in columns 2 to 5 of the second row increase by -.270, etc. This fixed horizontal distance restriction had an L^2 of 313 with 12 df and a BIC value of 194, versus $L^2 = 27$ with 6 df and a BIC of -32 for a quasi-symmetry model. This restriction therefore does not constitute a good model for these data.

The fixed horizontal restriction can be implemented in two steps. The starting point is a design matrix for symmetrical interaction, with identifiable parameters σ_{ij} in the upper triangle of the table, and with the redundant parameters in the highest category. The first step is to reparametrize this design matrix to let new parameters γ_{ij} indicate the horizontal distance from the diagonal⁹:

$$\gamma_{ij} = \sigma_{i,j+1} - \sigma_{ij} \quad (14)$$

Reparametrizing the σ_{ij} parameters in this manner will not affect the fit of the model. This happens a second step, when v_{ij} parameters are defined which restrict the γ_{ij} parameters with the same row index to have the same value¹⁰:

$$v_{ij} = \frac{1}{r-i} \sum_{j=i}^r \gamma_{ij} \quad (15)$$

Using reparametrization matrices based on equations (14) and (15) and using the formulas for transforming a design matrix in note 5, a design matrix for symmetric interaction can be transformed into a design matrix for deviation contrast parameters with a fixed horizontal distance restriction. The GLIMMAT macros described in chapter 9 used in conjunction with SAS IML software can be very useful purposes such as this.

The fixed diagonal distance restriction

It would be fairly straightforward to create a model with a fixed vertical distance restriction. However, it is more interesting to combine the notions of the horizontal and the vertical distance restrictions in a fixed diagonal distance restriction. This restriction would force the deviation contrast parameters to increase by a certain amount for each step in the diagonal direction from the main diagonal.

Table 13a
Full set of symmetrical interaction effect parameters using a fixed diagonal distance restriction on parameters with the deviation contrast

1.285	.235	-.140	-.346	-1.034
.235	.570	-.134	-.324	-.346
-.140	-.134	.548	-.134	-.140
-.346	-.324	-.134	.570	.235
-1.034	-.346	-.140	.235	1.285

Table 13a shows what the full set of deviation contrast parameters would look like after imposing a fixed diagonal distance restriction. The parameters are symmetric across the bottom left to upper right diagonal, as well as across the upper left to bottom right diagonal. The difference between a vertical step and a horizontal step has been used as a measure of diagonal distance, and the values of the identifiable fixed diagonal distance parameters are given in table 13b. Note that this model had a very poor fit: $L^2 = 1205$ with 12 df, and a BIC of 1086.

Table 13b
Identifiable parameters of a fixed diagonal distance restriction

-1.386	-.380	-.229	-1.375
--------	-------	-------	--------

To implement this restriction, the σ_y parameters are first reparametrized into diagonal distance parameters γ_y , which indicate the difference between a vertical and a horizontal step¹¹:

$$\begin{aligned}\gamma_y &= (\sigma_{i,j+1} - \sigma_y) - (\sigma_{i+1,j+1} - \sigma_{i,j+1}) \\ &= 2\sigma_{i,j+1} - \sigma_y - \sigma_{i+1,j+1}\end{aligned}\quad (15)$$

Next, an equality restriction must be placed on γ_y at 1, 2, 3 or 4 steps from the main diagonal¹²:

$$\begin{aligned}v_{11} &= \frac{1}{4}\gamma_{11} + \frac{1}{4}\gamma_{22} + \frac{1}{4}\gamma_{33} + \frac{1}{4}\gamma_{44} \\ v_{12} &= \frac{1}{3}\gamma_{12} + \frac{1}{3}\gamma_{23} + \frac{1}{3}\gamma_{34} \\ v_{13} &= \frac{1}{2}\gamma_{13} + \frac{1}{2}\gamma_{24} \\ v_{14} &= \gamma_{14}\end{aligned}\quad (16)$$

The reader can verify that diagonal steps as defined in equation (15) are equal for each diagonal step. For example,

$$2*-.235 -1.285 -.570 = 2*-.134 -.570 -.548 = -1.386;$$

$$2*-.140 -.235 +.134 = 2*-.324 +.134 +.134 = -.380;$$

$$2*-.346 +.140 +.324 = -.229.$$

As noted earlier, a model with a fixed diagonal distance restriction fits these data poorly by any criterion. However, the point to be seen here is that the substantive ideas behind the crossings parameter model can indeed be translated into restrictions on deviation contrast parameters.

Notes

¹ If η is a cross-classification of the factors, then equation (2) would contain more unknown parameters than equations in a full, saturated model. However, even restricted models will not be identifiable, because A is not of full rank, i.e. certain columns of A are linear combinations of other columns. Take for example the case where η is a cross-classification of two factors a and b , with 2 and 3 categories respectively. Our model would then be:

$$\begin{bmatrix} \eta_{11}^{ab} \\ \eta_{12}^{ab} \\ \eta_{13}^{ab} \\ \eta_{21}^{ab} \\ \eta_{22}^{ab} \\ \eta_{23}^{ab} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \theta^* \\ \theta_1^a \\ \theta_2^a \\ \theta_1^b \\ \theta_2^b \\ \theta_3^b \\ \theta_{11}^{ab} \\ \theta_{12}^{ab} \\ \theta_{13}^{ab} \\ \theta_{21}^{ab} \\ \theta_{22}^{ab} \\ \theta_{23}^{ab} \end{bmatrix}$$

This shows clearly that certain columns of A can be found by linear combinations of other columns, e.g. column 2 can be found by adding columns 7, 8 and 9. The column for the overall effect can always be found by adding the columns for the main effect parameters of one of the factors, so that even in the simple model of the effects of a single factor, A would not be of full rank.

Substantively, the fact that A is not of full column rank means that the same question has inadvertently been asked twice: knowledge of the main effect parameters implies knowledge of the overall term, knowledge of interaction effect parameters implies knowledge of main effects, and vice versa. The upshot is that restrictions must be placed on parameters so that parameters for an effect are relative to each other. One parameter for the main effect of each factor must be dropped, either by omitting it or by expressing it through other parameters. For

an interaction effect of factor a with k levels and factor b with l levels, $k + l - 1$ restrictions must be imposed.

² Entering $\beta = C\theta$ in equation (1) results in:

$$\eta = XC\theta$$

This shows that

$$A = XC$$

$$AC' = XCC'$$

$$X = AC'(CC')^{-1}$$

A full rank design matrix can therefore be found by postmultiplying the model matrix A by $C'(CC')^{-1}$.

³ Since $\beta = C\theta$, the full set of parameters using any contrast can be calculated afterwards using $\theta = C'(CC')^{-1}\beta$.

⁴ The contrast matrix for a second degree interaction effect can be found from the contrast matrices for the main effects by calculating the *Kronecker product* of the two matrices. For the Kronecker product, the second matrix is multiplied by each element of the first matrix. Similarly, the design matrix for an interaction effect can be found with the *horizontal direct product* of the design matrices for the main effects. The horizontal direct product is the matrix direct product of the second matrix by each column of the first matrix.

⁵ If Z is the new design matrix for the reparametrized θ parameters, then it must be so that $X = ZR$, since $\eta = Z\theta = ZR\beta$. Z can therefore be found by postmultiplying X by $R'(RR')^{-1}$.

⁶ A third type of model uses a nonlinear design, combining linear and multiplicative parameters. Two examples are Goodman's (1979) row and column model II for frequency tables, and Sobel's (1981) diagonal mobility model, for use with a dependent variable (this latter model does not relate to interaction effects however). Chapter 6 contains a "proportional asymmetry" model, which tests whether interaction parameters β_{ij}^{ab} and β_{ji}^{ab} are not equal as in the (quasi) symmetry model, but proportional for all $i \neq j$. This loglinear model also contains linear and multiplicative elements.

⁷ We did not have time to work out how to specify a redundant parameter in a reparametrization matrix. Designating a redundant parameter by the parameters that compose it will not work if restrictions are being made with one of the composing parameters, since the composing parameters are then changed.

⁸ In fact, we simplified this process by entering the parameters ordered from high to low. We wrote a macro in GLIM to calculate the differences, standard errors of differences, and T-values for differences between each parameter and the preceding one, and sorted these statistics by T-value. These programs are available on request.

⁹ A reparametrization matrix for deriving horizontal distance parameters γ_j from symmetrical interaction parameters σ_{ij} would be the following:

$$\begin{bmatrix} \gamma_{11} \\ \gamma_{12} \\ \gamma_{13} \\ \gamma_{14} \\ \gamma_{22} \\ \gamma_{23} \\ \gamma_{24} \\ \gamma_{33} \\ \gamma_{34} \\ \gamma_{44} \end{bmatrix} = \begin{bmatrix} -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & -1 & -2 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & -1 & -1 & -2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & 0 \\ 0 & 0 & -1 & 0 & 0 & -1 & 0 & -1 & -2 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & -1 & 0 & -1 & -2 \end{bmatrix} \begin{bmatrix} \sigma_{11} \\ \sigma_{12} \\ \sigma_{13} \\ \sigma_{14} \\ \sigma_{22} \\ \sigma_{23} \\ \sigma_{24} \\ \sigma_{33} \\ \sigma_{34} \\ \sigma_{44} \end{bmatrix}$$

The first three rows are straightforward expressions of the formula $\gamma_y = \sigma_{i,j+1} - \sigma_y$. The rows pertaining to γ_{14} , γ_{24} , γ_{34} and γ_{44} are a bit more complicated, since they refer to redundant parameters. For example, the fourth row would be $\gamma_{14} = \sigma_{15} - \sigma_{14}$. However, σ_{15} is a redundant parameter and must therefore be expressed as $\sigma_{15} = -\sigma_{11} - \sigma_{12} - \sigma_{13} - \sigma_{14}$, so the formula for row 4 becomes $\gamma_{14} = -\sigma_{11} - \sigma_{12} - \sigma_{13} - 2\sigma_{14}$.

¹⁰ This second reparametrization matrix for imposing equality restrictions on γ_y with the same row index would be:

$$\begin{bmatrix} v_{11} \\ v_{22} \\ v_{33} \\ v_{44} \end{bmatrix} = \begin{bmatrix} \frac{1}{4} & \frac{1}{4} & \frac{1}{4} & \frac{1}{4} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{3} & \frac{1}{3} & \frac{1}{3} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{2} & \frac{1}{2} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \gamma_{11} \\ \gamma_{12} \\ \gamma_{13} \\ \gamma_{14} \\ \gamma_{22} \\ \gamma_{23} \\ \gamma_{24} \\ \gamma_{33} \\ \gamma_{34} \\ \gamma_{44} \end{bmatrix}$$

This matrix is a straightforward translation of equation (15): $v_y = \frac{1}{r_i} \sum_{i=1}^r \gamma_y$. The first parameter v_{11} is the average of the identifiable γ_{1j} parameters, v_{12} is the average of the identifiable γ_{2j} parameters, etc.

¹¹ A reparametrization matrix for transforming symmetric interaction parameters σ_y into diagonal distance parameters γ_y would be:

$$\begin{bmatrix} \gamma_{11} \\ \gamma_{12} \\ \gamma_{13} \\ \gamma_{14} \\ \gamma_{22} \\ \gamma_{23} \\ \gamma_{24} \\ \gamma_{33} \\ \gamma_{34} \\ \gamma_{44} \end{bmatrix} = \begin{bmatrix} -1 & 2 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 2 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 2 & 0 & 0 & -1 & 0 & 0 & 0 \\ -2 & -1 & -2 & -3 & 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 2 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 2 & 0 & -1 & 0 \\ 0 & -2 & 1 & 0 & -2 & -1 & -3 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 2 & -1 \\ 0 & 0 & -2 & 1 & 0 & -2 & 1 & -2 & -2 & 1 \\ -1 & -2 & -2 & -4 & -1 & -2 & -4 & -1 & -4 & -4 \end{bmatrix} \begin{bmatrix} \sigma_{11} \\ \sigma_{12} \\ \sigma_{13} \\ \sigma_{14} \\ \sigma_{22} \\ \sigma_{23} \\ \sigma_{24} \\ \sigma_{33} \\ \sigma_{34} \\ \sigma_{44} \end{bmatrix}$$

The first three rows are straightforward expressions of equation (15): $\gamma_y = 2\sigma_{i,j+1} - \sigma_y - \sigma_{i+1,j+1}$. As for the fixed horizontal distance restriction, the rows pertaining to γ_{14} , γ_{24} , γ_{34} and γ_{44} are more complicated, since they refer to redundant σ_y parameters. So given that

$$\begin{cases} \gamma_{14} = 2\sigma_{15} - \sigma_{14} - \sigma_{25} \\ \sigma_{15} = -\sigma_{11} - \sigma_{12} - \sigma_{13} - \sigma_{14} \\ \sigma_{25} = -\sigma_{12} - \sigma_{22} - \sigma_{23} - \sigma_{24} \end{cases}$$

then $\gamma_{14} = -2\sigma_{11} - \sigma_{12} - 2\sigma_{13} - 3\sigma_{14} + \sigma_{22} + \sigma_{23} + \sigma_{24}$. For γ_{44} , we get:

$$\begin{cases} \gamma_{44} = 2\sigma_{45} - \sigma_{44} - \sigma_{55} \\ \sigma_{45} = -\sigma_{14} - \sigma_{24} - \sigma_{34} - \sigma_{44} \\ \sigma_{55} = \sigma_{11} + 2\sigma_{12} + 2\sigma_{13} + 2\sigma_{14} + \sigma_{22} + 2\sigma_{23} + 2\sigma_{24} + \sigma_{33} + 2\sigma_{34} + \sigma_{44} \end{cases}$$

$$\Rightarrow \gamma_{44} = -\sigma_{11} - 2\sigma_{12} - 2\sigma_{13} - 4\sigma_{14} - \sigma_{22} - 2\sigma_{23} - 4\sigma_{24} - \sigma_{33} - 4\sigma_{34} - 4\sigma_{44}$$

¹² The reparametrization matrix for imposing an equality restriction on diagonal distance parameters would be:

$$\begin{bmatrix} v_{11} \\ v_{12} \\ v_{13} \\ v_{14} \end{bmatrix} = \begin{bmatrix} \frac{1}{4} & 0 & 0 & 0 & \frac{1}{4} & 0 & 0 & \frac{1}{4} & 0 & \frac{1}{4} \\ 0 & \frac{1}{3} & 0 & 0 & 0 & \frac{1}{3} & 0 & 0 & \frac{1}{3} & 0 \\ 0 & 0 & \frac{1}{2} & 0 & 0 & 0 & \frac{1}{2} & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \gamma_{11} \\ \gamma_{12} \\ \gamma_{13} \\ \gamma_{14} \\ \gamma_{22} \\ \gamma_{23} \\ \gamma_{24} \\ \gamma_{33} \\ \gamma_{34} \\ \gamma_{44} \end{bmatrix}$$

This is a straightforward expression of equation (16).

Chapter 8

Redefining Interaction Parameters using the Deviation Contrast, for use in the Analysis of Square Tables

Abstract

The interaction term of a loglinear model for a square table can be seen as the net effect of three aspects of mobility or assortative marriage: (a) the propensity to immobility/inmarriage, (b) the social proximities between categories, (c) the differences in social proximities for the row and column variables. This paper discusses methods for redefining this interaction term into subterms, in order to capture these aspects of mobility or assortative marriage. A new element introduced here is the use of a "symmetric deviances" subterm, which maps the space between a model of quasi-independence and a quasi-symmetry model, in order to capture (b), the social proximities between categories. The redefinitions discussed here can be applied to parameters using any type of restriction, but this paper focuses parameters based on the deviation contrast (the parameters sum to zero).

A discussion of the redefinitions is followed by an example of religious assortative marriage in the Netherlands in 1956. This is followed by a discussion of the issue of table size and by a specification of rules for deriving parsimonious designs. The appendix shows how the redefinitions can be implemented in programs using SAS or SPSS software.

Introduction

In the analysis of square tables such as social mobility or assortative marriage, loglinear models with special restrictions on the interaction effects are used to test for special patterns. Hout (1983) contains an overview of these models, and Goodman (1984) contains many of Goodman's important papers on this subject. Most of these models focus on patterns of *mobility*, or *outmarriage*. Only in modified versions do they contain parameters that explicitly take *immobility*, or *inmarriage* into account (e.g. the quasi-crossings parameter or the quasi uniform association models). From a theoretical point of view however, immobility will be at least as important as mobility. This paper discusses an alternative design which starts by taking immobility/inmarriage into account, and derives parameters for mobility/outmarriage from these effects.

Many mobility models look at mobility in terms of patterns of odds-ratios, or can be meaningfully interpreted as patterns of odds-ratios (Goodman 1979). Such models are based on the difference contrast, since using the difference contrast for interaction effects of a log-

linear model results in log odds-ratios as parameters (see chapters 6 and 7). The design discussed below on the other hand, uses the deviation contrast. The deviation contrast, also referred to as the "usual" or "ANOVA" restrictions, is the common restriction that parameters sum to zero. This contrast has several attractive properties and will be especially useful when the variables do not have ordered categories.

A full interaction term using the deviation contrast can be split up into several subterms, each of which also uses the deviation contrast. As has been shown by Sobel, Hout and Duncan (1985) and Yamaguchi (1990), an interaction term (using any contrast) can be split into a "symmetric interaction" and a "skew symmetry" subterm. This paper discusses how the symmetric interaction subterm based on the deviation contrast, can subsequently be split into three subterms: an "overall diagonal", a "diagonal deviation", and a "symmetric deviances" subterm. The first two together correspond with the well known diagonal parameters such as used in a model of quasi-independence, translated to deviation contrast parameters. The "symmetric deviances" subterm is a deviation contrast based design for mobility or outmarriage.

Before explaining how to redefine the full interaction term into these diverse subterms, this paper starts by looking at contrasts in relation to mobility models. This is followed by a discussion on how to redefine the interaction term into different subterms and how these subterms relate to substantive concepts. To illustrate this, the next paragraph presents the parameters of a full interaction term and the redefined subterms, for a table of religious assortative marriage. This is followed by a discussion of table size and the special case of the four by four table. The main section concludes with a explanation on how to derive restricted designs for specific hypotheses from the redefined subterms.

Appendix A deals with the technical aspects of specifying these designs. Appendix A.1 shows how to specify a redefinition matrix to derive the designs discussed here, and contains an example using SAS software. Appendix A.2 shows how the effects can be estimated using SPSS.

Contrasts and mobility models

Parameters in models with categorical independent variables¹, such as the loglinear model, require restrictions in order to be identifiable. These restrictions can take many forms, using "contrasts" to express the identifiable parameters as linear combinations of the full set of (unidentifiable) model parameters (Bock 1975, Finn 1974). Take for example, an extremely simple loglinear model of an overall effect and the effects of variable a on the frequency distribution of a . This model would be specified as:

$$\log(F_i^a) = \theta^* + \theta_i^a \quad (1)$$

In this form, equation (1) would not be identifiable. The reason is that there are linear dependencies² between the overall effect θ^* and the effects of θ_i^a . A contrast removes this linear dependency by defining new identifiable parameters β_i^a as linear combinations of the model parameters θ_i^a , making the parameter relative in some way. This way, one parameter for each variable in each term can be dropped, thus removing the linear dependencies³.

The easiest restriction is to simply drop the parameter for a reference category; this technique is used by the program GLIM and in regression applications using dummy variables.

Parameters are relative to the reference category, which has the value zero. This restriction is equivalent to the simple contrast, which defines the identifiable parameters as the difference between the corresponding model parameter and the model parameter for the reference category c : $\beta_i = \theta_i - \theta_c$ ($c \neq i$). In the case of interaction effects, each parameter is relative to the row factor reference category and to the column factor reference category. Usually this will not be a very appropriate meaning to give parameters in a mobility model.

For the analysis of (square) tables with ordered categories, the difference contrast will often be very useful. This contrast compares each model parameter with the following (or preceding) model parameter: $\beta_i = \theta_i - \theta_{i-1}$. The interaction parameters therefore correspond with the row-wise differences between the column-wise differences and are equal to the log odds-ratios of the fitted values (chapters 6 and 7). Mobility models such as the association class of models (Goodman, 1979) are based on log odds-ratios, and others such as the crossings parameter model can be meaningfully interpreted in terms of log odds-ratios.

The association models are a powerful tool for systematically searching for a parsimonious description of the interaction patterns in a (square) table. Potentially, the association in the table can be described in a single parameter, using the uniform association model. In practise, mobility tables have high values for the diagonal cells, which are not taken into account as such by these models. This must be dealt with by using diagonal parameters using another contrast, which somewhat mars the elegance of association models. Also, the model is now no longer derived from a full interaction term. This could lead to problems if the model needs be expanded by removing restrictions. A final practical difficulty can be that association models assume ordered categories, but that this assumption will not always be fulfilled.

The deviation contrast, sometimes referred to as the "usual restrictions" or "ANOVA" restrictions, is the commonly used restriction that the sum of parameters over the categories of each variable it relates to equals zero. For a first degree effect, each identifiable parameter is defined as the deviation from the average of the model parameters for that factor: $\beta_i = \theta_i - \bar{\theta}_.$,

where $\bar{\theta}_. = \frac{1}{r} \sum_{i=1}^r \theta_i$. For an interaction effect, identifiable parameters are defined as the deviation from the row and column means, which are themselves deviations from the overall mean.

Since the parameters are deviations from the mean, parameters have a sum of zero, both row-wise, column-wise, and over the entire table. Parameters for one of the categories of each factor composing the effect are redundant, since they can be found by the negative sum of the parameters across the remaining categories of the factor in question.

The ability of deviation contrast parameters to provide parameters for each cell of the table makes it possible to develop mobility models which provide information on each type of immobility (inmarriage) and each type of mobility (outmarriage). Parameters are not relative to a reference category or the previous category, which simplifies the interpretation. Higher deviation contrast parameter values indicate that the fitted value is greater than expected by the lower order effects. In the analysis of square tables of mobility or assortative marriage patterns, higher (positive) values can be expected on the main diagonal of the table, lower (negative) values can be expected off the diagonal, particularly at several removes from the main diagonal if the categories are ordered. The difference contrast is generally speaking only useful for ordered categories, whereas the deviation can also be used for unordered categories. Another attractive property of the deviation contrast is that immobility or inmarriage will be the inverse of mobility or outmarriage, since the sum of the parameters on the diagonal plus the sum of the off-diagonal parameters equals zero.

Redefining interaction effects

For analyzing square tables, and especially if the categories are unordered, the deviation contrast can be an attractive option. However, the full interaction term reflects several distinct aspects of the process being studied. Taking assortative marriage as an example, three conceptually independent aspects of partner choice can be discerned:

- (a) **Inmarriage preference.** To what extent do the different categories have a preference for marriage with other group members.
- (b) **Social distance.** If marriages *are* mixed, which categories are first, second, last choice?
- (c) **Differences in social distance for men and women.** The preferences for other categories in the event of outmarriage need not be the same for men and women. For example, given that women are held to be more religious than men, a hypothesis might be that the social distance between Catholic or Protestant women and non-believing men would be larger than the social distance between non-believing women and Catholic or Protestant men.

These three aspects of partner choice clearly have counterparts for the case of mobility. There can be (a) a certain degree of immobility, (b) if mobility takes place, then some categories may be more accessible than others, and (c) upward mobility may differ from downward mobility. Hypotheses that one or more of these aspects is not present can be tested using some of earliest and simplest mobility models. If a quasi-symmetry model fits the data, then the hypothesis that (c) is present is falsified. If quasi-independence fits, then (b) is also not present. If the independence model fits, then of course (a), (b) and (c) are absent.

Given that these aspects are independent of each other, it makes sense to redefine the interaction term using the deviation contrast into *subterms*, which reflect each aspect separately. These subterms can then be a basis for designs with further restrictions, to test specific hypotheses on certain aspects of assortative marriage or mobility.

SYMMETRIC INTERACTION AND SKEW SYMMETRY

Sobel, Hout, Duncan (1985) and Yamaguchi (1990) have shown how an interaction effect, can be redefined into symmetric interaction and skew symmetry subterms. Yamaguchi also showed how examples of restricted skew symmetry designs based on patterns of odds-ratios (the difference contrast), to test hypotheses on upward versus downward mobility, or male/female differences in social distance.

The $(r-1)^2$ identifiable interaction parameters β_{ij} of two categorical independent variables, each with r categories, can be redefined as $\frac{1}{2}r(r-1)$ symmetric interaction parameters σ_{ij} and $\frac{1}{2}(r-1)(r-2)$ skew symmetric parameters v_{ij} :

$$\beta_{ij} = \sigma_{ij} + v_{ij} \quad (2)$$

Dropping the skew symmetric subterm results in a quasi-symmetry model. The skew symmetric parameters map the space between a quasi-symmetry model and a full, saturated model, and therefore indicate for which types upward mobility differ from downward mobility, or for which types of outmarriage the social distance between categories differs for men and women.

The symmetric interaction parameters σ_{ij} are defined as:

$$\sigma_{ij} = \frac{1}{2}(\beta_{ij} + \beta_{ji}) \quad (3)$$

Applying equation (3) to the full set of β_{ij} parameters (regardless of contrast) shows that $\sigma_{ii} = \beta_{ii}$ and that $\sigma_{ij} = \sigma_{ji}$. If the deviation contrast was used for β_{ij} , then σ_{ij} has the same redundant categories as β_{ij} .

The skew symmetry parameters v_{ij} are defined as:

$$v_{ij} = \frac{1}{2}(\beta_{ij} - \beta_{ji}) \quad (4)$$

Applying equation (4) to the full set of β_{ij} parameters shows that $v_{ii} = 0$ and that skew symmetry parameters in the upper triangle are the negative value of parameters in the lower triangle: $v_{ij} = -v_{ji}$ (hence the name *skew symmetric*; Yamaguchi 1990: 186).

DIAGONAL PARAMETERS AND SYMMETRIC DEVIANCES PARAMETERS

The symmetric interaction parameters σ_{ij} are the result of two phenomena: the amount of immobility/inmarriage, and the social distances between categories, in the event of mobility/outmarriage. If the social distances are the same for all types of mobility or outmarriage, then a model of quasi-independence will hold. What is wanted is therefore a subterm which maps the space between the quasi-independence and quasi-symmetry models and can measure these social distances.

This subterm can be derived by taking the diagonal parameters of a quasi-independence model and subtracting these from the symmetric interaction parameters, much as the skew symmetry parameters can be found by subtracting the symmetric interaction parameters from the interaction parameters. To do this, the diagonal parameters will have to be expressed using the contrast of the symmetric interaction parameters⁴.

In the following, it is assumed that the symmetric interaction parameters use the deviation contrast, that the last category is the redundant category, and that the identifiable symmetric interaction parameters are defined for the upper triangle of the square r by r table, excluding the last column, i.e. for $i = 1$ to $r - 1$, $j = i$ to $r - 1$. Expressing the diagonal parameters as deviation contrast parameters can be simplified by expressing them as two subterms: an overall diagonal subterm (analogous to the constrained quasi-independence model; cf. Goodman 1968), and a diagonal deviation subterm. In total therefore, the symmetric parameters are redefined into three subterms of deviation contrast parameters:

- a An *overall diagonal* subterm ζ_{ij} . The full set of parameters is derived from a single identifiable parameter ζ_{11} .
- b A *diagonal deviation* subterm δ_{ij} . The full set of parameters is derived from $r - 1$ identifiable parameters δ_{ii} , $i = 1$ to $r - 1$.
- c A *symmetric deviances* subterm. The full set of parameters is derived from $\frac{1}{2}r(r-1)(r-2) - 1$ identifiable parameters ω_{ij} , which are defined for $i = 1$ to $r - 3$, $j = 1$ to $r - 1$.

The symmetric interaction term is therefore redefined as:

$$\sigma_{ij} = \zeta_{ij} + \delta_{ij} + \omega_{ij} \quad (5)$$

The identifiable overall diagonal parameter ζ_{11} is defined as the mean value of the parameters on the diagonal of the full set of symmetric interaction parameters.

$$\zeta_{11} = \frac{1}{r} \sum_{i=1}^r \sigma_{ii} \quad (6)$$

Given that the full set of overall diagonal parameters use the deviation contrast and have a sum of zero, row-wise and column-wise, the full set can be derived from the single identifiable ζ_{11} as follows:

$$\begin{aligned} \zeta_{ii} &= \zeta_{11} \text{ for } i = 1 \text{ to } r \\ \zeta_{ij} &= -\frac{1}{r-1} \zeta_{11} \text{ for } i \neq j \end{aligned} \quad (7)$$

Interpreted as deviation contrast parameters, the overall diagonal parameter means that there is a uniform propensity to e.g. inmarriage for all categories. This propensity to inmarriage determines the extent of outmarriage for all types of mixed marriages.

The identifiable diagonal deviation parameters δ_{ii} ($i=1$ to $r-1$) are equal to the diagonal values of the symmetric interaction parameters, minus the overall diagonal parameter:

$$\delta_{ii} = \sigma_{ii} - \zeta_{11}, \text{ for } i = 1 \text{ to } r-1 \quad (8)$$

Because the diagonal deviation parameters are deviations from the mean of the diagonal values of σ_{ij} , $\delta_{rr} = -\sum_{i=1}^{r-1} \delta_{ii}$. With parameters for each diagonal cell, and given that the full set of parameters sums to zero row-wise and column-wise, the full set of diagonal deviation parameters can be derived from the identifiable parameters by:

$$\begin{aligned} \delta_{ii} &= \delta_{ii} \text{ for } i = 1 \text{ to } r-1 \\ \delta_{rr} &= -\sum_{i=1}^{r-1} \delta_{ii} \\ \delta_{ij} &= -\frac{1}{r-2} \delta_{ii} - \frac{1}{r-2} \delta_{jj} \text{ for } i \neq j \end{aligned} \quad (9)$$

As was the case for the overall diagonal parameters, the amount of e.g. outmarriage in the full set of diagonal deviation parameters is determined by the amount of inmarriage in the respective categories. The difference is that each category now has its own propensity to inmarriage, as a deviation from the average propensity to inmarriage for all categories. As the propensity to inmarriage is higher for a particular category, there will be less outmarriage. But in the event of outmarriage, there is no preference for one category over another, since the outmarriage parameters are proportional to the inmarriage preference.

The overall diagonal subterm ζ_{ij} together with the diagonal deviation subterm δ_{ij} are equivalent to the diagonal parameters such as used in a quasi-independence model, but expressed as deviation contrast parameters. The symmetric deviances parameters ω_{ij} can now be derived by subtracting the overall diagonal and diagonal deviation subterms from the symmetric interaction parameters σ_{ij} :

$$\omega_{ij} = \sigma_{ij} - \zeta_{ij} - \delta_{ij} \quad (10)$$

It follows from (7) and (8) that for the diagonal cells, $\zeta_{ii} + \delta_{ii} = \sigma_{ii}$ and that therefore $\omega_{ii} = 0$. Furthermore, the ω_{ij} parameters have a sum of zero within the inner triangles of the table (excluding the last row or the last column), since the last row/column has a sum of zero,

and the parameters are symmetrical. This means that if the $\frac{1}{2}(r-1)(r-2)-1$ identifiable ω_{ij} parameters are defined from $i = 1$ to $r-3$, $j = i$ to $r-1$, that the full set of symmetric deviances parameters can be found using:

$$\begin{aligned}\omega_{ii} &= \omega_{ii} \\ \omega_{ir} &= -\sum_{i=1}^{r-1} \omega_{ij} \\ \omega_{rj} &= -\sum_{j=1}^{r-1} \omega_{ij} \\ \omega_{r-2,r-1} &= -\sum_{i=1}^{r-3} \sum_{j=1}^{r-1} \omega_{ij}\end{aligned}\tag{11}$$

The symmetric deviances parameters show how much higher or lower the symmetric association parameters (quasi-symmetry) are, than would be expected on the basis of parameters on the diagonal (quasi-independence). Values of zero indicate neutrality between the two categories. Negative values indicate aversion, positive values indicate attraction between categories. The symmetric deviances parameters should therefore perhaps be referred to as measures of social proximity, rather than of social distance.

Example: Religious assortative marriage in the Netherlands in 1956

In order to illustrate the preceding derivations, this paragraph contains an example of how the interaction parameters for a square table can be split into symmetric interaction and skew symmetric subterms, and how the symmetric interaction subterm can itself be split into an overall diagonal, a diagonal deviations, and a symmetric deviances subterm. These redefinitions are applied to the interaction term of a saturated model for religious assortative marriage in the Netherlands in 1956 (see table 1). This table was taken from the data used in a forthcoming analysis on religious assortative marriage in Germany and the Netherlands.

Six religious denominations are discerned in table 1: (1) orthodox Protestant

Table 1
Table of denomination husband by denomination wife for the Netherlands in 1956

Husband's denomination	Wife's denomination					
	orthodox Protestant	liberal Protestant	other	none	Jewish	Catholic
orthodox Protestant	6533	1381	79	290	0	210
liberal Protestant	1403	20450	679	2385	7	1973
other	85	582	1036	373	2	232
none	321	3033	522	10333	17	1675
Jewish	1	12	3	21	49	10
Catholic	155	1697	218	1270	9	35226

("gereformeerd"), (2) liberal Protestant ("hervormd"), (3) other denominations (small Protestant denominations), (4) no denomination, (5) Jewish, (6) Catholic. The table was selected for a year in which religious assortative marriage was at a peak and frequencies on the diagonal are quite high – in fact, 83.8% of the marriages in table 1 were homogamous. An analysis shows that the association in table 1 is symmetric: a quasi-symmetry model has an L^2 of 12.2 with 10 df , which corresponds with a P-value of .273.

Such a high P-value is remarkable, given the large number of cases. Raftery (1986) argues that model selection based on P-values will lead to overfitting when applied to such large tables and proposed an alternative statistic, the BIC⁵. BIC is based on Bayesian statistics, and models with BIC values lower than zero are preferable to the saturated model. In a comparison of two or more models, the model with the most negative BIC is preferable. For a quasi-symmetry model of table 1, BIC is -102.

The association in table 1 is not quasi-independent – this model has an L^2 of 1164 with 19 df , and a strongly positive BIC value of 946. The diagonal parameters do capture most of the association in the table: an independence model has an L^2 of 119096 with 25 df and a BIC of 118810. The 6 diagonal parameters therefore reduce L^2 by 99.02%.

Table 2 contains the interaction term of a saturated model in subtable i , and the different subterms which this interaction term can be redefined into in subtables ii to vi . The (multiplicative) interaction parameters indicate how many times more often a type of marriage occurred, than would be expected on the basis of the sizes of the denominations, as indicated by the (multiplicative) main effect parameters. The interaction effects are therefore measures of relative assortative marriage, i.e. of assortative marriage, controlling for differences in the sizes of the categories for both husbands and wives (cf. Featherman and Hauser 1978, on the use of loglinear models to obtain measures of relative mobility). Note that because of the small cell counts⁶ for category 5 (Jewish), parameters for this category have large standard errors. Because a saturated model is overly-fitted for these data, the parameters in table 2 should be seen as a numerical example only. The parameters of a quasi-symmetry model can differ in important ways – e.g. the diagonal deviation parameters for orthodox Protestants and Catholics have much closer values in a quasi-symmetry model, than in table 2.

The interaction effect parameters β_{ij} in subtable i have strong, positive values on the diagonal, indicating high propensities to inmarriage. Of the off-diagonal values, only two are positive, both relating to mixed marriages between orthodox and liberal Protestants. The remaining off-diagonal β_{ij} parameters are all negative, but vary quite strongly in magnitude. Different types of mixed marriages differ strongly in relative frequency.

The symmetric interaction parameters σ_{ij} in subtable ii plus the skew symmetric parameters ν_{ij} in subtable iii equal the interaction parameters β_{ij} in subtable i . The symmetric interaction parameters have the same values on the diagonal as the interaction parameters, and the off-diagonal values are symmetric. The parameter $\sigma_{15} = -2.057$ shows that mixed marriages between orthodox Protestants and Jews had the lowest relative frequency by quite a margin. The second most infrequent marriage was $\sigma_{25} = -1.323$ between liberal Protestants and Jews, followed after a gap by $\sigma_{16} = -1.016$.

Table 2
The interaction effect for table 1 split up into separate sub-terms

<i>i</i>							<i>ii</i>							<i>iii</i>						
Interaction effect parameters β_{ij}							Symmetric interaction parameters σ_{ij}							Skew symmetry parameters v_{ij}						
1	2	3	4	5	6		1	2	3	4	5	6	1	2	3	4	5	6		
1	3.732	.545	.516	-.568	-2.337		3.732	.507	.504	-.662	-2.057	-1.016	1	0	.038	-.012	.094	-.280	.159	
2	.469	1.515	-.096	-.188	-1.355		.507	1.515	-.151	-.166	-1.323	-.382	2	-.038	0	.055	-.022	-.032	.037	
3	.492	-.206	2.164	-.205	-.615		-.504	-.151	2.164	-.157	-.693	-.660	3	.012	-.055	0	-.048	.077	.014	
4	-.756	-.145	-.109	1.527	-.258		-.662	-.166	-.157	1.527	-.280	-.261	4	-.094	.022	.048	0	.022	.002	
5	1.778	-1.391	-.770	-.303	5.127		-2.057	-1.323	-.693	-.280	5.127	-.774	5	.280	.032	-.077	.022	0	-.212	
6	-1.176	-.418	-.674	-.263	-.562		-1.016	-.382	-.660	-.261	-.774	3.093	6	-.159	-.037	-.014	-.002	.212	0	
<i>iv</i>							<i>v</i>							<i>vi</i>						
Overall diagonal parameters ζ_{ij}							Diagonal deviation parameters δ_{ij}							Symmetric deviances parameters ω_{ij}						
1	2	3	4	5	6		1	2	3	4	5	6	1	2	3	4	5	6		
1	2.860	-.572	-.572	-.572	-.572		.873	.118	-.044	.115	-.785	-.277	1	0	.961	.113	-.205	-.700	-.168	
2	-.572	2.860	-.572	-.572	-.572		.118	-1.345	.510	.670	-.231	.278	2	.961	0	-.089	-.264	-.520	-.088	
3	-.572	-.572	2.860	-.572	-.572		-.044	.510	-.695	.507	-.393	.116	3	.113	-.089	0	-.092	.272	-.204	
4	-.572	-.572	-.572	2.860	-.572		.115	.670	.507	1.333	-.234	.275	4	-.205	-.264	-.092	0	.525	.036	
5	-.572	-.572	-.572	-.572	2.860		-.785	-.231	-.393	-.234	2.268	-.625	5	-.700	-.520	.272	.525	0	.423	
6	-.572	-.572	-.572	-.572	2.860		-.277	.278	.116	.275	-.625	.233	6	-.168	-.088	-.204	.036	.423	0	

Shaded cells indicate identifiable parameters

$$\beta_{ij} = \sigma_{ij} + v_{ij}$$

$$\sigma_{ij} = \zeta_{ij} + \delta_{ij} + \omega_{ij}$$

These three symmetric interaction parameters have extremely large values and are quite widely spaced. Five parameters have values between $-.500$ and $-.799$: $\sigma_{13} = -.504$, $\sigma_{36} = -.660$, $\sigma_{14} = -.662$, $\sigma_{35} = -.693$, and $\sigma_{56} = -.774$. Marriages between orthodox Protestants and "other", between orthodox Protestants and "none", between "other" and Catholics, between "other" and Jews, and between Jews and Catholics were all infrequent to more or less the same extent. Another group of six parameters has values between $-.150$ and $-.399$: $\sigma_{23} = -.151$, $\sigma_{34} = -.157$, $\sigma_{24} = -.166$, $\sigma_{46} = -.261$, $\sigma_{45} = -.280$, and $\sigma_{26} = -.382$. These parameters relate to out-marriages between liberal Protestants and "other", liberal Protestants and "none", liberal Protestants and Catholics, "other" and "none", "none" and Jews, and between "none" and Catholic. A rather special parameter is $\sigma_{12} = .507$, between orthodox and liberal Protestants. This type of marriage occurred a good deal more frequently than would be expected on the basis of the main effects. However, it was much less frequent than any type of inmarriage.

The skew symmetry parameters v_j in subtable *iii* indicate the differences in social distances between the denominations for men and for women. Since the quasi-symmetry model had an acceptable fit by both the P-value and BIC criteria, this subterm as a whole is not significant. Values on the diagonal are zero, parameters in the upper triangle are negative values of parameters in the lower triangle. The two parameters with the largest absolute values, $v_{51} = .280$ and $v_{65} = .212$, relate to mixed marriages with Jews for which the cell counts are very small. The next largest absolute parameter value is $v_{61} = -.159$, which relates to marriages between Catholics and orthodox Protestants. If this parameter were significant, it would indicate that orthodox Protestant men were less willing to marry Catholic women, than Catholic men were willing to marry orthodox Protestant women.

The symmetric interaction subterm σ_y can itself be split up into an overall diagonal subterm ζ_y , a diagonal deviation subterm δ_y , and a symmetric deviances subterm ω_y . This is done in subtables *iv*, *v* and *vi* of table 2. The identifiable overall diagonal parameter $\zeta_{11} = 2.860$ can be derived by calculating the mean values of the diagonal cells of subtable *ii* (cf. equation (6)). The values for off diagonal cells are equal to $-\frac{1}{2}$ times ζ_{11} , as in equation (7). The overall diagonal subterm shows that generally speaking, there is a strong propensity to inmarriage. Since the overall diagonal subterm uses the deviation contrast, in which parameters are relative to each other, this high propensity to inmarriage implies that all outmarriages will be relatively infrequent.

The diagonal values of the diagonal deviation parameters δ_y in subtable *v* indicate the inmarriage propensity of each category, as deviations from the overall diagonal subterm ζ_{11} . These values can be calculated by subtracting ζ_{11} from the values on the diagonal of subtable *ii*, as in equation (8). Off-diagonal values can be calculated by adding $-\frac{1}{2}$ times the corresponding values on the diagonal, as in equation (9).

The diagonal deviation parameters show that category 5 (Jewish) was far more closed than the other categories, with $\delta_{55} = 2.268$. The orthodox Protestants ($\delta_{11} = .873$) and Catholics ($\delta_{66} = .233$) also had inmarriage preferences that were higher than average. The "other denominations" ($\delta_{33} = -.695$) had a lower than average inmarriage preference, while the categories "no denomination" ($\delta_{44} = -1.333$) and liberal Protestants ($\delta_{22} = -1.345$) were most open of all. Since the diagonal deviation parameters use the deviation contrast, these inmarriage propensities imply a certain amount of outmarriage. For example, the Jews and the orthodox Protestants were the two most closed groups, so $\delta_{15} = -.785$ indicates that outmarriage between the two groups would be rare, even if both felt neutral with regard to the other.

Subtable *vi* of table 2 contains the symmetric deviances parameters ω_j . These are derived by taking the outmarriage parameters of the overall diagonal parameters plus the diagonal deviation parameters, and subtracting these from the symmetric interaction parameters, as in equation (10). For example, the closed nature of the Jewish and orthodox Protestant denominations would lead us to expect an outmarriage parameter of $\zeta_{15} + \delta_{15} = -.572 - .785 = -1.357$. In fact, the outmarriage parameter for this type of marriage is even smaller: $\sigma_{15} = -2.057$, indicating that the two groups avoid each other in preference of other mixed marriage types. This is seen by $\omega_{15} = -2.057 + 1.357 = -.700$.

The symmetric deviances parameters indicate the preferences for partners of other denominations, given that a mixed marriage takes place. Orthodox Protestants had a strong first preference for marriages with liberal Protestants ($\omega_{12} = .961$), followed after quite a gap by "other denominations" ($\omega_{13} = .113$). The orthodox Protestants had a more or less equal aversion to marriage with Catholics ($\omega_{16} = -.168$) or "none" ($\omega_{14} = -.205$), and as noted above, marriages with Jews were least attractive of all: $\omega_{15} = -.700$. Liberal Protestants reciprocated the strong attraction to orthodox Protestants ($\omega_{12} = .961$), were fairly neutral with regard to Catholics ($\omega_{26} = -.088$) and "other" ($\omega_{23} = -.089$), had an aversion to "none" ($\omega_{24} = -.264$) and an even stronger aversion to marriage with a Jew ($\omega_{25} = -.520$).

"Other denominations" were attracted to Jews ($\omega_{35} = .272$) and to a lesser degree to orthodox Protestants ($\omega_{13} = .113$). They were fairly neutral regarding liberal Protestants ($\omega_{23} = -.089$) and "none" ($\omega_{34} = -.092$), and were least attracted of all to marriages with Catholics ($\omega_{36} = -.204$). Note that the preferences of "other denominations" were much less pronounced than those of the rest, due to the heterogeneous nature of this category. The category "no denomination" strongly preferred marriages with Jews ($\omega_{45} = .525$). It was neutral with regard to Catholics ($\omega_{46} = .036$) and "other" ($\omega_{34} = -.092$), and had an aversion to marriages with either orthodox ($\omega_{14} = -.205$) or liberal Protestants ($\omega_{24} = -.264$).

Jews had a strong first preference for marriage with "none" ($\omega_{45} = .525$), with Catholics in the second place ($\omega_{36} = .423$) and "other" in the third place after a gap ($\omega_{35} = .272$). Jews had a strong aversion to marriages with either liberal Protestants ($\omega_{25} = -.520$) or orthodox Protestants ($\omega_{15} = -.700$). Catholics preferred marriages with Jews ($\omega_{36} = .423$), stood neutral with regard to "none" ($\omega_{46} = .036$) and liberal Protestants ($\omega_{26} = -.088$) and had an aversion to orthodox Protestants ($\omega_{16} = -.168$) and "other" ($\omega_{36} = -.204$).

The issue of table size

These redefinitions can only be applied to a 4 by 4 or larger table. There is only one identifiable parameter for the interaction effect in a 2 by 2 table, so quasi-symmetry always holds. In a 3 by 3 table, 3 identifiable parameters would be used for the interaction in either the quasi-independence or quasi-symmetry model, so the two designs will be equivalent. From a 4 by 4 table up, quasi-symmetry uses more identifiable parameters for interaction than quasi-independence.

Because quasi-symmetry and quasi-independence are so close together for a 4 by 4 table, the symmetric deviances parameters have a simple structure. Table 3 shows that in the full set of symmetric deviances parameters, only three unique values, ω_{12} , ω_{13} , and $-\omega_{12} - \omega_{13}$, are derived from the two identifiable parameters. The full set of symmetric deviances parameters is now symmetric across the lower left/upper right diagonal, as well as the upper left/lower right diagonal.

Table 3
Symmetric deviances parameters for a 4 by 4 table

0	ω_{12}	ω_{13}	$-\omega_{12}-\omega_{13}$
ω_{12}	0	$-\omega_{12}-\omega_{13}$	ω_{13}
ω_{13}	$-\omega_{12}-\omega_{13}$	0	ω_{12}
$-\omega_{12}-\omega_{13}$	ω_{13}	ω_{12}	0

Shaded cells indicate identifiable parameters

The interpretation for the case of four categories is that the unique values of the symmetric deviance parameters are indications of the strengths of the first, second and third preferences of all of the groups. To illustrate this, table 1 was recoded to four categories: orthodox and liberal Protestants were merged, as were "other denominations" and "no denominations". Table 4 contains the symmetric deviances subterm of a saturated model for this recoded table. The three unique values are $\omega_{12} = .102$, $\omega_{13} = -.289$, and $-\omega_{12}-\omega_{13} = .187$. Each denomination had a strong aversion to one of the others, was attracted to a second, and was strongly attracted to a third. Protestants had a strong aversion to marriages with Jews, were somewhat attracted to marriages with "other", and felt that the "best" choice was a marriage with a Catholic. The category "other denomination" had a first preference for marriages with Jews, a second preference for marriages with Protestants, and an aversion to Catholics. Jews likewise had a first preference for marriages with "other", a second for marriages with Catholics, and an aversion to marriages with Protestants. Catholics had a first preference for marriages with Protestants, a second preference for marriages with Jews, and an aversion to marriages with "other".

Table 4
The symmetric deviances subterm of a saturated model for table 1, recoded to four categories

	Protestant	other/none	Jewish	Catholic
Protestant	0	.102	-.289	.187
other/none	.102	0	.187	-.289
Jewish	-.289	.187	0	.102
Catholic	.187	-.289	.102	0

Shaded cells indicate identifiable parameters

Parsimonious designs

Parsimonious designs can be created to test specific hypotheses by redefining a restricted set of parameters as linear combinations of parameters of a subterm. Two obvious restrictions are to set parameters to zero or to impose an equality restrictions. A parameter can be easily set to zero by deleting the corresponding column of the design matrix, and an equality restriction

can be imposed by adding the corresponding columns of the design matrix. Chapter 7 discusses the special problems of imposing such restrictions on deviation contrast parameters. The following rules show how to place restrictions on redundant deviation contrast parameters, as well as on identifiable parameters.

- (1) **A zero value constraint on an identifiable parameter:** Delete the design vector corresponding with that parameter.
- (2) **A zero value constraint on a redundant parameter:** The redundant parameter can be derived from a set of the identifiable parameters, since their sum is zero. Choose one of the identifiable parameters and subtract its design vector from the design vectors of the remaining parameters by which the redundant parameter is composed, then delete that design vector. The value for the parameter that was chosen can be found from the negative sum of the remaining identifiable parameters.
- (3) **An equality constraint between two identifiable parameters:** Add the design vector of one of the identifiable parameters to that of the second, then delete the first design vector.
- (4) **An equality constraint between a redundant parameter and an identifiable parameter in its composition:** Subtract $\frac{1}{2}$ times the column of the identifiable parameters design vector from the design vectors of the other parameters used to derive the redundant parameter, then delete it. The values for the constrained parameters can be found from the negative sum of the identifiable parameters, divided by 2.
- (5) **An equality constraint between a redundant parameter and an identifiable parameter that is not in its composition:** Subtract the identifiable parameter's design vector from the design vectors of the identifiable parameters that compose the redundant parameter, then delete it.
- (6) **An equality constraint between two redundant parameters:** Select an identifiable parameter that composes one of the two redundant parameters. Subtract its design vector from the design vectors of parameters used to derive that redundant parameter. Add it to the design vectors of parameters that derive the other redundant parameter, then delete it from the design matrix.

In the case of skew symmetry parameters v_{ij} , setting certain parameters to zero would be a logical step. This would make it possible to test hypotheses that the differences in social distance for men versus for women are only due to certain types of mixed marriages, or that upward mobility will differ from downward mobility only for certain combinations of origin and destination. It is important to keep in mind that deviation contrast parameters are being used

Table 5
The hollow restriction, applied to the skew symmetry subterm of a 5 by 5 table

0
	0
	0	0
	0	0	0
	0	0	0	0
$-v_{21}-v_{31}-v_{41}$	v_{41}	v_{31}	v_{21}	0

Values in the upper triangle have been omitted to enhance clarity
Shaded cells indicate identifiable parameters

when formulating such hypotheses, and that if parameters are low in one section of the table that they must be high in other places.

An example of a hypothesis on skew symmetric interaction might be that the asymmetries in the association are due to the extreme categories (the categories therefore need not be fully ordered). For example, a hypothesis might be that there is less upward mobility into the highest class, and more downward mobility into the lowest class, but that with regard to the classes in the middle, upward mobility and downward mobility are equal. To test this, a “hollow restriction” could be imposed on the skew symmetry parameters, setting the values of all parameters but those on the edge of the table to zero. Using this restriction, the asymmetry in the association is described using $r-2$ identifiable parameters, rather than $\frac{1}{2}(r-1)(r-2)$.

Table 5 shows how the hollow restriction would look for a 5 by 5 table.

Similarly, fixing symmetric deviances parameters ω_{ij} to zero would be a logical step in creating parsimonious designs. This would make it possible to test hypotheses on categories between which there would be neither attraction nor aversion. With regard to the denominations used in table 1, a hypothesis might be that the heterogeneous category “other denominations” were neutral with regard to the rest of the denominations. This could be tested by setting all the symmetric deviances parameters for this category to zero.

A “mirror restriction” could be used for a table with 5 or more ordered categories, in order to derive a single set of $r-1$ parameter values, indicating the first, second, last preferences, such as found for 4 by 4 tables. The parameters will then be symmetric across the bottom left to upper right diagonal; hence the name “mirror restriction”. Table 6a shows the design of symmetric deviance parameters for a 5 by 5 table, using letters a to e for the identifiable ω_{ij} parameters and table 6b shows how the mirror restriction that is to be imposed would look like.

Imposing a mirror restriction is relatively complicated, because it involves restrictions on redundant parameters. A first step is to set the value of d to $-b$. This is done by subtracting the

Table 6a
Symmetric deviance parameters for a 5 by 5 table

0	<i>a</i>	<i>b</i>	<i>c</i>	$-a-b-c$
	0	<i>d</i>	<i>e</i>	$-a-d-e$
		0	$-a-b-c-d-e$	$a+c+e$
			0	$a+b+d$
				0

Table 6b
The mirror restriction of the symmetric deviance parameters of a 5 by 5 table

0	<i>A</i>	<i>B</i>	<i>C</i>	$-A-B-C$
	0	$-B$	$-A+B-C$	<i>C</i>
		0	$-B$	<i>B</i>
			0	<i>A</i>
				0

Values in the lower triangle have been omitted to enhance clarity
Shaded cells indicate identifiable parameters

column of the design matrix for d from that for b , then deleting the former. Step 2 is to set the value of e equal to $-a+b-c$ (remember that b has already been altered). This can be done by subtracting the column of the design matrix for e from the columns for a and c and adding it to the column for b . With these two steps, a mirror restriction can be imposed on the ω_j for a 5 by 5 table. Note that other steps will be required for larger tables.

The preferences of the middle group would be rather strange, using the mirror restriction design in table 6b. That category would be equally attracted/repulsed by the top and bottom categories, and as equally repulsed/attracted by the second and second to last categories. It could be attractive to fix this parameter to zero, making the middle category strictly neutral. (If the number of categories is even, it would make more sense to impose an equality restriction on the two middle categories).

Evaluation

This paper shows how different aspects of mobility or assortative marriage can be captured using subterms based on the deviation contrast. The overall diagonal and diagonal deviation subterms together capture the propensities to immobility/inmarriage, the symmetric deviances parameters capture the social proximities between the categories, and the skew symmetry parameters capture the differences in social proximities for the row and column variables. New elements in this paper are the symmetric deviances parameters, and the derivation of these from parameters for the diagonal of the table.

Redefining the interaction term into subterms makes it possible to test whether each aspect of mobility/assortative marriage changes for group variables such as time or country. The redefined parameters all have a known interpretation, since they all use the same contrast. In this case, the deviation contrast was used, but the redefinitions could also be applied to difference contrast parameters. Another advantage is that unlike most mobility models, the symmetric deviations subterm relates only to mobility or outmarriage, and has the value of zero for cells on the diagonal of the table. A mobility model such as the uniform association model on the other hand, relates to both diagonal and off-diagonal frequencies.

The use of subterms can also form a starting point for developing parsimonious designs using the deviation contrast. Chapter 7 discusses restricted designs, derived by imposing restrictions on symmetric interaction parameters. One such design, the "levels restriction", imposes an equality constraint on outmarriage parameters and was used in chapter 2. The problem encountered there was that levels shifted from year to year, since changes of parameters on the diagonal implied changes for off-diagonal parameters. Through the use of subterms, changes in the propensities to inmarriage could be modelled separately from changes in the social proximities between denominations.

Appendix A: Estimating the redefined subterms

This appendix deals with the technical aspects of estimating the subterms discussed in this paper. These designs were developed by using contrasts to derive a design matrix for deviation contrast parameters and by using a redefinition matrix to redefine the parameters into the different subterms. This was done using the program GLIMMAT, a set of SAS macros using the SAS matrix language IML to create design matrices with contrasts and for estimating

Generalized Linear Models (see chapter 9). The GLIMMAT macros and other programs below are available on request⁷.

Specifying a redefinition matrix is a flexible method, but it requires a basic knowledge of matrix algebra. Fortunately, the design matrices of the redefined parameters have a relatively simple structure. Rather than present formulas, section A.2 contains an SPSS program for specifying these designs and incorporating them in the SPSS LOGLINEAR program. This SPSS program forms a practical means for estimating the parameters discussed here, particularly since the GLIMMAT macros are not very efficient for estimating models⁸.

If no special restrictions are applied to the subterms and if standard errors of the parameter estimates are not important, then the model can be estimated with whatever contrast is most practical. The parameters can then be transformed to deviation contrast parameters by normalizing the full set of parameters. For example, the program GLIM uses the simple contrast with the first category as contrast category (intrinsically aliased parameters). For an interaction effect, the parameters can be arranged in a table with zeros for category 1 of both variables. The parameters can then be normalized by subtracting the row mean and the column mean from each cell, and adding the overall mean.

However, this will only work for the highest order effects. If a three-way table is being analyzed, then the second degree interaction effects will not be correct if transformed in this way (cf. Long 1984, on estimable functions). The 3rd degree interaction effect can be transformed along these lines, by first normalizing for the row and column variables, then for the group variable. To derive correct 2nd degree interaction effects however, the mean values for the two variables that were subtracted from the 3rd degree interaction effects must first be added to estimates for the 2nd degree effects, before normalizing them. In such cases, it will be easier to directly estimate the parameters.

APPENDIX A.1: SPECIFYING A REDEFINITION MATRIX

Redefining parameters requires the use of elementary matrix operations. A redefinition matrix **D** must be defined in the form of a table, containing the original parameters in the columns and the new parameters in the rows. Each row of this table indicates how a new parameter is composed as a linear combination of original parameters. With the redefinition matrix, the original design matrix **X** can be transformed into a new design matrix **Z**, using $\mathbf{Z} = \mathbf{XD}(\mathbf{DD}')^{-1}$ (cf. chapters 7 and 8).

As an example, we present the redefinition matrix for deriving the identifiable parameters of the overall diagonal, diagonal deviation, and symmetric deviances subterms, from an existing design matrix for the symmetric interaction parameters of a 5 by 5 table.

The first row of the redefinition matrix relates to the identifiable overall diagonal parameter ζ_{11} . Equation (6) defines this parameter as the mean value of the values on the diagonal of the full set of symmetric interaction parameters. For our example with 5 categories, that

would be: $\zeta_{11} = \frac{1}{5} \sum_{i=1}^5 \sigma_{ii}$. However, σ_{55} is a redundant parameter, so equation (6) must be re-

specified in terms of identifiable σ_{ij} parameters only. It can be shown that equation (6) can be rewritten as⁹:

$$\zeta_{11} = \frac{2}{5} \sum_{i=1}^{i=4} \sum_{j=1}^{j=4} \sigma_{ij} \quad (\text{a.1})$$

Redefinition matrix for transforming the design matrix for symmetric interaction (deviation contrast, category 5 redundant) into a new design matrix with an overall diagonal subterm, a diagonal deviation subterm, and a symmetric deviances subterm

Redefined parameters	Original parameters									
	σ_{11}	σ_{12}	σ_{13}	σ_{14}	σ_{22}	σ_{23}	σ_{24}	σ_{33}	σ_{34}	σ_{44}
ζ_{11}	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$
δ_{11}	$\frac{1}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$
δ_{22}	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$\frac{1}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$
δ_{33}	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$\frac{1}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$
δ_{44}	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$\frac{1}{3}$
ω_{12}	$\frac{1}{6}$	$\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$	$\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$
ω_{13}	$\frac{1}{6}$	$-\frac{1}{6}$	$\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$	$\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$
ω_{14}	$\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$	$\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$	$\frac{1}{6}$
ω_{23}	$-\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{6}$	$-\frac{1}{6}$	$\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$
ω_{24}	$-\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$	$\frac{1}{6}$	$-\frac{1}{6}$	$\frac{1}{6}$	$-\frac{1}{6}$	$-\frac{1}{6}$	$\frac{1}{6}$

Row 1 of the redefinition matrix is an expression of equation (a.1): the identifiable overall diagonal parameter is equal to the sum of the identifiable symmetric interaction parameters, times $\frac{2}{3}$.

Rows 2 to 5 of the redefinition matrix pertain to the identifiable diagonal deviation parameters, which are defined as $\delta_{ii} = \sigma_{ii} - \zeta_{11}$, for $i = 1$ to $r - 1$. This can be implemented by first entering the negative value of row 1 in rows 2 to 5 of the redefinition matrix, thus incorporating $-\zeta_{11}$. Then, the value of 1 can be added to the cell for the appropriate σ_{ii} parameter. The rows therefore have the value of $\frac{1}{3}$ for the cell corresponding with σ_{ii} , and $-\frac{2}{3}$ elsewhere.

Rows 6 to 10 pertain to the symmetric deviances parameters ω_{ij} . According to equation (10), these are equal to: $\omega_{ij} = \sigma_{ij} - \zeta_{11} - \delta_{ij}$. For the off-diagonal cells for which ω_{ij} is defined and for 5 categories, $\zeta_{ij} = -\frac{1}{4}\zeta_{11}$ (equation (7)) and $\delta_{ij} = -\frac{1}{3}\delta_{ii} - \frac{1}{3}\delta_{jj}$ (equation (9)). Expressed in terms of identifiable parameters, $\omega_{ij} = \sigma_{ij} + \frac{1}{4}\zeta_{11} + \frac{1}{3}\delta_{ii} + \frac{1}{3}\delta_{jj}$.

Step 1 is to place the value of 1 in the cells of rows 6 to 10 for which the σ_{ij} parameter has the same subscript as the ω_{ij} parameter being defined. Next, $\frac{1}{4}\zeta_{11}$ is incorporated by adding row 1, divided by 4, to rows 6 to 10. Similarly, the appropriate rows corresponding with δ_{ii} and δ_{jj} , divided by 3, are added. Rows 6 to 10 of the redefinition matrix therefore have the value of $\frac{5}{6}$ for the cell for which the subscript of ω_{ij} matches that of σ_{ij} , $\frac{1}{6}$ for the two cells corresponding with δ_{ii} and δ_{jj} , and $-\frac{1}{6}$ elsewhere.

The following is a SAS PROC IML function module for creating a redefinition matrix. The argument R specifies the number of rows and columns, and the function returns a $\frac{1}{2}r(r-1)$ by $\frac{1}{2}r(r-1)$ redefinition matrix.

```
start rdfsym(R);
```

```

* initialize the matrix;
nRw=R*(R-1)/2;
rdf=j(nRw,nRw,0);

* overall diagonal parameter;
rdf[1, ]=2/R;

* diagonal deviation paras;
rdf[2:R, ]=-2/R;
do i=1 to R-1;
  j=1+(i-1)*(R-1)-(i-2)*(i-1)/2; * column number for appropriate sigma;
  rdf[i+1,j]=rdf[i+1,j]+1;
end;

* symmetric deviances;
k=R+1;
do i=1 to R-3; * para[R-2,R-1] is redundant;
  do j=i+1 to R-1;
    colnr=(i-1)*(R-1)-i*(i-1)/2+j; * column number for appropriate sigma;
    rdf[k,colnr]=1;
    rdf[k, ]=rdf[k, ]+rdf[1, ]/(R-1)+rdf[i+1, ]/(R-2)+rdf[j+1, ]/(R-2);
    k=k+1;
  end;
end;
* print rdf[format=6.3];
return (rdf);
finish;

```

The following program using the GLIMMAT macros (see chapter 9) can be used to estimate the parameters for table 2, assuming that the function module `rdfSym` has been stored in the IML library "glimmat.symDev" in an earlier program. Table 1 is read as the variable "freq" with 36 cases. The classification variables are then generated using the (user defined) macro "%gl", with values 1 to 6 in blocks of 6 (husb) and values 1 to 6 in blocks of 1 (wife). The "%glimmat" macro creates a design matrix for the main effects of "husb" and "wife", using the deviation contrast with the highest category as the redundant category (by default). The "%square" macro creates a design matrix for symmetric interaction and skew symmetric interaction of "husb" and "wife", and appends this to the previous design matrix. Using the "rdfSym" function module, a redefinition matrix "rDef" is created and used to transform "syms", the section of the design matrix pertaining to the symmetric interaction parameter, into "newdes". This new section of the design matrix is then placed in the design matrix itself, and new parameter labels are also specified. Finally, the parameters can be estimated using the "%glimest" macro, which by default estimates a loglinear model.

```

title 'Analysis of religious assortative marriage in the Netherlands '
      'in 1956';

%include glimmat glimsym glimest;

data nl56;
input freq @@;
freq=freq+.5; * .5 added due to empty cells;
wife=%gl(6,1);
husb=%gl(6,6);
/* categories: Orthodox Pr, Liberal Pr, other, none, Jewish, Catholic */
cards;
  6533   1381    79    290      0    210
  1403  20450   679   2385      7   1973
    85    582   1036    373      2    232
   321   3033   522  10333     17   1675
    1     12     3     21     49     10
   155   1697   218   1270      9  35226
;

proc iml;

```

```

%glimmat(depend=freq,model=husb wife);
%square(row=husb,col=wife,model=sym skew);

* get the "rdfSym" module to redefine the symmetric interaction paras;
reset storage=glimmat.symDev;
load module=(rdfSym);
rDef=rdfSym(6);

* perform the redefinition;
symcols=12:26; * columns of the design matrix for symmetric interaction;
syms=design[ ,symcols];
newdes=syms*rDef`*inv(rDef*rDef`);

* replace the old design with the new one;
design[ ,symcols]=newdes;

* define new parameter labels and insert them;
newlabs={'diag(0)', 'diag(1)', 'diag(2)', 'diag(3)', 'diag(4)', 'diag(5)',
'symdev(1,2)', 'symdev(1,3)', 'symdev(1,4)', 'symdev(1,5)',
'symdev(2,3)', 'symdev(2,4)', 'symdev(2,5)', 'symdev(3,4)', 'symdev(3,5)'};
label[symcols, ]=newlabs;

* estimate the model;
%glimest;

```

APPENDIX A.2: SPECIFYING THE DESIGN MATRIX DIRECTLY

Using a redefinition matrix is flexible and direct, since it allows new parameters to be defined as any linear combination of existing parameters. In practise it is not all that difficult, since specifying a redefinition matrix is straightforward, and transforming the design matrix is taken care of by the matrix algebra software. However, it turns out that the design matrix for the redefined effects has a relatively simple structure. It will often be practical to specify design vectors directly in a data step, and then to enter them as covariates in the loglinear program. The following program shows how this can be done using SPSS.

The program makes use of the command "vector" to create an array of variables representing columns of the design matrix. For example, the command "vector d(5)" will create 5 variables: d1, d2, d3, d4, d5. In the program below however, the number of variables in each of the vectors is specified as 200, in order to avoid having to change these statements if a different sized table is to be analyzed. Two variables "R" and "C" are defined at the beginning of the program, to indicate the number of row and column categories respectively. The values of "R" and "C" are used in "loop" structures to determine how many variables are actually in a vector. The following vectors are created to correspond with each subterm discussed here:

subterm	vector	number of variables
σ_{ij}	sig(15)	$R * (R-1) / 2$
v_{ij}	nu(10)	$((R-1) * (R-2)) / 2$
ζ_{ii}	z11	1
δ_{ij}	d(5)	$(R-1)$
ω_{ij}	ome(9)	$((R-1) * (R-2)) / 2 - 1$

The program starts by reading in table 1 as the variable "freq", with 36 cases. The classification variables are then calculated as "row", with values 1 to 6 in blocks of 6, and "col",

with values 1 to 6 in blocks of 1. At this point, the variables corresponding with columns of the design matrix are defined in the "loop" structures. After the "vectors" have been defined, the label itself is read. A "weight by freq" statement is necessary before the loglinear procedure, to indicate that cell frequencies rather than raw data are being used.

In the loglinear procedure itself, these variables are specified as covariates in the "loglinear" statement, and entered in the model in the "design" statement. Note that the covariates must be specified individually in the "design" statement: the use of "to" is not allowed there. This program estimates three versions of the saturated model, first with a normal interaction effect (subtable *i* in table 2), then with the interaction effect redefined into symmetric and skew symmetric subterms (subtables *ii* and *iii* respectively), then with overall diagonal, diagonal deviation, symmetric deviances and skew symmetric subterms (subtables *iv*, *v*, *vi*, and *iii* respectively).

The program can be easily adapted to analyze other problems. A different sized table can be incorporated by specifying the appropriate value for "R", and by modifying the "loglinear" and "design" statements to take the new number of variables in each "vector" into account (a comment above each "vector" statement specifies the number of variables as "nvecs").

```
set length=none

data list free / freq

compute R=6
compute C=R

* create the classification variables
compute row = 1+mod(trunc(($casenum-1)/C),R)
compute col = 1+mod(trunc(($casenum-1)/1),C)

* small cell counts ==> add .5 to the frequencies
compute freq=freq+.5

* nvecs=R*(R-1)/2
vector sig(200)
compute k=1
loop i=1 to R-1
+ loop j=i to R-1
+   compute sig(k)=0
+   if ((row=i and col=j) or (row=j and col=i)) sig(k)= 1
+   if ((row=i or row=j) and (col=R)) sig(k)=-1
+   if ((row=R) and (col=i or col=j)) sig(k)=-1
+   if ((row=R and col=R) and (i^=j)) sig(k)= 2
+   if ((row=R and col=R) and (i =j)) sig(k)= 1
+   compute k=k+1
+ end loop
end loop

* nvecs=((R-1)*(R-2))/2
vector nu(200)
compute k=1
loop i=2 to R-1
+ loop j=1 to i-1
+   compute nu(k)=0
+   if (row=i and col=j) nu(k)= 1
+   if (row=j and col=i) nu(k)=-1
+   if (row=i and col=R) nu(k)=-1
+   if (row=j and col=R) nu(k)= 1
+   if (row=R and col=i) nu(k)= 1
+   if (row=R and col=j) nu(k)=-1
+   compute k=k+1
+ end loop
end loop
```

```

* nvecs=1
compute z11=-1/(R-1)
if (row=col) z11=1

* nvecs=(R-1)
vector d(200)
loop i=1 to R-1
+ compute d(i)=0
+ if (row=i or col=i) d(i)=d(i)-1/(R-2)
+ if (row=R or col=R) d(i)=d(i)+1/(R-2)
+ if (row=i and col=i) d(i)= 1
+ if (row=R and col=R) d(i)=-1
end loop

* nvecs=((R-1)*(R-2))/2 - 1
vector ome(200)
compute k=1
loop i=1 to R-3
+ loop j=i+1 to R-1
+ compute ome(k)=0
+ if ((row=i and col=j) or (row=j and col=i )) ome(k)= 1
+ if ((row=i and col=R) or (row=R and col=i )) ome(k)=-1
+ if ((row=R-2 and col=R-1) or (row=R-1 and col=R-2)) ome(k)=-1
+ do if (j <= R-3)
+ if ((row=j and col=R) or (row=R and col=j )) ome(k)=-1
+ if ((row=R-2 and col=R) or (row=R and col=R-2)) ome(k)= 1
+ if ((row=R-1 and col=R) or (row=R and col=R-1)) ome(k)= 1
+ else if (j=R-2)
+ if ((row=R-1 and col=R) or (row=R and col=R-1)) ome(k)= 1
+ else if (j=R-1)
+ if ((row=R-2 and col=R) or (row=R and col=R-2)) ome(k)= 1
+ end if
+ compute k=k+1
+ end loop
end loop

* Religious Assortative Marriage, Netherlands, 1956
begin data
6533 1381 79 290 0 210
1403 20450 679 2385 7 1973
85 582 1036 373 2 232
321 3033 522 10333 17 1675
1 12 3 21 49 10
155 1697 218 1270 9 35226
end data

```

weight by freq

```

loglinear row col (1,6) with sig1 to sig15, nu1 to nu10,
z11, d1 to d5, ome1 to ome9
/ noprint=default
/ print=estim
/ criteria=delta(0)
/ design=row, col, row by col
/ design=row, col,
sig1 sig2 sig3 sig4 sig5 sig6 sig7 sig8 sig9 sig10
sig11 sig12 sig13 sig14 sig15
nu1 nu2 nu3 nu4 nu5 nu6 nu7 nu8 nu9 nu10
/ design=row, col,
z11 d1 d2 d3 d4 d5
ome1 ome2 ome3 ome4 ome5 ome6 ome7 ome8 ome9
nu1 nu2 nu3 nu4 nu5 nu6 nu7 nu8 nu9 nu10

```

Notes

¹ The designs discussed here can be used in any model that is based on a design matrix, including generalized linear models (Nelder and Wedderburn 1972, Aitkin et al. 1989).

² The linear dependencies in equation (1) can be easily seen using an example in matrix form. Equation (1) can be written in matrix form as:

$$\boldsymbol{\eta} = \mathbf{A}\boldsymbol{\theta} \quad (i)$$

where $\boldsymbol{\eta}$ is a vector of log frequencies, $\mathbf{A}$ is a *model* or *incidence* matrix, and $\boldsymbol{\theta}$ is a matrix of *model* parameters. If variable a has 4 categories, then equation (i) would be:

$$\begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \\ \eta_4 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ \theta_4 \end{bmatrix} \quad (ii)$$

The linear dependency in equation (ii) can be seen in the fact that column 1 of the model matrix $\mathbf{A}$ can be obtained by adding columns 2 to 5.

³ The identifiable parameters $\boldsymbol{\beta}$ are defined as linear combinations of the model parameters using a contrast matrix $\mathbf{C}$:

$$\boldsymbol{\beta} = \mathbf{C}\boldsymbol{\theta} \quad (iii)$$

For example, the deviation contrast defines identifiable parameters as deviances from the mean of the model parameters: $\beta_i = \theta_i - \theta_{\cdot}$, where $\theta_{\cdot} = \frac{1}{r} \sum_{i=1}^r \theta_i$. Equation (iii) would then be written as:

$$\begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \end{bmatrix} = \begin{bmatrix} \frac{3}{4} & -\frac{1}{4} & -\frac{1}{4} & -\frac{1}{4} \\ -\frac{1}{4} & \frac{3}{4} & -\frac{1}{4} & -\frac{1}{4} \\ -\frac{1}{4} & -\frac{1}{4} & \frac{3}{4} & -\frac{1}{4} \end{bmatrix} \begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ \theta_4 \end{bmatrix} \quad (iv)$$

A contrast matrix $\mathbf{C}_{(ab)}$ for an interaction effect between variables a and b can be derived from the contrast matrices $\mathbf{C}_{(a)}$ and $\mathbf{C}_{(b)}$ for the separate effects of a and b , by using the Kronecker product: $\mathbf{C}_{(ab)} = \mathbf{C}_{(a)} \otimes \mathbf{C}_{(b)}$. The Kronecker product multiplies each element of $\mathbf{C}_{(a)}$ by each element of $\mathbf{C}_{(b)}$. In this way, $\mathbf{C}$ can be constructed for complex models, not just for the effects of a single variable.

Given $\mathbf{C}$, equation (i) can be transformed to an identifiable form:

$$\boldsymbol{\eta} = \mathbf{X}\boldsymbol{\beta} \quad (v)$$

where $\mathbf{X}$ is a full rank design matrix. If equation (v) is equivalent to equation (i), then it must be so that $\mathbf{A} = \mathbf{X}\mathbf{C}$, since $\boldsymbol{\beta} = \mathbf{C}\boldsymbol{\theta}$. The full rank design matrix $\mathbf{X}$ can therefore be found using:

$$\mathbf{X} = \mathbf{A}\mathbf{C}'(\mathbf{C}\mathbf{C}')^{-1} \quad (vi)$$

⁴ The most obvious way to fit diagonal parameters for a quasi-independence model is to create a dummy for each diagonal cell. The diagonal parameters then turn out to use a simple contrast between the diagonal cell and the mean value of off-diagonal cells, so that they indicate the log odds of immobility versus mobility, or inmarriage versus outmarriage. The full

set of parameters estimated in this fashion has the values of the identifiable parameters d_i ($i = 1$ to r) on the diagonal cells of and r by r table, and 0 elsewhere.

This full set of parameters can be transformed to deviation contrast parameters γ_{ij} by subtracting the row mean, subtracting the column mean, and adding the overall mean to each cell of this table. Both the row and column means of the table are equal to $\frac{1}{r}d_+$, and the overall

mean equals $\frac{1}{r^2}d_+$, where $d_+ = \sum_{i=1}^r d_i$. So for cells on the diagonal,

$$\begin{aligned}\gamma_{ii} &= d_i - \frac{1}{r}d_i - \frac{1}{r}d_i + \frac{1}{r^2}d_+ \\ &= \frac{r-2}{r}d_i + \frac{1}{r^2}d_+\end{aligned}\tag{vii}$$

and for off-diagonal cells:

$$\gamma_{ij} = -\frac{1}{r}d_i - \frac{1}{r}d_j + \frac{1}{r^2}d_+, \text{ for } i \neq j\tag{viii}$$

These γ_{ij} parameters will be equal to $\zeta_{ij} + \delta_{ij}$. The overall diagonal parameter ζ_{ii} will be equal to the mean of γ_{ii} :

$$\begin{aligned}\zeta_{ii} &= \frac{1}{r} \sum_{i=1}^r \gamma_{ii} \\ &= \frac{1}{r} \sum_{i=1}^r \left(\frac{r-2}{r}d_i + \frac{1}{r^2}d_+ \right) \\ &= \frac{1}{r} \left(\frac{r-2}{r} \sum_{i=1}^r d_i + \frac{1}{r}d_+ \right) \\ &= \frac{r-1}{r^2}d_+\end{aligned}\tag{ix}$$

From (ix), it can be derived that

$$\begin{aligned}\delta_{ii} &= \gamma_{ii} - \zeta_{ii} \\ &= \frac{r-2}{r}d_i + \frac{1}{r^2}d_+ - \frac{r-1}{r^2}d_+ \\ &= \frac{r-2}{r}d_i + \frac{2-r}{r^2}d_+\end{aligned}\tag{x}$$

⁵ BIC can be calculated for large tables by $BIC = L^2 \cdot df \cdot \log(N)$, where N is the number of cases.

⁶ Because of small cell counts for the Jewish category in table 1, .5 was added to all cells when estimating the parameters.

⁷ To obtain the programs used in this paper, contact John Hendrickx, Department of Sociology, University of Nijmegen, P.O. Box 9108, 6500 HK Nijmegen, the Netherlands; e-mail u211310@hnykuh11.urb.kun.nl. The GLIMMAT macros are also available by sending e-mail to "listserv@uicvm" on bitnet, or to "listserv@uicvm.cc.uic.edu" on internet, with the

text "get glimmat package" (no subject line). The GLIMMAT files can also be obtained by FTP to "uicvm.uic.edu" (user "anonymous", no password necessary), in the directory "uicstat". The file "glimmat.\$package" provides information on which files to download.

⁸ Unfortunately, SAS PROC CATMOD does not allow covariates to be included in loglinear models, so there is no easy way of using the design matrix generated by the GLIMMAT macros in a CATMOD program.

⁹ σ_{rr} is equal to the negative sum of the redundant parameters in the last column of the table: $\sigma_{rr} = -\sum_{i=1}^{r-1} \sigma_{ir}$. Because $\sigma_{ir} = -\sum_{j=1}^{r-1} \sigma_{ij}$, this can be rewritten as $\sigma_{rr} = \sum_{i=1}^{r-1} \sum_{j=1}^{r-1} \sigma_{ij}$. And given that the parameters are symmetric, σ_{rr} can be expressed in terms of identifiable parameters as two times the identifiable symmetric interaction parameters, minus the identifiable parameters on the diagonal of the table (to prevent these from being counted twice):

$$\sigma_{rr} = 2 \sum_{i=1}^{r-1} \sum_{j=1}^{r-1} \sigma_{ij} - \sum_{i=1}^{r-1} \sigma_{ii} \quad (xi)$$

The identifiable overall diagonal parameter, defined as the mean value of the values on the diagonal of the full set of symmetric interaction parameters, can therefore be expressed in terms of identifiable parameters as:

$$\zeta_{11} = \frac{1}{r} \left(\sum_{i=1}^{r-1} \sigma_{ii} + \sigma_{rr} \right) = \frac{1}{r} \left(\sum_{i=1}^{r-1} \sigma_{ii} + 2 \sum_{i=1}^{r-1} \sum_{j=1}^{r-1} \sigma_{ij} - \sum_{i=1}^{r-1} \sigma_{ii} \right) = \frac{2}{r} \sum_{i=1}^{r-1} \sum_{j=1}^{r-1} \sigma_{ij} \quad (xii)$$

Chapter 9

Using SAS Macros and PROC IML to Create Special Designs for Generalized Linear Models

Abstract

Generalized linear models (GLMs) incorporate several well known statistical models, such as regression, analysis of variance, logit, probit, loglinear, in a single statistical framework. The SAS® sample library contains a set of macros for emulating the program GLIM (Generalized Linear Interactive Modelling). I have developed a set of macros that improve upon the originals macros in several ways. The macros run within PROC IML, which makes it possible to modify the design matrix or to manipulate the results using IML statements. The paper discusses an application of these macros and PROC IML in order to apply restrictions to the trend in a loglinear model. The macros are described in Appendix A and the programs for the example are in Appendix B. The GLIMMAT macros themselves are available from "listserv@uicvm" on bitnet, or "listserv@uicvm.cc.uic.edu" on internet, by sending the text "get glimmat package" (no subject line). The GLIMMAT files can also be obtained by FTP to "uicvm.uic.edu" (user "anonymous", no password necessary), in the directory "uicstat". The file "glimmat.\$package" provides information on which files to download.

Introduction

Generalized linear models extend the framework of classic regression and analysis of variance to allow for distributions of the dependent y variate other than normal, and by letting the fitted values be a link function of the linear predictors (see Nelder and Wedderburn 1972, McCullagh and Nelder 1983, Aitkin et al. 1989). In this way GLMs incorporate a number of well known models in a single statistical framework: a.o. regression, analysis of variance, logit, probit, and loglinear models. The SAS® sample library contains a file GLIM SAS, which uses macros and PROC NLIN or PROC IML to emulate the GLIM program developed by the Royal Statistical Society. I have written macros programs that improve upon the macros in GLIM SAS in several ways: %GLIMMAT, %SQUARE, and %GLIMEST.

The macro %GLIMMAT generates a full rank design matrix, with the option of specifying the contrast (i.e. type of parametrization) for each factor in each term of the model statement.

It combines the functions of the macros %INITIAL, %CLASS, %DIRECT and %INTERAC in the GLIM SAS file. The macro %SQUARE is used to generate designs for square table data: halfway effects, difference effects, symmetric interaction effects, and skew symmetric effects. It must be used together with %GLIMMAT. The macro %GLIMEST can be used to estimate a large number of generalized linear models (GLMs), using iteratively reweighted least squares. Estimation can take place with either PROC IML or PROC NLIN, using sections of the %GLIM2 and %GLIM macros in the GLIM SAS file. The macros require SAS/IML® and SAS/STAT®, version 6. These macros are described in Appendix A.

The most important advantage of these alternative macros is that they create the design matrix using PROC IML, rather than with data step commands. This makes it possible to modify the design matrix prior to estimation in order to impose special restrictions. The results are also presented using PROC IML – if PROC NLIN is used for estimation, its own output is re-routed. Results are therefore accessible as matrices and can be manipulated using IML commands. Other advantages are a single model statement, the option of specifying contrasts for each variable in each term, clear labelling of parameters.

I have found these macros to be useful tools for developing designs with special restrictions. For small problems, estimation speed and memory requirements are acceptable (on a fairly fast VM/CMS mainframe). For larger problems, the design matrix can be written to a SAS dataset or text files for use in other programs.

As an example of such a special design, I would like to discuss trend smoothing in loglinear models, by imposing moving average restrictions of degree m to parameters using the difference contrast. Calculating a moving average of time series data is a standard technique for smoothing trends and removing seasonal effects. An analogous design for loglinear models is fairly easy to implement using PROC IML and the %GLIMMAT macros.

In the paragraphs below, I will discuss how a moving average restriction can be applied to difference contrast parameters, how a full set of parameters can be derived from the reduced set of estimated parameters, and when models with moving average restrictions are nested. This is illustrated by a sample application on a 4 by 4 by 7 table of husband's denomination by wife's denomination by year of marriage, for Austria, 1914 to 1920. The programs are included in Appendix B.

Imposing m degree moving average restrictions on difference contrast parameters

BACKGROUND

I am doing research on trends and patterns of religious homogamy, using loglinear models on tables of denomination husband by denomination wife by year of marriage. Religious homogamy is measured by the second order effects of denomination husband by denomination wife and the presence of trends can be detected by testing for significance of the third order effects of denomination husband by denomination wife by time. Given that there are changes in homogamy, I want to smooth away minor fluctuations which are only due to small cell counts.

To do this, I decided to impose a moving average restriction on parameters based on the backward difference contrast. The use of contrasts is a flexible method for imposing restrictions on models with categorical predictor variables. Such models specify a parameter for

each category of the predictor variables and for all combinations of categories. This full set of parameters is referred to here as "model parameters". The vector of model parameters is denoted by θ , and an element by θ'_i , where x is the variable (or combination of variables in an interaction) the parameter refers to, and i is the category (combination of categories). Corresponding with the model parameters is a "model matrix" A , composed of zeros and ones.

Not all model parameters can be estimated without some further restrictions, because some model parameters are linearly dependent on others. To estimate the model, one parameter per category of each variable in each term must be dropped. The most common restriction is to let the sum of the parameters equal zero, after which one parameter can be dropped. This is referred to here as the deviation contrast; other terms are ANOVA restrictions or the centered contrast. However, many other restrictions, or "contrasts", are conceivable. A contrast specifies a set of identifiable parameters β as linear combinations of the model parameters (Finn 1974, Bock 1975, Lammers 1984). With the resulting contrast matrix, the model matrix A can be transformed into a full rank design matrix X . How this is done is discussed more fully below.

MOVING AVERAGE RESTRICTIONS ON DIFFERENCE CONTRAST PARAMETERS

The difference contrast defines the identifiable parameters as the corresponding model parameter minus the previous model parameter (for the second to the last category of the factor). So for a factor t with w categories, there are $w-1$ identifiable difference parameters:

$$\beta'_i = \theta'_{i+1} - \theta'_i, \text{ for } i = 1 \text{ to } w-1 \quad (1)$$

The next step is to impose the moving average restriction. Calculating an m degree moving average involves taking the average of successive groups of m difference parameters. Therefore, if the new parameters are τ'_i , then $w-m-1$ restricted parameters can be calculated:

$$\tau'_i = \frac{1}{m} \sum_{j=1}^m \beta'_{i+j-1}, \text{ for } i = 1 \text{ to } w-m \quad (2)$$

By applying an m degree moving average restriction, $m-1$ degrees of freedom are gained per effect in which the factor t is included. A first degree MA restriction can be regarded as unrestricted, while a $w-1$ degree MA restriction will result in a single parameter, which indicates the average difference between categories. If the categories are equally spaced, this will be equal to a linear trend parameter. The main usefulness of imposing m degree MA restrictions is the situation in between, when the trend is not linear, but many minor fluctuations in the unrestricted trend are not substantial. By removing meaningless fluctuations, a clearer representation of the trend is obtained, thus facilitating interpretation.

Note that it might seem to be a logical step to combine equations (1) and (2) and to specify that:

$$\tau'_i = \frac{\theta'_{i+m} - \theta'_i}{m}, \text{ for } i = 1 \text{ to } w-m \quad (3)$$

However, specifying the restricted parameters in this way generates a different design matrix, than when a moving average restriction is applied to difference contrast parameters. The resulting parameters are in fact precisely as the equations specify them. This is easiest to see in

the situation where a $w-1$ degree MA restriction is applied. Applying equation (3) with $m=6$ to a factor t with $w=7$ categories results in a design matrix which estimates a single parameter. In the full set of parameters for this design, the parameter in the last category is 6 times the value of the first parameter, and the rest are zero (cf. the design matrix on the left in table 1). On the other hand, if a 6th degree moving average restriction is applied to difference contrast parameters, the increase from category to category in the full set of parameters is equal (cf. the design matrix on the right).

Table 1
Correct and incorrect design matrices for a 6th degree moving average restriction on a factor with 7 categories

<i>Incorrect</i>	<i>Correct</i>
Design matrix based on a directly specified contrast (equation (3))	Design matrix based on a moving average restriction of difference contrast parameters (equations (1) and (2))
$\begin{bmatrix} -3 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 3 \end{bmatrix}$	$\begin{bmatrix} -3 \\ -2 \\ -1 \\ 0 \\ 1 \\ 2 \\ 3 \end{bmatrix}$

IMPLEMENTING AN M DEGREE MOVING AVERAGE RESTRICTION

To create a design matrix for a model with an m degree moving average restriction, the first step is to create a design matrix for estimating difference parameters. This can be done by defining a contrast matrix C , and using this to derive the design matrix X . The contrast matrix forms a table with the difference parameters β in the rows, and the model parameters in the columns, according to equation (1). For example, for a factor t with 7 categories, the contrast matrix C for difference parameter β_i ($i=1$ to 6) would be:

	θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	θ_7
β_1	-1	1					
β_2		-1	1				
β_3			-1	1			
β_4				-1	1		
β_5					-1	1	
β_6						-1	1

Zeros have been left blank to enhance clarity.

With C the design matrix X can be derived from a model matrix A , which is composed of ones and zeros, based on categories of the factor t . This can be done by

$$X = AC'(CC')^{-1} \quad (4)$$

The second step is to impose the m degree moving average restriction on the difference parameters. This is done by constructing a redefinition matrix R , which maps the new restricted parameters τ_i from the existing difference parameters β_i , according to equation (2). For a factor t with 7 categories and a 2nd degree MA restriction, the redefinition matrix R would be:

	β_1	β_2	β_3	β_4	β_5	β_6
τ_1	$\frac{1}{2}$	$\frac{1}{2}$				
τ_2		$\frac{1}{2}$	$\frac{1}{2}$			
τ_3			$\frac{1}{2}$	$\frac{1}{2}$		
τ_4				$\frac{1}{2}$	$\frac{1}{2}$	
τ_5					$\frac{1}{2}$	$\frac{1}{2}$

Zeros have been left blank to enhance clarity.

With R , the design matrix X for difference parameters can be transformed into a design matrix P for m degree MA restricted parameters by:

$$P = XR'(RR')^{-1} \quad (5)$$

P can be included in the complete design matrix to estimate m degree moving average parameters of the factor t . Often the MA restriction will not be applied to the effects of t itself, but to the effects of t in some interaction effect. The design matrix for interaction effects can be constructed using a horizontal direct product. The horizontal direct product of $X_{(1)}$ and $X_{(2)}$ calculates the elementwise matrix product of each column of $X_{(1)}$ with each column of $X_{(2)}$.

CALCULATING THE FULL SET OF PARAMETERS

Applying a moving average restriction wins degrees of freedom, but the interpretation of the estimated parameters would be difficult. A solution is to calculate a full set of model parameters, which will then have a smoothed trend. The full set of parameters must be calculated using the contrast and redefinition matrices, or by deleting other effects from the fitted values. I will discuss this latter method first.

An easy way to calculate these parameters is to take the log expected frequencies and to subtract the parameters of the other effects. For example, take the following model for a three way table (of the variables a by b by t , with r , c , and w categories respectively):

$$\log(F_{abc}) = \beta^* + \beta_i^a + \beta_j^b + \beta_k^c + \beta_{ij}^{ab} + \beta_{jk}^{bc} + \beta_{ik}^{ac} + \beta_{ijk}^{abc} \quad (6)$$

The term β_{ijk}^{abc} refers to the third order interaction of changes of the association between a and b for each category of variable t . The parameters relating to t in this third order interaction will have an m th degree moving average restriction applied to difference contrast parameters. All β effects have the deviation contrast (sum of zero). The redundant parameters for all terms except β_{ijk}^{abc} can be calculated quite simply, given that the sum of the parameters over the categories of a variable equal zero. So given the full set of parameters for all other

terms, a full set of parameters for the term $\beta_y^{ab} \tau_i^t$ can be calculated by subtracting the appropriate parameter values from $\log(F_{ijk})$.

I have found that it is a good practise to calculate a full set of parameters in this way when experimenting with restricted designs. Things can go wrong and this is one way of tracking down mistakes. Once the full set of parameters has been calculated, one can check whether the estimated parameters can be derived from the full set as intended.

As stated above, a second way of calculating a full set of parameters is to make use of the contrast matrix **C**. A vector of model parameters θ can be derived from the vector of parameter estimates β by:

$$\theta = C'(CC')^{-1}\beta \quad (7)$$

Note that **C** must be the contrast matrix for all effects contained in β . The vector β will usually be a subvector of the parameter estimates.

The %GLIMMAT macro does not calculate a contrast matrix for an interaction effect. However, the contrast matrix **C** for the interaction effect of factor *a* with contrast matrix $C_{(1)}$ and factor *b* with contrast matrix $C_{(2)}$ can be calculated by calculating the Kronecker product (direct product) of $C_{(1)}$ and $C_{(2)}$:

$$C = C_{(1)} \otimes C_{(2)}$$

The Kronecker product multiplies each element of $C_{(2)}$ by each element of $C_{(1)}$. (The IML operator for the Kronecker product is “@”).

As noted above, imposing an *m* degree difference restriction entails two steps. First, using equation (1), the difference contrast is imposed on the model parameters θ , using contrast matrix **C**, to derive the vector of difference parameters β . In matrix notation, equation (1) can be written as: $\beta = C\theta$. Then, using equation (2), an *m* degree moving average restriction is imposed on the difference parameters β using the redefinition matrix **R** to derive restricted parameters τ . Equation (2) can be written as: $\tau = R\beta$.

So, given a vector τ of *m* degree MA parameter estimates, either for a single factor or holding all other variables in an interaction term constant, the difference parameters β can be derived by: $\beta = R'(RR')^{-1}\tau$. Then, the full set of parameters θ can be derived from β by: $\theta = C'(CC')^{-1}\beta$.

If the factor *t* on which the MA restrictions have been applied is part of an interaction effect, then the above operation could be performed for all combinations of the categories of the other variables. In a three way interaction, the vector τ would relate to τ_{ijk}^{ab} for *a*=1 and *b*=1, for *a*=1 and *b*=2, etc. This would be cumbersome, and a better method is to use the complete contrast matrix for the interaction. The contrast matrix **G** for the interaction effect of factors *a* and *b* can be calculated from their respective contrast matrices using the Kronecker product, e.g. $G = C_{(1)} \otimes C_{(2)}$.

The contrast/redefinition matrix **K** for the first step would then be: $K = G \otimes R$. With **K**, a full set of parameters is derived for factors *a* and *b*, but only the difference parameters have been derived for the factor *t*. For the second step, the “contrast” matrix **H** for factors *a* and *b* will therefore be based on identity matrices: $H = I(r) \otimes I(c)$, where *r* and *c* are the number of categories of factors *a* and *b*. The complete contrast matrix **L** can be calculated with $L = H \otimes C$, and with **L**, the full set of parameters for the interaction effect can be calculated.

When applying successive m degree moving average restrictions, it can turn out that a restricted model with more degrees of freedom has a *lower* likelihood ratio L^2 than a less restricted model. This is a result of the fact that models with higher degree MA restrictions are not always nested under models with lower degree MA restrictions. If the models are nested, then it is possible to write parameters with a higher degree restriction as linear combination of parameters with a lower degree restriction, since the expanded model contains all effects of the reduced model. Therefore, a model with qm degree MA restriction ($q > 1$, $qm < w$, the number of categories of the variable) will be nested under a model with an m degree MA restriction, since the qm degree MA parameters λ'_j can be derived from the m degree MA parameters λ'_i . For example, for a factor t with 7 levels, 4th degree MA parameters λ'_i can be derived from 2nd degree MA parameters as follows:

$$\lambda'_1 = (\beta'_1 + \beta'_2 + \beta'_3 + \beta'_4) / 4 = ((\beta'_1 + \beta'_2) / 2 + (\beta'_3 + \beta'_4) / 2) / 2 = (\tau'_1 + \tau'_3) / 2$$

$$\lambda'_2 = (\beta'_2 + \beta'_3 + \beta'_4 + \beta'_5) / 4 = ((\beta'_2 + \beta'_3) / 2 + (\beta'_4 + \beta'_5) / 2) / 2 = (\tau'_2 + \tau'_4) / 2$$

$$\lambda'_3 = (\beta'_3 + \beta'_4 + \beta'_5 + \beta'_6) / 4 = ((\beta'_3 + \beta'_4) / 2 + (\beta'_5 + \beta'_6) / 2) / 2 = (\tau'_3 + \tau'_5) / 2$$

In general, for $q > 1$ and $qm < w$, κ'_i parameters ($i=1$ to $w-qm$) with a qm degree moving average restriction can be derived from τ'_i ($i=1$ to $w-m$) parameters with an m degree MA restriction, since:

$$\begin{aligned} \kappa'_i &= \frac{1}{qm} \sum_{j=1}^{qm} \beta'_{i+j-1} \\ &= \frac{1}{q} \sum_{f=1}^q \left\{ \frac{1}{m} \sum_{g=1}^m \beta'_{i+m(f-1)+g-1} \right\} \\ &= \frac{1}{q} \sum_{f=1}^q \tau'_{i+m(f-1)} \end{aligned} \quad (8)$$

However, it will not be possible to derive 3rd degree MA parameters from 2nd degree MA parameters, because they are both based on different sets of difference parameters.

EXAMPLE

In this example, I will show which concrete steps are necessary to impose an m -degree moving average restriction and what the results will be. The data are a 4 by 4 by 7 table of religious denomination husband by religious denomination wife by year of marriage for Austria between 1914 and 1920 as published by the Austrian Bureau of Statistics. Four religious denominations were discerned: Lutheran, Catholic, "other/none", and Jewish. The following loglinear model is to be estimated for this table:

$$\log(F_{ijk}) = \beta^* + \beta_i^h + \beta_j^w + \beta_k^y + \beta_{ik}^{hy} + \beta_{jk}^{wy} + \omega_{ij}^{hw} + \omega_{jk}^{hw} + \tau_i^y \quad (9)$$

The superscript " h " stands for husband's denomination (the variable `relH` in the program), superscript " w " stands for wife's denomination (`relW`) and " y " stands for year of marriage (`year` in the program). All of the β parameters use the deviation contrast (i.e. have

a sum of zero). The ω parameters, for the association between denomination husband and denomination wife, uses the deviation contrast but is also restricted to symmetry, for reasons of parsimony. The τ parameters uses the difference contrast, to which an m degree moving average restriction will be applied. The purpose now is to find a parsimonious description of the trend in religious assortative marriage, by applying as high as possible degree moving average restriction to the parameters of "year", in the third order interaction $\omega_{ij}^{hw} \tau_k^j$.

Using the program QSTDIF1 SAS in Appendix B for the first run, and QSTDIF2 SAS for subsequent runs, I estimated all 6 possible restricted moving average models for this table. Since these are population data with a large number of cases ($N=331486$), none of the models fit by the usual standard, the probability based on a chi-squared distribution of the likelihood ratio L^2 with df of the model. For situations like this, an alternative measure BIC, developed by Raftery (1985), is often used in comparable applications such as mobility research. BIC (Bayesian Information Coefficient) can be approximated for large samples by:

$$BIC = L^2 - df \log(N) \quad (10)$$

A BIC value less than zero indicates that by Bayesian criteria, the model is more likely than the saturated model. For comparison between several models, the one with the lowest BIC is preferable.

Table 2 shows the fit of the successive models. A 4th degree moving average restriction is optimal according to the BIC criterion. The L^2 rises to rather high levels, but all models would be acceptable by BIC: the effects that are deleted are significant, but only because of the size of the "sample". Note that the likelihood ratio L^2 rises with each successive restriction, but that this need not always be the case, since the models are not nested. Table 3 reports the parameter estimates for the third order term in table form. The values for other combinations of assortative marriage could be calculated quite easily by taking a column of table 3, arranging its values in the appropriate cells of a 4 by 4 table. The missing parameters can then be easily found, given that the parameters are symmetric and have a sum of zero over the rows and columns.

Interpreting the trend of religious assortative marriage on the basis of the estimates in table 3 is difficult. The 4th degree moving average restriction splits the 7 year period into three overlapping sub-periods, within each of which change is linear. For the combination "Lutheran: Lutheran", there was a drop in homogamy during the first sub-period, with little

Table 2
Models with successive degree moving average restrictions on the trend for religious assortative marriage in Austria, 1914 to 1920

		L^2	df	BIC
1	1st degree moving average (i.e. no restriction)	64	21	-203
2	2nd degree MA restriction	96	27	-247
3	3rd degree MA restriction	168	33	-251
4	4th degree MA restriction	222	39	-274
5	5th degree MA restriction	388	45	-183
6	6th degree MA restriction (i.e. linear trend)	455	51	-193

Table 3

Parameter estimates for third order term of denomination husband by denomination wife (restricted to symmetry) by year of marriage (4th degree moving average restriction)

Assortative marriage combination	cells	Relates to categories of variable "year"		
		5 $\leftrightarrow$ 1	6 $\leftrightarrow$ 2	7 $\leftrightarrow$ 3
Lutheran:Lutheran	(2,2)	-.287	-.020	-.002
Lutheran:Jewish	(2,3)	.310	.324	.155
Lutheran:other/none	(2,4)	.161	-.100	.059
Jewish:Jewish	(3,3)	-.329	-.317	-.116
Jewish:other/none	(3,4)	-.276	-.220	-.251
other/none:other/none	(4,4)	.059	.295	.057

change afterward. Jewish inmarriage, on the other hand, dropped during the entire period, but most strongly at the beginning. For a proper interpretation, the full set of parameters should be calculated. This was done with the program PARMS SAS in Appendix B.

Table 4 shows the full set of parameters derived from the actual estimates in table 3 (the symmetric counterparts of parameters, e.g. the values for "Lutheran:Catholic", "Jewish:Catholic", etc., have been excluded to enhance clarity). Figure 1 shows a plot of the conditional association between denomination husband and denomination wife, i.e. $\omega_y^{hw} + \omega_y^{hw} \tau_k^y$. Compare these to table 5 and figure 2, which show the corresponding values for model 1, with no moving average restrictions. These show that strong fluctuations, particularly at the beginning of the series, have been smoothed out. This is strongly apparent for Jewish and Catholic inmarriage, and for Catholic: Jewish mixed marriages. On the whole, figure 1 gives is less erratic than figure 2, although the trend is far from smooth.

This is largely due to the fact that the assortative marriage patterns changed strongly after 1918. The almost linear downward trend for Jews, Lutherans and Catholics levelled off or increased again, while inmarriage in the category "other/none" showed erratic fluctuations in 1919 and 1920. Given these results, a model might be tested that imposed different trend restrictions before and after 1918. One possibility might be to impose a linear restriction for the period up to 1918, and to impose a restriction of no change for the last two years.

Figure 1
The trend in religious assortative marriage
in Austria, 1914 to 1920
Quasi symmetry with 4th order difference time
restriction

Table 4

Full set of parameters (excluding symmetric counterparts) for the third order term $\omega_{ij}^{hw} \tau_k^?$:
Yearly changes in the association of denomination husband and denomination wife
For model 4 (4th degree moving average restriction)

Assortative marriage combination	year of marriage						
	1914	1915	1916	1917	1918	1919	1920
Catholic:Catholic	.437	.072	.178	-.024	-.227	-.064	-.372
Catholic:Lutheran	.497	.404	.287	.023	-.241	-.412	-.558
Catholic:Jewish	-.771	-.437	-.268	.071	.409	.414	.583
Catholic:other/none	-.163	-.038	-.197	-.069	.059	.061	.348
Lutheran:Lutheran	.712	.081	-.051	-.244	-.437	.000	-.060
Lutheran:Jewish	-.798	-.671	-.177	.133	.444	.626	.442
Lutheran:other/none	-.411	.186	-.059	.088	.235	-.215	.176
Jewish:Jewish	.837	.665	.114	-.183	-.479	-.604	-.350
Jewish:other/none	.732	.443	.331	-.021	-.373	-.436	-.675
other/none:other/none	-.158	-.590	-.075	.002	.080	.590	.151

Figure 2
Religious assortative marriage in Austria,
1914 to 1920

Quasi symmetry with no time restrictions

Table 5

Full set of parameters (excluding symmetric counterparts) for the third order term $\omega_{ij}^{hw} \tau_{ij}^y$:
Yearly changes in the association of denomination husband and denomination wife
For model 1 (no moving average restriction)

Assortative marriage combination	year of marriage						
	1914	1915	1916	1917	1918	1919	1920
Catholic:Catholic	1.327	.100	-.279	-.291	-.168	-.160	-.529
Catholic:Lutheran	.961	.325	.102	-.222	-.039	-.510	-.617
Catholic:Jewish	-2.263	-.362	.393	.444	.309	.635	.844
Catholic:other/none	-.025	-.063	-.216	.068	-.103	.035	.303
Lutheran:Lutheran	.528	.124	.198	-.435	-.429	.029	-.014
Lutheran:Jewish	-.796	-.695	-.272	.480	.243	.618	.422
Lutheran:other/none	-.693	.246	-.029	.178	.225	-.136	.210
Jewish:Jewish	1.851	.778	-.281	-.686	-.444	-.677	-.541
Jewish:other/none	1.209	.279	.160	-.238	-.109	-.576	-.724
other/none:other/none	-.492	-.462	.084	-.008	-.013	.678	.212

Conclusion

Imposing m degree moving average restrictions to difference contrast parameters for the trend can smooth away minor fluctuations that are only due to small cell counts. Using PROC IML, it is fairly easy to impose the desired restrictions and to estimate the model using the %GLIMEST macro. The ability to save results and delete parameters from fitted values proved to be invaluable when first working with this design. In the beginning, I imposed the restriction in a single step, rather than first creating the design matrix for difference contrast parameters and then imposing a moving average restriction. By deleting the unrestricted parameters from the fitted values, I was able to see that the full set of parameters was not as I had intended them to be.

Appendix A: Description of the macros %GLIMMAT, %SQUARE and %GLIMEST

This is a description of three macros derived from the file GLIM SAS in the SAS sample library: %GLIMMAT, %SQUARE, and %GLIMEST. Enhancements are:

- The original macros used data step statements to create the design matrix, while %GLIMMAT uses PROC IML (Interactive Matrix Language). This makes it possible to manipulate the design matrix using IML statements prior to estimation, in order to create special designs.
- The original macros dropped the first category of a factor to achieve model identification. %GLIMMAT allows for several types of parametrizations (contrasts) for each factor in each term.
- Regardless of whether PROC IML or PROC NLIN is used for estimation, the %GLIMEST macro starts and finishes in PROC IML. Results such as fitted values and parameter estimates are available as matrices and can be manipulated using IML statements.
- The model can be specified as a single statement. Upper and lower case specification of options is possible, and keyword values may be truncated. The program can detect whether factors are character or numerical.
- Parameters are labeled using the variable names and categories; the contrast used and the reference category are reported.
- A module for detecting and correcting linear dependencies in the design matrix is used before estimation.
- Prior weights can be specified in the IML version (previously only in the NLIN version).
- In the IML version, a SETUP option can be used to store the estimation program as a module. The program can be run again on different datasets or using different designs, without re-reading and re-compiling the %GLIMEST macro.

The files are:

MATSETUP SAS	MATSEUP SAS must be run once before the %GLIMMAT macro can be used. It creates a number of IML function modules which are used by %GLIMMAT. These are stored in a storage catalog called GLIM-MAT.SETUP.
GLIMMAT SAS	Contains the %GLIMMAT macro for generating a design matrix and a %GL macro for generating classification variables in a data step.
GLIMSYM SAS	Contains the %SQUARE macro.
GLIMEST SAS	Contains the %GLIMEST macro for estimating GLMs.
GLIMIML SAS	Read in by %GLIMEST if IML estimation is requested.

INTRODUCTION TO GENERALIZED LINEAR MODELS

A generalized linear model extends the basic framework of the regression and analysis of variance models (normal models). Like these, the effects of continuous and categorical predictor variables are modelled on a dependent variable y . However, while normal models assume that y has a normal distribution, GLM's allow for other distributions as well, such as a poisson distribution, gamma distribution, a binomial distribution (for binary response data).

The normal model also assumes that the effects of the predictor variables on the dependent variables are linear. GLMs continue to treat the effects of the independent variables on the linear predictor η as linear, but lets a link function mediate between η and the dependent variable y . Generalized linear models define $\eta = g(\mu)$, where g is the link function, and the mean μ is equal to the expected value of y ($\mu = E(y)$). Examples of link functions are the log link, the inverse link, the power link. If y has two response categories, then the logit link function or probit link function can also be used (together with the binomial distribution).

Table A.1

Several common statistical models and their error distributions and link functions if specified as generalized linear models

Model	Error distribution	link function
regression/analysis of variance	normal	identity
loglinear	poisson	log
logit	binomial	logit
probit	binomial	probit

The generalized linear model can therefore be stated as follows. For n cases and m linear predictors x_j (continuous variables or dummy variables with appropriate restrictions), there are m corresponding parameters β_j to be estimated:

$$\eta = \sum_{j=1}^m x_j \beta_j \quad (\text{A.1})$$

The mean μ is associated with the linear predictor η by the inverse link function:

$$\mu = E(y) = f(\eta) \quad (\text{A.2})$$

where: f is the *inverse* of the link function.

Once an appropriate error distribution and link function has been chosen, the purpose of the %GLIMEST macro program is to estimate the vector of parameters, B . This is done using weighted least squares for a normal distribution and an identity link, and iteratively reweighted least squares for other GLMs. For more information see Nelder and Wedderburn (1972), McCullagh and Nelder (1983), Aitkin et al. (1989).

THE %GL MACRO

The %GL macro (generate levels) is for use in a data step. It generates a new factor with k levels, in blocks of b . The specification is:

factor=%gl(*k*,*b*);

The %GL macro can be used to generate the classifying variables if only a table is available. For example, to generate the factors for a 3 by 4 table:

```
%include glimat glimest;
data;
input freq @@;
row=%gl(3,4);
col=%gl(4,1);
cards;
-----
```

THE %GLIMMAT MACRO

Before using the %GLIMMAT macro, the storage catalog GLIMMAT.SETUP must be created using the program MATSETUP SAS. This need only be done once.

The %GLIMMAT macro constructs a full rank design matrix based on a model statement, using the contrast specified for each factor. The user must start PROC IML before invoking the %GLIMMAT macro. An example of a %GLIMMAT statement:

```
proc iml;
%glimmat(data=first,depend=freq,
          model=row col group row*col col*group
          para=dev dev dif sim(3)*sim(5) dev(3)*orp(2));
```

Several options are possible in the form *keyword=values*. Upper or lower case characters may be used. The options must be separated by commas. Several *values* can be specified for certain options, separated by spaces. Some *values* may contain *suboptions* in brackets, without using spaces: *value(suboption)*.

The most important options are DEPEND= and MODEL=. Possible options are:

data=	The default is the most recently created SAS dataset.
depend=	Required. The dependent y variable.
model=	Default is an overall effect (grand mean) only. Variables are assumed to be categorical, unless defined as continuous in the direct= statement (see below). Variables may be either character or numerical. Interactions may specified as var1*var2. The model must be written out completely, there are no symbols for nested effects or for including lower order effects if higher order interactions have been specified.
direct=	Specifies that the variables are to be treated as continuous rather than as categorical.
para=	Specifies the contrast to be used for each variable. Default is the deviation contrast with the last category as redundant category (in this case, the IML function DESIGNF is used). Specification is parallel to the model= statement: a contrast must be specified for each variable, including direct variables. This also holds for variables in interaction terms: the parametrization for each variable must be specified as <i>contrast1*contrast2</i> .

There are several possible values for the `para=` option. Only the first three characters of each value are significant, but values may be longer. For some contrasts a reference category *refcat* can be specified in brackets joined to the contrast values. If *refcat* is omitted then the first category is used. If the contrast value is invalid, then the deviation contrast is used, with the lowest category as redundant reference category (if no contrast is specified, then the highest category is reference category).

<code>dev(refcat)</code>	Deviation contrast.
<code>sim(refcat)</code>	Simple contrast
<code>dum(refcat)</code>	Dummy variable contrast
<code>dif(dir)</code>	Difference contrast, backward version is default. If the first character of <i>dir</i> (direction) is an "F" then the forward difference contrast is used, otherwise the backward difference contrast is used.
<code>hel</code>	Helmert contrast
<code>orp (degree/metric)</code>	The orthogonal polynomial contrast. Two suboptions are possible, separated by a slash "/" (no spaces). <i>Degree</i> specifies the order of the polynomial to be used, with a maximum of $k-1$ for a factor with k levels (cf. the ORPOL option <i>maxdegree</i>). For example, the contrast <code>orp (1)</code> will model a linear effect of the factor. <i>Metric</i> allows an IML row vector containing a new metric to be used, rather than the factor categories (cf. the ORPOL option <i>weights</i>). This vector must be previously defined within PROC IML.
<code>bas</code>	A basic model matrix. The design matrix will not be of full rank, but can be manipulated before parameter estimation takes place.

%GLIMMAT creates the following matrices:

<code>Z</code>	An n by 1 variable containing the dependent variable Y .
<code>N</code>	A scalar containing the number of input units n .
<code>OBS</code>	A scalar containing the sum over Z . <code>OBS</code> is used by the %GLIMEST macro to check whether %GLIMMAT terminated properly. If <code>OBS</code> is undefined, %GLIMEST stops processing.
<code>DESIGN</code>	An n by m matrix containing the design matrix X .
<code>LABEL</code>	An m by 1 vector containing descriptive labels for the parameter estimates.
<code>PZATION</code>	An m by 1 vector containing descriptive labels of the contrast type used for each parameter estimate.

In some cases, it might be desirable to export the design matrix for use in another program. This can be done by:

```
create matout from design;
append from design;
```

This creates the dataset *matout* with with the design matrix in the form of variables `coll` to `colm`. This can be merged with the input dataset (e.g. *matin*):

```
data matin;
merge matin matout;
```

Alternatively, the design matrix could be written to an output text file (e.g. *design data a*):

```
data _null_;
set matout;
file 'design data a';
put (coll-coll2) (3.0);
```

(The output format must be suitable for the contrast(s) used. Not all contrasts create integer values.)

THE %SQUARE MACRO

The %SQUARE macro creates special designs for square table data: halfway effects, difference effects, symmetric interactions, skew symmetric interactions. The %SQUARE macro appends matrices to design, label and pzation, and uses the auxiliary macros %CLASS and %INTRCT, which are created by %GLIMMAT. A sample statement might be:

```
proc iml;
%glimmat(depend=freq,model=origin dest);
%square(row=origin,col=dest,model=sym,para=dif*dif)
```

for a quasi-symmetry design.

Utilizing all options of %SQUARE, a saturated model for row variable a and column variable b , both with r categories:

$$\eta_{ij}^{ab} = \beta^* + \beta_i^a + \beta_j^b + \beta_{ij}^{ab}$$

can be redefined into the following parameters:

$$\eta_{ij}^{ab} = \beta^* + h_i + h_j + d_i + d_j + \sigma_{ij} + v_{ij}$$

These effects are:

halfway effects

$$h_i = \frac{1}{2}(\beta_i^a + \beta_i^b)$$

Hope (1971, 1982). The $r-1$ halfway parameters constrain the main effects of the row and column variable to equal values.

difference effect

$$d_i = \frac{1}{2}(\beta_i^a - \beta_i^b)$$

The $r-1$ difference parameters measure the differences between the main effects of the row and column variables. (Also referred to as "marginal shift" parameters by Sobel, Hout and Duncan, 1985).

symmetric interactions

$$\sigma_{ij} = \frac{1}{2}(\beta_{ij}^{ab} + \beta_{ji}^{ab})$$

The $r(r-1)/2$ symmetry parameters constrain interaction effects to a pattern of symmetry.

skew symmetric interactions

$$v_{ij} = \frac{1}{2}(\beta_{ij}^{ab} - \beta_{ji}^{ab})$$

Sobel, Hout and Duncan (1985); Yamaguchi (1990). The $(r-2)(r-1)/2$ parameters measure the asymmetric component of the interaction effect.

The options for the %SQUARE macro are:

row=	Name of the row variable.
col=	Name of the column variable.
model=	The following options can be used for special designs (minimal truncation is in capitals):
	Main
	Half halfway effects
	Diff
	MShift difference effects

Inter
 SYmm symmetry effects
 SKew
 ASym skew symmetry effects

Interactions of special effects with other variables can also be specified. The effects can be used in the model statement, e.g.

model=half half*group sym sym*group

para= Specifies the contrast to be used, using the same syntax as in %GLIMMAT. Two contrasts must be specified for symmetric or skew symmetric interactions.

THE %GLIMEST MACRO

The %GLIMEST macro performs maximum likelihood estimation of the parameters specified in the design matrix, using iteratively reweighted least squares. An example is:

```
%glimest(error=norm,link=inv,print=iter diff tval);
```

By default, estimation takes place using PROC NLIN, which tends to be faster and uses less memory (although at our site, the IML version was slightly faster for small jobs). Both versions use a common section for evaluating options and printing the results. In the NLIN version is used, then the output of PROC NLIN itself is rerouted using PROC PRINTTO. PROC IML is used to process the results, and the output is almost identical, regardless of which program was used for estimation.

There are several options for the %GLIMEST macro, but the error= option will usually be the most important. The options are:

error= The distribution of the dependent variable. Possible values are Poisson, Gamma, Normal, Binomial. Only the first character is significant. The default value is Poisson.

link= The link function. Possible values are: LOGit, Identity, LOG, INverse, ROOT, CLOGlog, PRObit. The first two characters are significant, except for the logit link, which requires four characters. The default link function depends on the error distribution:

Error distribution	Link Function
Poisson	Log
Gamma	Inverse
Normal	Identity
Binomial	Logit

total= Required if the error distribution is binomial. The name of a variable containing the values of the binomial denominator, i.e. the total number of trials per input unit. The dependent variable contains the number of successes per input unit.

offset= The name of a variable containing offset values, a known component of the dependent variable. These values are discounted during estimation.

cellw= The name of a variable containing cell weights for each case. These can be structural zeros in a loglinear analysis, or cell counts for the corresponding cell means in an analysis of variance.

converge= The convergence criterion. Default value is .0001.
maxiter= The maximum number of iterations. Default value is 10.
format= The format to be used when printing numeric matrices. Default value is 12.3.
print= Request that additional output be printed. Possible values are:
 iter Parameter estimates at each iteration (ignored in the NLIN version).
 covar The covariance matrix of parameter estimates.
 correl The correlation matrix of parameter estimates.
 diff A matrix of differences between parameters.
 std A matrix of the standard errors of these differences.
 tratio A matrix of the t-ratios of these differences.
 prob A matrix of the probabilities of the differences (assuming normality).
output= Value is the name of a SAS data set to which fitted values and standardized residuals are written, together with the input data set. Use of this option means PROC IML will be exited after the %GLIMEST macro has been run.
outest= Value is the name of a sas data set to which are written the variables ESTIMATE, STDERR, TRATIO, and TERM (parameter estimates, standard errors, t-values and the first 8 characters of the descriptive labels for the parameter estimates).
anodev= For loglinear analysis, a special table for the analysis of deviance is used. Specifying a value other than MOB for this keyword gives the analysis of deviance table usually used.
est= Specifies whether NLIN or IML is to be used for estimation. Default is NLIN.
setup= Value is the name of a storage catalog to be used (automatically sets `est=iml`). If this option is specified, then the %GLIMEST program is compiled as a PROC IML module called GLIMRUN, but not executed. To execute the program in the same session, specify: `run GlimRun`; To run %GLIMEST on another data set or design with exactly the same options, specify:
 `reset storage=nameUsed;`
 `run glimRun;`
 Where *nameUsed* is the name of the storage catalog specified with `setup=`. Note that because %GLIMMAT uses the storage catalog GLIMMAT.SETUP, the default libref of the storage catalog will also be "GLIMMAT".

%GLIMEST creates several matrices, depending on the options used. Several important matrices are:

MU An n by 1 vector containing the fitted values (the mean μ).
BETA An m by 1 vector containing the parameter estimates β .
PARMETER An m by 3 matrix containing parameter estimates, standard errors, and T-values.
SOURCE A 3 by 4 matrix containing the analysis of deviance table. Columns refer to the *df*, *Ratio* (SSQ for a normal distribution), *Mean* (Ratio divided by *df*), *Prob* (probability based on a χ^2 distribution for *Mean* and *df*). Rows refer to values for the *Model*, *Deviance*, and *Total*.
COVAR An m by m matrix containing the covariance matrix of the parameter estimates.

The names of other matrices are printed in the output. The names of matrices created using the print= option correspond with the option name, i.e. COVAR, CORREL, DIFF, STD, TRATIO, PROB.

Appendix B: Programs

QSTDIF1 SAS

```
title1 'Austria, 1914-1920: quasi-symmetry, variable through time';
```

```
%include glimmat glimsym glimest;
```

```
proc format;
```

```
value O4rel 1='Catholic' 2='Lutheran' 3='Jewish' 4='other/none';
```

```
data aus14;
```

```
input freq @@;
```

```
relH=%gl(4,4);
```

```
relW=%gl(4,1);
```

```
year=%gl(7,16);
```

```
year=year+1913;
```

```
label relH='Husband''s denomination'
```

```
relW='Wife''s denomination';
```

```
cards;
```

43234	439	0	6
491	1200	0	1
0	0	1146	150
34	3	89	188
25820	363	7	6
371	877	0	5
8	1	1398	126
38	5	49	171
24861	325	8	5
337	853	2	1
61	2	1144	107
23	3	40	107
26915	322	23	16
391	910	6	2
44	6	1132	105
24	6	34	132
36698	716	19	8
395	1191	7	4
48	7	1437	119
33	8	47	155
67498	558	51	54
598	3098	12	9
79	11	1419	173
112	17	109	2024
72029	715	147	91
679	3462	14	11
95	11	2579	81
78	14	116	521

```
;
```

```
proc freq data=aus14;
```

```
weight freq;
```

```
format relH relW O4rel.;
```

```
tables year*relH*relW / norow nocol nopercnt;
```

```
data; set aus14;
```

```
freq=freq+.5; * small cell counts;
```

```
proc iml;
```

```
%glimmat(depend=freq,model=relH relW year relH*year relW*year);
```

```
%square(row=relH,col=relW,model=sym,para=dev*dev);
```

```

title2 'Moving average restriction of degree 1';

* function module differ already present in storage catalog GLIMMAT.SETUP;
* start differ(order);
*   conmat=(-I(order-1) || j(order-1,1,0) )+( j(order-1,1,0) || I(order-1));
*   return (conmat);
* finish differ;

* function module for the moving average restriction;
start moveAve(ncats,order);
  ma=j(ncats-order,ncats-1,0);
  act=j(1,order,1/order);
  do i=1 to nrow(ma);
    ma[i,i:order-1]=act;
  end;
  return (ma);
finish;

* function module for producing labels for MA parameters;
start dfolab(prefix,ncats,order);
  rw1=prefix || '(' || '0' || '-' || '0' || ')';
  rslt=repeat(rw1,ncats-order,1);
  cl1=(order+1):ncats;
  cl2=1:ncats-order;
  rslt[,3]=char(cl1,3);
  rslt[,5]=char(cl2,3);
  rslt=rowcatc(rslt);
  return (rslt);
finish;

* use the difference contrast for the variable "year";
read all var {year};
cntr=differ(7);
timedif1=design(year)*cntr`*inv(cntr*cntr`);

* impose an m-degree moving average restriction;
rstr=moveave(7,1);
timedifm=timedif1*rstr`*inv(rstr*rstr`);

* create the design matrix for interaction with the symmetric effects
  of relH and relW;
symint=design( ,50:55);
timeint=hdir(symint,timedifm);

* create labels for the new parameters;
* NOTE: function module NEXTLAB is in storage catalog GLIMMAT.SETUP;
labs=dfolab('year',7,1);
labint=label[50:55, ];
timelabs=nextlab(labint,labs);

* create labels for the contrast type of the new parameters;
pars=j(nrow(labs),1,'MA(1)');
parint=pzation[50:55, ];
timepar=nextlab(parint,pars);

* store matrices and modules for use in subsequent runs;
reset storage=diford.austr;
store;

* append the new design matrix to the old one;
design=design || timeint;
label=label // timelabs;
pzation=pzation // timepar;

free / Z design label pzation N obs;

%glimest(setup=glimmat.poislog);
run glimrun;

```

QSTDIF2 SAS

```

title1 'Austria, 1914-1920: quasi-symmetry, variable through time';

```

```

proc iml;
%macro difford(ncats,order);
  title2 "Moving average restriction of degree &order";

  reset storage=diford.austr;
  load;

  rstr=moveAve(&ncats,&order);
  timedifm=timedif1*rstr`*inv(rstr*rstr`);
  timeint=hdir(symint,timedifm);

  labs=dfolab('year',&ncats,&order);
  timelabs=nextlab(labint,labs);

  pars=j(nrow(labs),1,"MA(&order)");
  timepar=nextlab(parint,pars);

  design=design || timeint;
  label=label // timelabs;
  pzation=pzation // timepar;

  reset storage=glimmat.poislog;
  run glimrun;
%mend;

%difford(7,4);

reset storage=betamu.austr;
store beta mu;

```

PARMS SAS

```

title1 'Interpret parameters of model for Austria, 1914-1920';
title2 '4th order difference restriction on time effects';

proc iml;
name1={'Catholic' 'Lutheran' 'Jewish' 'other/none'};

name2=1:7;
name2=1913+name2;
name2=char(name2,4);

name3=repeat(name1,7,1);

yeargrp=name2` || j(7,4-1,' ');
yeargrp=shape(yeargrp,0,1);

reset storage=betamu.austr;
load beta mu;

start rtrSym(R); * redefinition matrix for symmetry restriction;
  Rm1=R-1;
  sym=j(Rm1*(Rm1+1)/2,Rm1**2,0);
  k=1;
  do i=1 to Rm1;
    do j=i to Rm1; /* i<=j; symmetry */
      sym[k,(i-1)*Rm1+j]=sym[k,(i-1)*Rm1+j]+1/2;
      sym[k,(j-1)*Rm1+i]=sym[k,(j-1)*Rm1+i]+1/2;
      k=k+1;
    end;
  end;
  return (sym);
finish;

reset storage=diford.austr;
load module=(deviate differ moveAve);

facRes=deviate(4,1);
intRes=facRes@facRes;
trans=rtrSym(4)*intRes;

```

```

timeRes=trans@moveAve(7,4);
timeCon=I(16)@differ(7);

actEst=beta[56:73, ];
fulldif=timeRes`*inv(timeRes*timeRes`)*actEst;
full=timeCon`*inv(timeCon*timeCon`)*fulldif;

full=shape(full,0,7);
full=shape(full`,0,4);
print yeargrp full[format=8.3 rowname=name3 colname=name1];

```

Chapter 10

Models for Status Inconsistency and Mobility: A Comparison of the Approaches by Hope and Sobel with the Mainstream Square Additive Model

Abstract

This paper is about the analysis of effects of status inconsistency and mobility on a dependent variable. We compare the mainstream square additive baseline model to alternative designs by Hope (1971, 1975) and Sobel (1981, 1985). Both writers claim that the square additive baseline model also contains some status inconsistency effects. An examination of the relationships between the square additive model, Hope's halfway/difference model, and Sobel's simple diagonal reference model shows that the effects uncovered by Sobel and Hope pertain to the inequality of the effects of the status variables on the dependent variable. These salience difference effects are therefore distinct from the non-additive status inconsistency effects which would be detected using the square additive approach. Less restricted versions of the diagonal reference model, the DM-1 and DM-2 models as well as a recent model by Weakliem (1992), are also examined with regard to additive/non-additive components and symmetry of effects.

Introduction

I know a discontented gentleman
Whose humble means match not his haughty spirit
Richard the Third, Act IV. SC. II

The purpose of status inconsistency models is to ascertain whether having different ranks on two (or more) status variables affects attitudes and behavior. A wide range of dependent variables have been used, but political radicalism, prejudice/racism, psychological stress and social integration are the more important types. Structural characteristics such as ethnicity, education, occupation, income have typically been used as status variables. In addition, mobility has often been treated as a special case of status inconsistency, using the variables status father/status son. There are substantive differences between status inconsistency and mobility,

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but also a considerable theoretical overlap. The status variables are transformed to a common scale in most status inconsistency research, in which case the research methods are identical. Henceforth we will use the terms status inconsistency and mobility interchangeably.

Status inconsistency was a popular research topic in the 1960s. Wilson and Zurcher (1976) list a large number of articles for a wide range of dependent variables. Often cited articles are Lenski (1954, 1956), Jackson (1962), Jackson and Burke (1965), Blalock (1966, 1967) and Duncan (1966). There was some debate as to the proper model (see Whitt 1983, for an overview), but after this had been resolved in favor of an analysis of variance model, the so-called square additive model, empirical results refuted the predictions.

For many the matter was then closed, but Hope (1971, 1975) and Sobel (1981, 1985) argued that the square additive model was unsuitable and proposed alternatives. Hope's alternative approach has been applied by Wilson (1979), Zurcher and Wilson (1979), Whitt (1983), and Slomczynski (1989). Sobel's approach has been applied by De Graaf and Ultee (1987, 1990), De Graaf and Ganzeboom (1990), Sorenson (1989), De Graaf (1991), De Graaf and Heath (1992), and Weakliem (1992).

Are there grounds for a resurrection (Wilson 1979) of status inconsistency research? What information can the alternative approaches by Hope and Sobel give that the square additive model cannot, and is this information of interest to researchers? Sobel's approach contains multiplicative terms and requires different estimation techniques: is it totally different from the square additive model and Hope's approach, or does it simply implement the same basic principles in a slightly different fashion?

In order to answer these questions, we will map the relationships between three models for the analysis (using categorical status variables) of status inconsistency and mobility: the mainstream square additive model, Hope's halfway/difference model, and Sobel's diagonal reference¹ model. Particular attention is given to less restricted versions of the diagonal reference model, the DM-1 and DM-2 models by Sobel, and a recently developed alternative by Weakliem (1992). These derivations have been checked in a re-analysis of the OCG-1 data in Sobel (1981); programs² and results are available on request. When non-equivalent models were being compared, such as the diagonal reference model and the square additive model, the fitted values of the more parsimonious model were used as input for the complex model, in order to check the validity of our derivations.

Background

Status inconsistency research began as a stratification problem. Lenski (1954) wanted to prove that a uni-dimensional treatment of status would be inappropriate, and posited that if differences between status dimensions could have an effect on a dependent variable, this would prove that these status dimensions cannot be reduced to an underlying status continuum without important loss of information. Later analyses tended to shift focus to status inconsistency as a determinant of behavior, and theorizing became more social-psychological in nature.

Jackson (1962) theorized that status inconsistency would affect behavior because it would cause a stressful role conflict, since the status inconsistent ego would wish to ignore his low status dimension, while alter would wish to ignore ego's high status dimension. Geschwender (1967) posited that over- or underfulfillment of reward expectations (income, occupation) based on "investments" (race/ethnicity, education) would lead to cognitive dissonance, which

could be coped with in three sequential stages: (1) emotional response, (2) social change attempt, (3) social isolation/psychosomatic symptoms. Both authors assumed that effects would be affected by the specific status dimensions in the analysis, and that effects need not be symmetric, e.g. the effect of high education/low occupation need not be the same as the effect of low education/high occupation.

As for research methods, the earliest attempts by Lenski (1954, 1956) and Jackson (1962), simply used the status variables to construct a measure of status inconsistency and proceeded with the analysis. The results confirmed their predictions, but others³ objected that this could have been due to the status variables themselves, because the effects of these had not been (adequately) controlled.

Blalock (1966) showed that the problem went deeper. If X_1 and X_2 are two status variables with continuous scales and $(X_1 - X_2)$ is treated as the measure of status inconsistency (assuming that the scales have been made comparable, e.g. by standardizing them) then it will be impossible to control for the effects of the status variables and status inconsistency. The equation

$$Y = b_1X_1 + b_2X_2 + b_3(X_1 - X_2) + \varepsilon \quad (1)$$

will be unidentifiable. $(X_1 - X_2)$ is a linear transformation of X_1 and X_2 , making it impossible to derive unique estimates of b_1 , b_2 and b_3 .

The square additive model

The identification problem indicates that in order to determine status inconsistency effects, it is necessary to first account for the effects of the status variables in a baseline model (Duncan 1966). This can be done in an analysis of variance model for status variables with categorical scales, denoting the additive effects as the contribution to explained variance by the status variables, and interaction effects as the contribution by status inconsistency. We assume in the following that the status variables have an equal number of categories, which results in a square table of means, for which the diagonal cells are status consistent.

The square additive baseline model for two status variables X_1 and X_2 , with categories $i, j=1$ to r , is specified for respondent $k=1$ to n as:

$$Y_{ijk} = \hat{\mu}_{ij} + \varepsilon_{ijk}, \text{ where } \hat{\mu}_{ij} = \mu + \alpha_i + \beta_j \quad (2)$$

We assume that the constraints $\sum_{i=1}^r \alpha_i = 0$ and $\sum_{j=1}^r \beta_j = 0$ have been used⁴. In that case, the square additive model takes the status variables into account by defining expected behavior for each combination of statuses, based on the average behaviors in the categories of the respective status variables.

The full model introduces an interaction term γ_{ij} (with $2r-1$ identification constraints) to test for status inconsistency effects:

$$\hat{\mu}_{ij} = \mu + \alpha_i + \beta_j + \gamma_{ij} \quad (3)$$

If equation (3) explains significantly more variance than equation (2), then there are deviations from the expected behaviors defined by the baseline model. The γ_{ij} parameters correspond with "unusual" behaviors associated with a particular combination of statuses and can therefore justifiably be equated with status inconsistency effects. Patterns of these status in-

consistency effects could be determined by imposing extra constraints on γ_i parameters, e.g. setting certain parameters to equal values or to zero. This would be in accordance with the theoretical expectations of Jackson and Geschwender that only certain types of status inconsistency have effects on a particular dependent variable.

The square additive model became the mainstream model for testing status inconsistency and mobility effects. However, results were largely disappointing. Using a large number of dependent variables, Jackson and Curtis (1972) found significant interaction effects in only 12% of the hypotheses tested, while those they did find did not replicate across populations. Subsequently, many researchers considered the status inconsistency issue closed.

Hope's approach

THE DIAMOND MODEL

Hope (1971, 1975) proposed to rehabilitate status inconsistency. He posited that the square additive model is incorrect, because its main effects also contain some status inconsistency effects. According to his reasoning, the fact that the effects of $(X_1 - X_2)$, the most logical operationalization of status inconsistency, cannot be identified using the square additive model, shows that these effects are already contained in the main effects of X_1 and X_2 .

In view of Lenski's (1954) original work, Hope felt that it would instead be more appropriate to control for an overall status dimension and to test for the effects of an orthogonal status inconsistency dimension. In 1971 he devised a halfway/difference model for the analysis of variance approach, which he renamed the "diamond model" in 1975, when he also extended his approach to include continuous status variables. We will use the term "diamond model" to refer to analyses with continuous status variables and reserve the term "halfway/difference model" for analysis of variance, in which we are primarily interested here.

Hope's (1975) diamond model for continuous variables transforms the status variables into two orthogonal variables for overall status (Z_1) and status inconsistency (Z_2):

$$Y = b_1 Z_1 + b_2 Z_2 + \epsilon \quad (4)$$

where $Z_1 = w_1 X_1 + w_2 X_2$, $Z_2 = w_3 X_1 - w_4 X_2$, and $w_1 w_3 - w_2 w_4 = 0$

However, since the status variables have a common scale, equal weights are a logical choice and Hope's diamond model is usually simplified to:

$$Y = b_1 (X_1 + X_2) + b_2 (X_1 - X_2) + \epsilon \quad (5)$$

By using an overall status dimension as baseline criterion, rather than X_1 and X_2 separately, Hope is able to identify the effect of the status inconsistency term $(X_1 - X_2)$. Equation (5) rotates the original X axes by 135° so that the line $X_1 = X_2$ becomes the new Z_1 axis and the line $X_1 = -X_2$ becomes the Z_2 axis. The line $X_1 = X_2$ can be seen as the ratio of rewards expected for given investments in terms of Geschwender's theory, and the Z_2 axis indicates how much the actual set of statuses differs from the expected set (cf. also Alschuler 1973).

Hope's diamond model was criticized by House (1978), Sobel (1981) and Zimmerman (1985) because of its use of an overall status dimension. This would correspond with a unidimensional class concept, which many theorists reject in favor of multiple social status di-

mensions. However, the concept of status inconsistency logically implies the complementary concept of status consistency, which indicates a construct of overall status.

House (1978) also argued that equation (5) will indicate the presence of status inconsistency effects whenever the effects of the status variables on a dependent variable differ: if $\hat{Y} = c_1X_1 + c_2X_2$, then in equation (5), $b_1 = \frac{1}{2}(c_1 + c_2)$ and $b_2 = \frac{1}{2}(c_1 - c_2)$. Actually, it is a corollary to the notion of a single, underlying status continuum that the status variables which are manifestations of this latent concept will have effects of approximately the same magnitude. This was Lenski's motive for testing for status inconsistency effects in order to falsify the hypothesis of a status continuum.

This criticism does clarify what Hope's model in fact does. Equation (5) will explain exactly as much variance of Y as a linear model of X_1 and X_2 . It only restates the case in terms of the explanatory power of a construct of overall, consistent status and a dimension indicating the disparate strengths of the two status variables in determining the concept measured by the dependent variable. The fact that for example parents' status influences voting behavior more than the respondent's own present status can be of interest, and it might be worthwhile to transform the model so that this information is given. However, effects of this nature are still effects of the status variables: they have only been restated.

THE HALFWAY/DIFFERENCE MODEL

Rotating a square table of means by 135° results in a diamond shape. However, for categorical status variables, we have chosen Hope's original name, the halfway/difference model. This is specified as:

$$\hat{\mu}_{ij} = \mu + h_i + h_j + d_i + d_j, \quad (6)$$

where $h_i = \frac{1}{2}(\alpha_i + \beta_i)$ and $d_i = \frac{1}{2}(\alpha_i - \beta_i)$

The halfway parameters indicate the average effect on the dependent variable of the row and column variable for each category. This is equivalent to modelling the effects of an underlying, overall status variable. Each difference effect indicates the unequal influence on the dependent variable of the row and column variable for that category: the difference in salience (to use Sobel's term) of the row and column variable.

The halfway/difference model as presented in equation (6) is a transformation of the square additive model, but Hope also proposed submodels by using the polynomial contrast for the difference effects, and testing whether only the linear, or the linear and quadratic terms would fit the data adequately. If a linear constraint is imposed on both the halfway and difference effects, then equation (6) is equivalent to equation (5).

If there are only halfway effects in a halfway/difference model, then the status variables can be treated as a single underlying status variable (for the dependent variable in question). If the difference effects are significant, then the status variables have unequal salience. Hope calls these effects status inconsistency effects, but although they are based on (X_1, X_2) , we question the appropriateness of the term. Because a halfway/difference model is equivalent to the square additive baseline model, status inconsistency effects in the usual sense can still be found by testing for interaction effects. Therefore, at least a distinction must be made between these salience difference "status inconsistency" effects, and status inconsistency effects in the usual, non-additive sense.

Hope's halfway/difference model shows that, just as the (between cells) effects of an ANOVA model can be divided into additive and non-additive components, the additive component in turn can be divided into equal/unequal effect components. It is the "unequal" additive effects component (i.e. difference effects) that contain linear status inconsistency effects and preclude the use of such an effect with the square additive model as baseline: the square additive model already contains the linear status inconsistency effects (and higher order polynomials of the difference effects as well).

The differences in the strengths of the effects of the status variables on behavior will often be of theoretical interest. Especially in the case of mobility research (De Graaf and Ultee 1987, 1990) or the comparison of influence of husbands and wives (Sorenson, 1989; De Graaf and Ganzeboom, 1990), this difference in salience can be of as much interest as non-additive effects. However, these researchers analyzed the difference in salience using Sobel's approach, which is discussed below.

Sobel's approach

THE DIAGONAL REFERENCE MODEL

Sobel (1981, 1985) criticized both the square additive and Hope's approach. He agreed with Hope that $(X_1 - X_2)$ is the obvious operationalization of status inconsistency or mobility, and that the fact that such a variable cannot be identified in the square additive model indicates that this model implicitly contains linear status inconsistency effects in its main effects. However, as noted above, he objected to Hope's use of a measure of overall status.

Instead, Sobel proposed to construct a model of the acculturation process that takes place when status inconsistency occurs and to use this as a baseline. The model was originally designed for mobility effects research, but Sobel (1985) proposed that it can be applied to status inconsistency problems as well. Sobel's simple diagonal reference baseline model for a square r by r table of means is:

$$\hat{\mu}_{ij} = p\mu_{ii} + (1-p)\mu_{jj} \quad (7)$$

The diagonal of the table of means is the focus of interest for Sobel. He posited that when acculturation takes place, status inconsistent will take their cues from the status consistent. Status inconsistent will then be faced with two referent behaviors, one for each status value. Consequently, the means of off diagonal cells are a compromise between the mean of the diagonal cell for the score on X_1 (μ_{ii}) and the mean of the diagonal cell for the score on X_2 (μ_{jj}). The parameter p expresses the relative salience of X_1 and X_2 . If $p > \frac{1}{2}$, then X_1 has greater salience, since the behavior of status inconsistent resembles the behavior of the status consistent with their score on X_1 more than the behavior of status consistent with their score on X_2 . Sobel also specified that p lies in the closed interval $[0,1]$. This is not a condition for the model however, it is simply a property of p that it will *generally* lie between zero and one. The reason for this and the exceptions are discussed below.

Because salience is expressed by a multiplicative parameter, equation (7) is not a linear model. Sobel uses nonlinear least-squares estimation to derive values of p and the values of diagonal cells μ_{11} to μ_{rr} of a square table of means, such that these optimally reproduce all values μ_{ij} . This seems to make the diagonal reference model totally different from other mod-

els. A first step in facilitating comparison with other models is to incorporate an overall mean, which can be done by rewriting equation (7) as:

$$\hat{\mu}_y = \mu + pv_i + (1-p)v_j, \text{ where } \sum_{i=1}^I v_i = 0 \quad (8)$$

Table 1 compares the designs of the square additive, halfway, and diagonal reference models for a 3 by 3 table of means. The overall mean is not added to the cells in order to facilitate a comparison of the additive effects; the marginals of the tables contain the additive components.

The relationships between the square additive model and the diagonal reference model can be determined by examining the situation in which both produce the same predicted values. In that case, for the diagonal cells, $v_i = \alpha_i + \beta_i = 2h_i$. The diagonal values μ_{ii} in equation (7) can therefore be seen the effects of an underlying continuum, based on equally weighted status variables.

As for the off-diagonal cells, if the models produce the same fitted values, then the additive components will be the same, so

Table 1
A comparison of the designs of the square additive model, Hope's halfway model and Sobel's diagonal reference model

Square additive model				
	(1)	(2)	(3)	<i>all</i>
(1)	$\alpha_1 + \beta_1$	$\alpha_1 + \beta_2$	$\alpha_1 + \beta_3$	α_1
(2)	$\alpha_2 + \beta_1$	$\alpha_2 + \beta_2$	$\alpha_2 + \beta_3$	α_2
(3)	$\alpha_3 + \beta_1$	$\alpha_3 + \beta_2$	$\alpha_3 + \beta_3$	α_3
<i>all</i>	β_1	β_2	β_3	μ
Halfway model				
(1)	$2h_1$	$h_1 + h_2$	$h_1 + h_3$	h_1
(2)	$h_2 + h_1$	$2h_2$	$h_2 + h_3$	h_2
(3)	$h_3 + h_1$	$h_3 + h_2$	$2h_3$	h_3
<i>all</i>	h_1	h_2	h_3	μ
Simple diagonal reference model ($\mu_{ii} = \mu + v_i$; cf. equation (8))				
(1)	v_1	$pv_1 + (1-p)v_2$	$pv_1 + (1-p)v_3$	pv_1
(2)	$pv_2 + (1-p)v_1$	v_2	$pv_2 + (1-p)v_3$	pv_2
(3)	$pv_3 + (1-p)v_1$	$pv_3 + (1-p)v_2$	v_3	pv_3
<i>all</i>	$(1-p)v_1$	$(1-p)v_2$	$(1-p)v_3$	μ

The overall term is not added to cells in order to enhance clarity.
Parameters under the heading "*all*" are the additive main effect parameters

$$\begin{aligned}
 p\alpha_i &= \alpha_i \\
 p(\alpha_i + \beta_i) &= \alpha_i \\
 p &= \frac{\alpha_i}{\alpha_i + \beta_i} = \frac{1}{1 + \frac{\beta_i}{\alpha_i}}
 \end{aligned}
 \tag{9}$$

Equation (9) clarifies why p usually lies in the interval $[0,1]$. If α_i and β_i both have the same sign and neither is equal to zero, $\frac{\beta_i}{\alpha_i}$ will be between zero and infinity, and p will lie between one and zero. If the signs of α_i and β_i are opposite, then p can have any value. However, in actual analyses, the status variables can be expected to have effects in the same direction (although the effects may both be near zero).

If $p = \frac{1}{2}$, then the main effects are equal, and the halfway model and the diagonal reference model are equivalent (Sobel 1981). A $p \neq \frac{1}{2}$ in Sobel's approach means that the d_i values in Hope's model will be unequal to 0. The distinction is that Sobel expresses unequal salience of the status variables through the *ratio* of the main effect parameters, while Hope uses the *difference* between them⁵.

An advantage of Sobel's model is that it is derived from a theory of an acculturation process. However, several criticisms can be raised against this theory. Will status inconsistencies really look to the status consistents for cues? How will they know a status inconsistent from a status consistent during superficial initial contacts? What happens when the association between the status variables diminishes? As Sobel notes "But if, for example, the proportion of stayers in a destination class is small, this may decrease the visibility of stayers and diminish their ability to define the sociocultural norms that typify the destination class" (Sobel 1981: 904).

However, even if these criticisms were to be considered to be strong enough to reject the theory of the acculturation process, the diagonal reference model would still yield valuable insights. An alternative way of looking at the diagonal reference model is in terms of marginal values (cf. table 1), to be used for the analytical purpose of determining expected cell values. Sobel's model imposes a constant inequality (as opposed to the variable inequality of Hope's difference parameters) on the marginal means: the main effect of X_1 must be

$\frac{p}{1-p}$ times the effect of X_2 . The expected behavior for each situation (each cell) is therefore

biased to a constant extent to the average behavior of one of the status variables.

As for the advantages and disadvantages of Sobel's approach versus that of Hope, the simple diagonal reference model expresses unequal salience in a single parameter, whereas the difference variable has $r-1$ (non-redundant) parameters. A linear constraint can be placed on the difference parameters in Hope's model, but will lead to an unacceptable loss of fit unless the main effects of the square additive model are (approximately) linear too. Sobel's model on the other hand, does not even require ordered categories. If the main effects of the status variables have a reasonably similar profile, i.e. are strongly positive and strongly negative for the same categories, then it will be possible to impose the constraint that α_i is $\frac{p}{1-p}$

times β_i , with no great loss of fit. Sobel's diagonal reference model will explain almost as much variance as the square additive baseline model, with fewer parameters.

This advantage is partially offset by the possibility that p will not be meaningful. If the numerator of the ratio p is based on is zero, then p will be zero irrespective of the denominator; if the denominator is zero, p is undefined. If the effects of X_1 or the effects of X_2 on the dependent variable are near zero, then the values of p will become extreme. This will show up in a large value of the asymptotic standard error of p . In this situation, the difference parameters of Hope's approach will still be meaningful. However, given the nature of the data used in status inconsistency and mobility analyses, it is not likely that one or both status variables will have near zero effects.

THE DM-1/DM-2 MODELS

Sobel felt that in some cases it might be too restrictive to use one salience parameter p . For example, if mobility out of a class is strong, then that class might be expected to have less impact than other classes (Sobel 1985: 710). Sobel therefore extended his model to let p vary either with X_1 (the DM-1 model) or with X_2 (the DM-2 model). His diagonal reference model DM-1 is:

$$\hat{\mu}_y = p\mu_u + (1-p)\mu_y \quad (10)$$

The DM-2 model is the same as DM-1, except that the X_2 specific weights p_j are used. An undesirable property of these models is that they are asymmetrical, in the sense that they require salience of origin versus destination to vary either by origin (DM-1) or destination category (DM-2).

The simple diagonal reference model is nested within the square additive model, and can be supplemented with non-additive status inconsistency effects. The DM-1/DM-2 models, on the other hand, contain a non-additive component. This can be seen by specifying p_i in equation (10) as $q+r_i$, with $\sum_{i=1} r_i = 0$. The DM-1 model can then be written as:

$$\hat{\mu}_y = q\mu_u + (1-q)\mu_y + r_i\mu_u - r_i\mu_y \quad (11)$$

All elements in equation (11) are additive, with the exception of the term $-r_i\mu_y$. This component must be attributed to unique combinations of X_1 and X_2 and should therefore, in the linear modelling scheme, be associated with status inconsistency, rather than incorporated in the baseline model.

However, as rewritten in equation (11), the DM-1 model consists of the simple diagonal reference model plus a status inconsistency term $r_i(\mu_u - \mu_y)$. $\mu_u - \mu_y$ can be seen as a *cross pressures* component indicating the difference in the behaviors of referents. The parameter r_i indicates the relative influence of cross pressures for each origin class.

If the DM-2 model is used, there would be a destination specific parameter s_j (with $q+s_j=p_j$ and $\sum_{j=1} s_j = 0$). The DM-1 and DM-2 models could therefore be combined into a *DM* model, in the following fashion:

$$\hat{\mu}_y = q\mu_u + (1-q)\mu_y + (r_i + s_j)(\mu_u - \mu_y) \quad (12)$$

This model contains r_i parameters for the origin specific influence and s_j parameters for the destination specific influence of cross pressures, thus circumventing the undesirable asymme-

try of the DM-1/DM-2 models. The $r_i(\mu_u - \mu_y)$ and $s_j(\mu_u - \mu_y)$ terms are treated as mobility effects, using the simple diagonal reference model as a baseline.

By treating them as simple diagonal reference baseline models plus a non-additive, "cross-pressures" status inconsistency term, the DM-1/DM-2 models can be re-interpreted in a meaningful way within the linear modelling scheme, for which the distinction additive/non-additive is crucial. However, the diagonal reference approach combines multiplicative and additive effects, and this raises the question whether the additive/non-additive distinction is appropriate for this approach, or whether alternatives might be devised that are better suited. This will be discussed in the following paragraph, on a recent alternative model by David Weakliem.

DAVID WEAKLIEM'S MODEL

David Weakliem (1992) formulated an alternative to the DM-1/DM-2 models, that allows salience parameters to vary per category of the common scale. In his model, $\hat{\mu}_y$ is the weighted sum of μ_u and μ_y . However, the weights w_y are dependent on both origin and destination, and are a function of an overall salience parameter ϕ and salience deviation parameters π_i . Weakliem's model is as follows:

$$\hat{\mu}_y = w_y \mu_u + (1 - w_y) \mu_y$$

$$\text{where } w_y = \frac{\phi \pi_i}{\phi \pi_i + \pi_j} \text{ and } \prod_{i=1}^r \pi_i = 1 \quad (13)$$

A restriction must be placed on the π_i parameters. Weakliem let the sum over the parameters equal r , but we prefer to let the product over π_i equal 1. If all π_i parameters are equal to 1, then Weakliem's model is equivalent to the simple diagonal reference model, with $w_y = \frac{\phi}{\phi + 1} = p$. Values of π_i less than 1 mean that for category i of the common scale, X_i has less than average salience compared to X_2 .

A criticism of the DM-1/DM-2 models was that they are asymmetrical, since they require that differences in salience depend on either origin category or destination category. Weakliem's model can be seen as a synthesis of the DM-1/DM-2 models. The DM-1 model can be rewritten as:

$$\hat{\mu}_y = w_y \mu_u + (1 - w_y) \mu_y$$

$$\text{where } w_y = p_i = p \delta_i = \frac{\phi \delta_i}{\phi \delta_i + \delta_j} \quad (14)$$

$$\text{with } \prod_{i=1}^r \delta_i = 1 \text{ and } p = \frac{\phi}{\phi + 1}$$

In this specification, the DM-1 model resembles Weakliem's model, with an overall salience parameter p and salience deviation parameters δ_i , which depend only on the X_i category. Likewise, the DM-2 model could be respecified as:

$$\hat{\mu}_{ij} = w_{ij}\mu_u + (1 - w_{ij})\mu_{jj} \quad (15)$$

where $w_{ij} = p_j / p\delta_j = \frac{\phi\delta_j}{\phi\delta_j + \delta_j}$

Weakliem's model synthesizes these two models, by specifying that w_{ij} is dependent on salience deviation parameters π_i and π_j for both X_1 and X_2 .

Like the DM-1 and DM-2 models, Weakliem's model has $2r$ non-redundant parameters, 1 more than the square additive model. It also contains non-additive effects. This can be seen by re-writing it as:

$$\hat{\mu}_{ij} = w_{i.}\mu_u + w_{.j}\mu_{jj} + (w_{ij} - w_{i.})\mu_u + (1 - w_{ij} - w_{.j})\mu_{jj} \quad (16)$$

where $w_{i.} = \frac{1}{r} \sum_{j=1}^r w_{ij}$ and $w_{.j} = \frac{1}{r} \sum_{i=1}^r w_{ij}$

The terms $w_{i.}\mu_u$ and $w_{.j}\mu_{jj}$ are of course additive, but the remainder of equation (16) is not. However, it is not possible to write $w_{i.}$ or $w_{.j}$ as simpler expressions of π_i and ϕ , and we are unable to specify the non-additive terms in a substantively meaningful way.

Instead, Weakliem's model could be seen as a submodel in a "generalized diagonal reference" approach, that should be seen as an alternative to linear ANOVA modelling. By relaxing the restriction on the w_{ij} parameters are functions of the ϕ and π_i parameters, the diagonal reference approach can be expanded to an equivalent of a saturated ANOVA model. One way of doing this might be:

$$\hat{\mu}_{ij} = w_{ij}\mu_u + (1 - w_{ij})\mu_{jj} \quad (17)$$

where $w_{ij} = p\kappa_{ij}$, $\kappa_{ii} = 1$, and $\prod_{i=1}^r \prod_{j=1}^r \kappa_{ij} = 1$

In equation (17), p is an overall salience parameter, and κ_{ij} are weights for the individual cells. There are r parameters μ_u , 1 parameter p , and $r^2 - r$ parameters κ_{ij} , which means there are as many unknown parameters as known cell values, so that the model will fit μ_{ij} perfectly⁶. Weakliem's model is a restricted version of the model in equation (17), that takes into account the overall status effect of the status variables (the μ_u parameters) and the differences in salience (the ϕ and π_i parameters). In this modelling strategy, Weakliem's model does not utilize information from specific combinations of cells, but only exhausts the explanatory power of the status variables themselves. It could therefore be seen as the counterpart to the square additive baseline model in such a generalized diagonal reference approach.

We can conclude that Weakliem's model successfully extends the basic idea of the simple diagonal reference model to allow for unequal salience per category of the common scale. The simple diagonal reference model can be seen as a restricted submodel of Weakliem's model (all salience deviation parameters are equal to 1). The DM-1/DM-2 models can be seen as alternative baseline models, to test the hypothesis that salience deviation parameters vary for origin category only (DM-1), or for destination category only (DM-2).

Conclusions

In this paper, we examined the relationships between the square additive model, which is used as a baseline for detecting status inconsistency and mobility effects, and alternative approaches by Hope and Sobel. These alternatives have in common the use of a construct of overall status as the new baseline criterion. This is a logical stance, since the existence of an underlying overall status dimension would preclude the existence of status inconsistency and therefore of status inconsistency effects.

The effects of an overall status dimension are given by the halfway parameters in Hope's halfway model or by the diagonal parameters μ_{ii} in Sobel's diagonal reference model. These parameters indicate to what extent the main effects of the square additive model have equal strength, i.e. the equality in the main effects. These parameters can be supplemented by parameters that relate to the inequality of the main effects of the status variables. This is measured by the difference parameters in Hope's approach as a subtraction, and by salience parameters based on a ratio in Sobel's approach. Inequality of the main effects means that one of the status variables has a stronger effect on the dependent variable, has greater salience for the respondent. We agree with Sobel that these effects do not constitute status inconsistency effects; they are in any case distinct from status inconsistency effects that are based on specific combinations of cells.

The DM-1/DM-2/Weakliem baseline models each have one parameter more than a square additive model would have and contain some non-additive effects. A formal objection to the use of these models in conjunction with non-additive status inconsistency terms is that a model with all interaction terms cannot be fitted. This problem could be solved by using restricted version of a generalized diagonal reference model. Alternatively, the DM-1/DM-2 models could be regarded as simple diagonal reference models plus a non-additive "cross-pressures" term, in addition to other non-additive terms for status inconsistency effects.

Finally, the question to be answered is whether the alternative baseline models provide justification for new status inconsistency and mobility research. The halfway/difference baseline model is equivalent to the square additive model, and a restricted version with a linear constraint on the halfway and/or difference effects cannot be justified unless it does not explain significantly less variance than the square additive model. The simple diagonal reference model usually explains almost as much variance as the square additive model, and when it does not, this will be because salience is not equal for all categories, and either the DM-1, DM-2, or Weakliem's model should be used instead. These models do not explain all the variance of the square additive model, but on the other hand they are less parsimonious, so that it is possible, but highly unlikely, that interactions will be found using these models as a baseline where none were found using the square additive model.

One conclusion is that neither Hope's nor Sobel's approach will result in the detection of more interaction effects than the square additive model. However, recent work comparing the relative influence of partners or class origin versus class destination show that these models for the analysis of salience have proven useful in their own right. Sobel's model has the advantage that one is able to model the salience of both status dimensions with one single parameter. Furthermore, Sobel's model is a good example of how to translate theoretical ideas into a mathematical model.

¹ De Graaf and Ganzeboom (1990) suggested the name "diagonal reference model", instead of Sobel's term "diagonal mobility model" in order to avoid confusion with Goodman's log-linear diagonal mobility models for loglinear analysis of mobility frequency tables.

² Ben Pelzer of our computer support department found that NLR by SPSSX is very suitable for estimating Sobel's diagonal reference model. Program speed is high, derivatives do not have to be specified, and the accuracy of initial values only marginally affect program speed. For estimating halfway/difference models, we used GLIMMAT, a set of SAS macros using PROC IML to construct design matrices and estimate generalized linear models (chapter 9).

All models discussed in the text assume a continuous dependent variable with a normal distribution. Hope's halfway/difference model is also used in loglinear models of mobility frequency tables (Hope 1981, 1982, 1991; Sobel, Hout and Duncan 1985). The substantive issues are different, but the design techniques are identical.

Sobel's nonlinear diagonal reference model can also be used with a dichotomous dependent variable in a logitistic model (De Graaf and Heath 1992; De Graaf, Nieuwbeerta and Heath 1992, Weakliem 1992). Chapter 11 shows how PROC NLIN by SAS can be used to emulate the GLIM 3.77 program and thus to estimate nonlinear designs in loglinear, logit, or other GLIM-type models. CNLR by SPSSX can also be used to estimate logitistic diagonal reference models (De Graaf and Heath 1992; De Graaf, Nieuwbeerta and Heath 1992).

The basic idea of the diagonal reference model, i.e. fitting main effects that are proportional to each other, has also been implemented for asymmetric interaction in loglinear model, in the "proportional asymmetry model" (chapter 6).

³ Jackson and Burke (1965) cite two articles criticizing the inadequate control on effects of the status variables: Robert Edward Mitchel (1964), "Methodological notes on a theory of status crystallization", *Public Opinion Quarterly* 28: 315-325 and N.J. Demerath III (1962), "Status discrepancy and vertical status: criticisms and suggested remedies", paper read at the American Sociological Association meetings, Washington D.C. Other critics were Blalock (1966, 1967) and Duncan (1966).

⁴ Other constraints, or contrasts (Bock 1975), are also possible. The contrast used will not affect the detection of non-additive effects, but would affect the interpretation of interaction parameters.

⁵ An alternative way of looking at the diagonal reference model is in terms of the effects of an underlying overall status variable based on weights p and $1-p$, which are determined on empirical grounds. Seen this way, Sobel's simple diagonal reference model would be a counterpart to Hope's halfway model.

⁶ The parameters from this model can be calculated directly using the observed means. We were unable to derive the parameter values using NLR by SPSSX, presumably because the program assumes an over-identified model. This did succeed if the restriction $\kappa_{12}=1$ was used, rather than restrict the product over all κ_j parameters to be 1. The program showed no perfect correlations between parameters, so the model is indeed identified.

Chapter 11

Specifying Link Functions and Error Distributions for Categorical Models using Nonlinear Designs

Abstract

On the basis of a program from the SAS sample library, this paper describes how Generalized Linear Models (GLMs) can be estimated using the SAS nonlinear regression program PROC NLIN. This can be extended by adding nonlinear predictors. A number of sample programs are given, such as the diagonal reference model by Sobel (1981, 1985) in a logit model, and Goodman's (1979, 1985) uni and multi-dimensional log-multiplicative row and columns model II.

Introduction

In the 1980s, models began to emerge that used nonlinear designs for categorical models other than the usual analysis of variance type. A first example is Goodman's (1979) row and column model II (RCII). This is a log-multiplicative (also called log bilinear) model for estimating scale parameters for the row and column variables of a table, such that a uniform association parameter will emerge if these scales are used. An example of an application is determining a measure of mobility in a society and of social distance between occupational categories. The RCII model is a loglinear model with a nonlinear design: its design incorporates both additive and multiplicative elements (see below for a fuller discussion).

Another example of a nonlinear design is Sobel's (1981) diagonal reference model. This model is used with a dependent variable and two predictor variables with equal categories. The model tests for proportional effects of the two variables. An application is to determine whether origin status or destination has greater weight in determining voting behavior. This is a nonlinear design in an analysis of variance context, but it might be useful to be able to apply this design in a logit model or a probit model (Sobel and Arminger, 1989).

Nonlinear designs can be specified in a nonlinear regression program if the dependent variable has a normal distribution, but this is not the case for loglinear or logit models. On the other hand, linear designs can be estimated in models where a distribution other than normal is assumed for the dependent variable, using the program GLIM 3.77, or other programs for estimating Generalized Linear Models (GLM's). A GLM also allows for the specification of a link function, so that the dependent variable is the inverse link function of the linear predictors. A wide range of statistical models is thus subsumed in one conceptual framework: re-

gression and analysis of variance (normal distribution, identity link function), loglinear models (poisson distribution and log link), logit models (binomial distribution and logit link), probit models (binomial distribution and probit link).

It turns out to be possible to emulate GLIM using the SAS program for nonlinear regression, PROC NLIN. This opens the possibility of incorporating a nonlinear design in a model that assumes an error distribution other than normal, and/or using a link function other the identity link. The program GLIM SAS in the SAS sample library contains two macros for estimating GLM's. %GLIM2 uses PROC IML statements (matrix algebra), while %GLIM uses PROC NLIN, nonlinear regression¹. From the %GLIM macro we have derived the steps necessary to program a nonlinear design using link functions and error distributions, using PROC NLIN.

Our purpose is to present a practical and flexible method for estimating existing nonlinear designs and for developing new nonlinear designs in future work. The emphasis is on practical programming of these models, so sample programs including data, are included in the text. These programs require a fairly good knowledge of SAS programming, such as working with arrays. A basic knowlegde of differential calculus is needed to develop designs (Appendix A contains a brief review of the rules of differentiation). The final example, a multi-dimensional RCII model, requires the use of matrix algebra, using SAS PROC IML (Interactive Matrix Language).

The following paragraph contains a brief introduction to Generalized Linear Models. This is followed by a description of the %GLIM macro and the statements necessary to incorporate link functions and error distributions, and to generate initial values for the model. This is illustrated by a main effects logit model using two predictor variables. We then present some sample programs using nonlinear designs in the GLM framework. First, we fit a diagonal reference design (Sobel, 1981) in a logit model. We proceed to present two designs for loglinear models, a proportional asymmetry model and a power distance model, as illustrations of how to implement new ideas, using the programming methods presented here. In the last paragraph, we show how to fit a quasi RCII model (Goodman, 1979) and a 2 dimensional RCII model (Goodman, 1985). These models are rather involved, but the programs for estimating them can be very useful in situations where flexibility is required, and therefore serve as more than simply examples of incorporating nonlinear designs in GLM type models.

Introduction to Generalized Linear Models

Generalized Linear Models (GLM's) were introduced by Nelder and Wedderburn (1972). These models extend the basic techniques used in classic regression and analysis of variance models by allowing different specifications of link functions and error terms. While classic analysis of variance assumes that the dependent variable has a normal distributions and the predicted values are an "identity function" (i.e. no transformation takes place) of the linear predictors, GLM's allow for several link functions and distributions of the dependent y variate, thus containing several commonly used models in one conceptual framework (McCullagh and Nelder, 1983; Aitken et al., 1989).

A generalized linear model for the dependent variable y , involving n cases and m parameters, solves the equation

$$\eta = \sum_{j=1}^m x_j \beta_j$$

η is a link function of the expected values of the dependent variable y ; i.e. $E(y) = \mu$, and $\eta = g(\mu)$, where g is the link function and μ is the mean. Maximum likelihood estimates are found for β_j using Iteratively Reweighted Least Squares, with weights depending on the distribution y is assumed to have.

The predefined error terms in the GLIM 3.77 program are:

- (1) normal
- (2) poisson
- (3) gamma
- (4) binomial

The predefined link functions are:

- (1) identity
- (2) log
- (3) reciprocal
- (4) root
- (5) exponential
- (6) logit
- (7) probit
- (8) complementary log-log

Program structure of the %GLIM macro

NOTATION

The notation used in the %GLIM macro is sometimes confusing. We use a slightly different notation, to maintain a distinction between SAS internal variables such as `_WEIGHT_` and `_ITER_`, and to avoid referring to macro variables. The differences are summarized below:

Term	Notation	%GLIM macro notation	GLIM 3.77 notation
Dependent variable	<code>Y</code>	<code>&VARIABLE</code>	<code>%yv</code>
Linear predictors	<code>pred</code>	<code>_Y_</code>	<code>%lp</code>
Mean (predicted values)	<code>MU</code>	<code>_MU_</code>	<code>%fv</code>
Derivatives variable	<code>DER</code>	<code>_DER_</code>	
Binomial denominator	<code>cellTot</code>	<code>&TOTAL</code>	<code>%bd</code>

In the following, we will use monspaced fonts for symbols that refer directly to programming statements. The specifications can be directly incorporated in a SAS program. When referring to more general statistical issues, we use italics or greek symbols.

GENERAL

The GLIM 3.77 program can derive maximum likelihood parameter estimates by using iteratively reweighted least squares. The SAS %GLIM macro basically does this also: the NOHALVE

option of PROC NLIN must be used, and weights are specified using the special variable `_WEIGHT_`. The error distribution of the model determines which weights must be used.

The link function is incorporated by specifying that the predicted values MU are the inverse link function of the predictor terms, and through the specification of the derivatives. For this reason, if the link is not identity, the derivatives must be specified. Estimation algorithms that use derivatives, such as `method=GAUSS` or `method=MARQUARDT`, must be used (i.e. `method=DUD` will not work).

GLM's also use a *scale parameter*, which is the denominator of the standard errors of the parameter estimates. For a normal distribution, the scale parameter is equal to the Residual Mean Square, for the gamma distribution it must be estimated, and for the poisson and binomial distributions it is equal to 1. The scale parameter is incorporated by specifying the PROC NLIN option `SIGSQ=1`. The %GLIM macro does this for all distributions, but warns users that the standard errors of parameter estimates must be corrected in the normal or gamma distributions are used². We found that omitting the SIGSQ option led to correct standard errors of parameter estimates when the normal distribution was assumed.

PROC NLIN requires a data set containing the dependent variable and variables representing the design matrix for the model. The (linear) parameters to be estimated are initialized with the value of zero. In the NLIN program, the first iteration uses weighted least squares to determine good starting values for the parameters and is therefore treated separately. The predicted values MU are given an initial value of 0, the auxiliary variable for calculating derivatives DER is given an initial value of 1, the `_WEIGHT_` variable is given an error distribution dependent variable, and the dependent variable is temporarily transformed using the link function. The result is that parameter estimates for the second iteration have the same values as if a weighted least squares regression had been run using these weights and the Y variate transformation.

In the subsequent iterations, MU is set equal to the inverse link function of `pred`, a variable containing the predictor terms. In a linear model, `pred` is equal to the sum of each parameter times its design vector. The auxiliary variable DER is respecified on the basis of the link function. The `_WEIGHT_` variable is respecified on the basis of the error term.

After each iteration, the derivatives are evaluated. These statements all have the same structure: the derivative for a parameter is equal to the design vector for that parameter times the auxiliary variable DER, which is a transformation of the predicted values MU that is appropriate for the link function.

SPECIFYING THE ERROR TERM

Specifying weights

The error term is specified by defining the special SAS variable `_WEIGHT_`. Different weights are used for the first iteration (which calculates starting values for the parameters) than for following iterations.

Error Distribution	Initial weights (first iteration)
normal	<code>_WEIGHT_=1</code>
poisson	<code>_WEIGHT_=Y</code>
gamma	<code>_WEIGHT_=Y**2</code>
binomial	<code>_WEIGHT_=Y*(cellTot-Y)/cellTot</code>
* Y is assigned the value of .1 if it is zero and of cellTot-.1 if it is equal to cellTot.	

In subsequent iterations, the `_WEIGHT_` values are:

Error Distribution	weights for susequent iterations
normal	<code>_WEIGHT_=1</code>
poisson	<code>_WEIGHT_=1/MU</code>
gamma	<code>_WEIGHT_=1/MU**2</code>
binomial	<code>_WEIGHT_=1/(cellTot*P*(1-P))</code>
* P is the probability of success. It's value will depend on the link function (see below)	

This assumes that no initial weights are being used. Otherwise, the `_WEIGHT_` variable can be multiplied by a variable (`_REPLIC_` in the %GLIM macro) containing weights for each case. For the normal and gamma distributions, if the variance is known then this can be specified using a nuisance value (`&NVALUE` in %GLIM). The weight variable must be multiplied by the nuisance value for the gamma distribution, and divided by the nuisance value for the normal distribution.

The loss function

The smaller %GLIM macro in the SAS/STAT User's guide differs from the full %GLIM macro, in that it specifies values for the `_LOSS_` automatic variable. Doing so modifies the "criterion function" (pp. 1149). We found that specifying the loss function did not affect the results, but the program converged slightly faster. For the first iteration, `_LOSS_=0`. For subsequent iterations:

Error Distribution	loss function in second and subsequent iterations
normal	<code>_LOSS_=(Y-MU)**2/_WEIGHT_</code>
poisson	<code>_LOSS_=(Y*log(MU)-MU)/_WEIGHT_</code>
gamma	not specified
binomial	<code>_LOSS_=(-Y*log(P)-(cellTot-Y)*log(1-P))/_WEIGHT_</code>
* P is the probability of success. It's value will depend on the link function (see below)	

Initial values

Initial values must be specified for parameters in PROC NLIN, but the %GLIM macro simply initializes all linear predictors to the value of zero, then calculates adequate initial values in the first iteration (using Weighted Least Squares). The variable for predicted values MU is set to zero and the auxiliary variable for calculating derivatives DER is set to 1, and Y is temporarily transformed using the link function.

link function	specification for initial values
identity	
log	$Y = \log(Y)$
reciprocal	$Y = 1/Y$
root	$Y = \sqrt{\text{abs}(Y)}$
exponential	$Y = Y^{**} \text{index}$
logit	$Y = \log(Y / (\text{cellTot} - Y))$
probit	$Y = \text{probit}(Y / \text{cellTot})$
complementary log-log	$Y = \log(-\log(1 - Y / \text{cellTot}))$
<p>* If Y=0 then Y= .1</p> <p>** If Y=0 then Y=2</p> <p>*** index must be specified if the exponential link function is being used.</p>	

The model specification

The %GLIM macro simply specifies the model as $Y = MU$ (the statement in the %GLIM macro is: MODEL &VARIABLE= MU_ ;). MU is specified for the second and subsequent iterations as the inverse link function of the predictor terms pred. For linear designs, pred is equal to each parameter in the model times its design vector³. Pred is specified at the beginning of the statements for the second and subsequent iterations.

link function	specification of MU for second and subsequent iterations
identity	$MU = \text{pred}$
log	$MU = \exp(\text{pred})$
reciprocal	$MU = 1 / \text{pred}$
root	$MU = \text{pred}^{**2}$
exponential	$MU = \text{sign}(\text{pred}) * (\text{abs}(\text{pred}))^{** (1 / \text{index})}$
logit	$E = \exp(\text{pred})$ $P = E / (1 + E)$
probit	$MU = \text{cellTot} * P$ $P = \text{probnorm}(\text{pred})$
complementary log-log	$MU = \text{cellTot} * P$ $E = \exp(\text{pred})$ $P = 1 - \exp(-E)$ $MU = \text{cellTot} * P$
<p>* MU as specified for the binomial error distribution, which must be used with these link functions⁴</p> <p>P = the probability of success</p>	

Specification of derivatives

The %GLIM macro uses an auxiliary variable DER to assist in the specification of the derivatives. Given that the predictors are all linear, a general expression for the derivatives can be derived from the specification of MU as an inverse link function of *pred*. This is placed in the variable DER and then multiplied by the design vector for the parameter for which derivatives are being calculated, so that the derivatives apply to cases where the parameter applies.

link function	specification of derivatives for second and subsequent iterations
identity	DER=1
log	DER=MU
reciprocal	DER=-1+MU**2
root	DER=2*pred
exponential	DER=(1/index)*MU/pred
logit	E=exp(pred) DER=E*CellTot/(E+1)**2
probit*	DER=CellTot/(sqrt(2*pi)*exp((-1/2)*pred**2))
complementary log-log	E=exp(pred) DER=E*exp(-E)*CellTot
* p1=3.1415927	

Example 1: A logit model using PROC NLIN

To clarify the material presented above, we present a logit model (binomial error distribution logit link function) using PROC NLIN. The data used here is from British electoral studies in 1970, 1974, 1979, 1983 and 1987. The dependent variable is class identification (*classid*) with the value of 1 for identification with the middle class, and 0 for identification with the working class. The two predictor variables are father's occupation (*Focc*) and respondent's occupation (*occ*), both with 7 categories. These are recoded to the EGP classification (Erikson, Goldthorpe, Portocarero), after which categories were combined, to obtain the following values:

- 1 controllers
- 2 routine nonmanual
- 3 self employed
- 4 farmer
- 5 skilled manual/supervisor
- 6 unskilled manual
- 7 farm worker

Cases were selected for which the respondent was employed, for which his occupation and that of his father were non-missing, and for which respondent's class identification was not missing. This resulted in 8453 valid cases. These data are read in table form in the following program, CLASSID SAS:

```
data dsct classid,
input classid b1Denom @@,
```

```

Focc=1+mod(int((_n_-1)/7),7);
Occ=1+mod(int((_n_-1)/1),7);

array xa(7);
array xb(7);
do i=1 to 7;
  if Focc=i then xa(i)=1; else xa(i)=0;
  if Occ=i then xb(i)=1; else xb(i)=0;
end;
drop i;

cards;
525 669 207 320 45 76 5 6 47 112 43 122 6 11
122 175 53 130 9 22 . . 15 62 17 65 0 3
136 213 80 180 58 136 4 6 40 127 40 156 1 7
37 59 20 41 19 32 36 62 10 50 14 86 3 8
287 610 202 601 63 174 4 11 155 871 140 861 3 16
136 318 106 387 34 100 1 1 76 509 129 794 5 15
11 23 6 21 1 9 2 6 7 61 22 103 3 26

```

The data are arranged in pairs, with the frequency of classid per cell, followed by the total frequency per cell. The rows are for father's occupation and the column pairs are for son's occupation. Note that cell (2,4) is empty (father routine nonmanual, son farmer). This has no adverse effects on the models. The data are read in free format. In the input statement, "@@" is specified in order to instruct SAS to continue reading in the horizontal direction - normally the program would read two cases per line, then proceed to the next line. The variables for father's occupation and son's occupation can be generated in statements that emulate the GLIM 3.77 function %gl, for generate levels. The variable Focc contains the values 1 to 7, in blocks of 7, the variable occ contains the values 1 to 7, in blocks of 1.

With the classification variables, design vectors can now be generated for use in subsequent programs. The array statements define 7 new variables xa1, xa2, ... xa7 and 7 new variables xb1, xb2, ... xb7. In the do loop, these new variables are defined as dummy variables for each category of the row and column factors, respectively.

Having read the data and design information into the (permanent) SAS dataset dset.classid, we can proceed with a program for a main effects logit model, in MAINLGT SAS:

```

title 'Main effects logit model on class identification data';

proc nlin nohalve sigsq=1 data=dset.classid;
parms intercpt=0 a2=0 a3=0 a4=0 a5=0 a6=0 a7=0
      b2=0 b3=0 b4=0 b5=0 b6=0 b7=0;

pred=intercpt + a2*xa2 + a3*xa3 + a4*xa4 + a5*xa5 + a6*xa6 + a7*xa7 +
      b2*xb2 + b3*xb3 + b4*xb4 + b5*xb5 + b6*xb6 + b7*xb7;

if _iter_=-1 then do;
  mu=0;
  _loss_=0;
  if classid=0 then classid=0.1;
  if classid=biDenom then classid=biDenom-0.1;
  _weight_=classid*(biDenom-classid)/biDenom;
  classid=log(classid/(biDenom-classid));
end;
else do;
  E=exp(pred);
  der=E*biDenom/(E+1)**2;
  P=E/(1+E);
  mu=P*biDenom;
  _weight_=1/(biDenom*P*(1-P));
  _loss_={-classid*log(P)-(biDenom-classid)*log(1-P)}/_weight_;
end;

```

```

model classid=mu;

der.intercpt=der;
der.a2=der*xa2;
der.a3=der*xa3;
der.a4=der*xa4;
der.a5=der*xa5;
der.a6=der*xa6;
der.a7=der*xa7;
der.b2=der*xb2;
der.b3=der*xb3;
der.b4=der*xb4;
der.b5=der*xb5;
der.b6=der*xb6;
der.b7=der*xb7;

output out=dset.mainlgt p=fitted;

/* use the fitted values to calculate the deviance; */

data one; set dset.mainlgt;
if classid=0 then dev1=classid*log(classid/fitted);
else dev1=0;
if classid=biDenom then dev2=(biDenom-classid)*
                                log( (biDenom-classid)/(biDenom-fitted) );
else dev2=0;
dev=2*(dev1+dev2);

proc summary data=one;
var dev;
output out=two sum=;

data _null_; set two; file print;
* degrees of freedom = 48 units - 13 parameters = 35;
prob=1-probchi(dev,35);

put // 'Deviance is:' dev 8.3 ' with 35 df.'
    / 'prob=' prob 6.3;

```

In PROC NLIN, the options `nohalve` and `sigsq=1` are used. The parameters must be initialized, but the values used are irrelevant, since the first iteration is used to calculate good initial values. The predictor term `pred` contains the linear predictors $\sum_{j=1}^m x_j \beta_j$, which are specified in a straightforward fashion. The parameter for the first category of the row and column factors was dropped (the restriction used in GLIM 3.77)

In the first iteration (`_iter_=-1`), starting values are calculated using weighted least squares. For all GLM's, `mu=0` and `_loss_=0` for the first iteration. For the binomial distribution, the dependent y variate is (temporarily) transformed if it is equal to either the minimum value (0) or maximum value (the cell total, which is the variable `biDenom` in this case). The `_weight_` value for the binomial distribution is specified, then the dependent y variate is transformed to the link function value of itself. Parameters then get weighted least squares estimates for this transformed value of y . Note again that this is a temporary transformation, which applies for the first iteration only.

In the subsequent iterations, `mu` is specified as the inverse link function of the predictor terms, times the binomial denominator. The variables `_weight_` and `_loss_` are given appropriate values for the binomial error distribution. The model can then be specified as $y = \mu$; this is the same for all GLM's.

The specification of the derivatives is quite simple. A variable `der` is specified as a general expression of the derivative of the dependent variable for a linear predictor, when the

logit link is used. This expression must be multiplied by each parameter's design vector, to ensure that the derivative for that parameter is in accordance with its subscript.

The calculation of the general statement for derivatives is not too difficult. The logit model specifies that $y = p \cdot b$, where

b = the binomial denominator

p = the probability of success = $\frac{e}{1+e}$, and

$e = \exp(\eta)$. For a linear design, $\eta = \sum_{j=1}^m x_j \beta_j$.

The derivatives can be found using a number of steps (see appendix A for a brief review of the rules of differentiation). First, the derivative of e with respect to β_j is calculated. This is then used to calculate the derivative of p , with which the derivative of y can be calculated. The first step, the derivative of e with respect to β_j is:

$$\frac{de}{d\beta_j} = \frac{d}{d\beta_j} \{\exp(\eta)\} = \frac{d\eta}{d\beta_j} \cdot \exp(\eta)$$

This follows from the chain rule and the rule for the derivative of an exponential function. It can be further simplified to:

$$\frac{d\eta}{d\beta_j} \cdot \exp(\eta) = \frac{d}{d\beta_j} \left\{ \sum_{j=1}^m x_j \beta_j \right\} \cdot e = x_j e$$

Since the derivative of the linear predictors with respect to one of the parameters is simply the design vector of that parameter, $\frac{de}{d\beta_j}$ resolves to a simple expression. Having found $\frac{de}{d\beta_j}$, we can now calculate the derivative of p with respect to β_j , since p is a function of e . This uses the quotient rule, after which the expression can be simplified.

$$\begin{aligned} \frac{dp}{d\beta_j} &= \frac{\frac{de}{d\beta_j} \cdot (1-e) - e \cdot \frac{d}{d\beta_j} [1-e]}{(1-e)^2} \\ &= \frac{\frac{de}{d\beta_j} - e \cdot \frac{de}{d\beta_j} - \left(e \cdot -\frac{de}{d\beta_j} \right)}{(1-e)^2} \\ &= \frac{\frac{de}{d\beta_j}}{(1-e)^2} \\ &= \frac{x_j e}{(1-e)^2} \end{aligned}$$

The last step is to specify the derivatives of y with respect to β_j . This can be done by:

$$\frac{dy}{d\beta_j} = \frac{d}{d\beta_j}(pb) = \frac{x_j e}{(1-e)^2} \cdot b = x_j \cdot der, \text{ where } der = \frac{e \cdot b}{(1-e)^2}.$$

This shows that a general expression *der* can be found that, multiplied by the design vector of a parameter, correctly specifies the derivatives of that parameter.

A last step in the SAS program is to calculate the deviance of the model. The PROC NLIN output reports the residual *df* and residual weighted sum of squares. The deviance must be calculated using the fitted values, which are output to the SAS dataset `dset.mainlgt` after the specification of the derivatives. The deviance for a logit model can be calculated by:

$$deviance = 2 \sum_{i=1}^n \left\{ y_i \cdot \log\left(\frac{y_i}{\mu_i}\right) + (b_i - y_i) \cdot \log\left(\frac{b_i - y_i}{b_i - \mu_i}\right) \right\}$$

In the dataset after PROC NLIN (`data one;`) the deviance values for each case are calculated. This is done in two components to avoid an expression containing $\log(0)$. These deviance values are summed over the cases in PROC SUMMARY and written to SAS dataset "two". In the last "`data _null_;`" statements, the value of the deviance is appended to the SAS output file.

The residual weighted *SS* of this model was 38.6, with 35 *df*. The deviance was 40.1, so that assuming an asymptotic χ^2 distribution, the probability of the model is .255. The parameters will be presented after example 2, which fits a nonlinear design on the same data.

Example 2: A simple diagonal reference design in a logit model

The above example showed how to estimate a GLM using a nonlinear regression program. It stands to reason that, with a few modifications, a nonlinear design could also be incorporated in a generalized "linear" model. As an example, we use the simple diagonal reference model (SDR) introduced by Sobel (1981). This design was developed for use with a continuous dependent variable, and two predictor variables with an equal number of categories. Its purpose is to ascertain the respective weights of the independent variables in determining the dependent variable. For this example, the SDR design will be used to determine whether origin class or destination class has a greater effect on class identification. The simple diagonal reference design for a normal model is specified as⁵:

$$y_{ijk} = v_{ij} + \varepsilon_{ijk} \quad \text{where} \\ v_{ij} = qv_{.i} + (1-q)v_{.j}$$

For $i, j = 1$ to r , $k = 1$ to n , r being the number of rows/columns of the row and column factors. v_{ij} is the cell mean for category i of the row factor and category j of the column factor. Under the model, the cell means for off-diagonal cells are a weighted sum of the cell means on the diagonal, using weights q and $(1 - q)$. If $q = .5$, the row and column factors have equal weight in determining the dependent variable, if $q > .5$ then row factor has greater weight, if $q < .5$ then the column factor has greater weight. The model estimates r values $v_{.i}$ and 1 parameter q .

This is a nonlinear design, since it contains both additive and multiplicative terms. For the normal distribution, it is not difficult to specify in a nonlinear regression program. The SDR design can also be incorporated in a nonlinear program for GLM type models with a few

modification. The model now specifies linear-multiplicative predictors instead of only linear predictors:

$$\eta_{ijk} = qv_{ii} + (1-q)v_{jj}$$

again for $i, j = 1$ to r , $k = 1$ to n . The model now assumes a distribution of the dependent variable y_{ijk} which need not be the normal distribution, but this has no implications for the program. The dependent variable is now associated with the predictor terms through a link function:

$$E(y_{ijk}) = f(\eta_{ijk}) \text{ where } f \text{ is the inverse link function.}$$

Because of this, the specification of the derivatives is of course altered. For the rest, the program requires no alterations.

As an example, we present the SDR design in a logit model, using the same data as in example 1. The program SDRLGT SAS was specified as follows:

```

title 'Simple Diagonal Reference logit model '
'on class identification data';

proc nlin nohalve sigsq=1 data=dset.classid;
parms q=.5
      nu1=-1.5 nu2=-1.5 nu3=-1.5 nu4=-1.5 nu5=-1.5 nu6=-1.5 nu7=-1.5;
array nu(7);
pred=q*nu(Focc) + (1-q)*nu(Occ);

if _iter_=-1 then do;
  mu=0;
  _loss_=0;
  if classid=0 then classid=0.1;
  if classid=biDenom then classid=biDenom-0.1;
  _weight_=classid*(biDenom-classid)/biDenom;
  classid=log(classid/(biDenom-classid));
end;
else do;
  E=exp(pred);
  der=E*biDenom/(E+1)**2;
  P=E/(1+E);
  mu=P*biDenom;
  _weight_=1/(biDenom*P*(1-P));
  _loss_=(-classid*log(P)-(biDenom-classid)*log(1-P))/_weight_;
end;

model classid=mu;

der.q=der*( nu(Focc)-nu(Occ)) ;
der.nu1=der*( q*xa1 + (1-q)*xb1) ;
der.nu2=der*( q*xa2 + (1-q)*xb2) ;
der.nu3=der*( q*xa3 + (1-q)*xb3) ;
der.nu4=der*( q*xa4 + (1-q)*xb4) ;
der.nu5=der*( q*xa5 + (1-q)*xb5) ;
der.nu6=der*( q*xa6 + (1-q)*xb6) ;
der.nu7=der*( q*xa7 + (1-q)*xb7) ;

output out=dset.sdrlgt p=fitted;

/* use the fitted values to calculate the deviance; */

data one; set dset.sdrlgt;
if classid=0 then dev1=classid*log(classid/fitted);
else dev1=0;
if classid^=biDenom then dev2=(biDenom-classid)*
                                log( (biDenom-classid)/(biDenom-fitted) );
else dev2=0;
dev=2*(dev1+dev2);

proc summary data=one;
var dev;

```



```

output out=two sum=;

data _null_; set two; file print;
* degrees of freedom = 48 units - 8 parameters = 40;
prob=1-probchi(dev,40);

put // 'Deviance is:' dev 8.3 ' with 40 df.'
    / 'prob=' prob 6.3;

```

The changes in the program are the specification of the predictor term, and the specification of the derivatives. The same design vectors as in MAINLGT SAS can be used here too - this is explained below.

We will start with an examination of the predictor term. For a model such as this, the specification in the program is almost the same as the symbolic representation. An array of 7 v_u parameters is defined (`array nu(7);`) and the model is specified in a straightforward fashion:

```
pred=q*nu(Focc) + (1-q)*nu(Occ);
```

The specification of the derivatives would seem to be more complicated now, but this is only slightly true. The specification of the derivatives in example 1 indicate that when a logit link function is used, for any parameter τ that is a predictor of η ,

$$\frac{dy}{dt} = \frac{d\eta}{d\tau} \cdot der$$

This is a consequence of the presence of exponents in the inverse logit function. The problem is therefore not more difficult than calculating the derivatives of the parameters of the SDR design in a normal model.

The parameter $\frac{d\eta}{dq}$ is the simplest, since it applies uniformly to all cases.

$$\frac{d}{dq} \{qv_u + (1-q)v_y\} = v_u - v_y$$

The derivatives for the v_u parameters are slightly more difficult, since these do not have the same value for all cases. The derivatives will be:

$$\frac{d}{dv_u} \{pred\} = 1 \quad \text{if row} = i \text{ and col} = j$$

$$\frac{d}{dv_u} \{pred\} = q \quad \text{if row} = i \text{ and col} \neq j$$

$$\frac{d}{dv_u} \{pred\} = 1-q \quad \text{if row} \neq i \text{ and col} = j$$

$$\frac{d}{dv_u} \{pred\} = 0 \quad \text{if row} \neq i \text{ and col} \neq j$$

This can be specified more simply in a program using dummy variables for the row and column factors. By multiplying q and $1-q$ by the dummies for $row = i$ and $col = i$, the derivatives statements for v_u are given appropriate values:

```

der.nu1=der*( q*xa1 + (1-q)*xb1) ;
---
der.nu7=der*( q*xa7 + (1-q)*xb7) ;

```

With these slight changes, the program for estimating a main effects design logit model is adapted to a program for estimating a simple diagonal reference design logit model. As in example 1, the fitted values are written to an output dataset and used to calculate the deviance. The model had a weighted ss of 47.5; the deviance was 49.3 with 40 *df*, with prob = .149. The increase in deviance from the main effects model was 9.182 with 5 *df*, for which prob = .102. The SDR logit model is an improvement over a main effects logit model.

The parameters of the SDR logit model and the main effects logit model are presented in table 1. The q parameter of the SDR model is .457, which means that respondent's occupation weighs more strongly than father's occupation in determining class identification, but that the difference in weight is not too strong. The a_i and b_j parameters indicate that origin and destination status have near equal effects. The v_u parameters show that category 1 (controllers) has a strong middle class identification. Category 4 (farmers) are neutral, while categories 2 and 4 (routine non-manual workers and the self-employed) have a slight working class orientation. Categories 5, 6 and 7 (skilled manual/ supervisor, unskilled manual, farm worker) have a strong working class orientation. Note the high standard error for v_{77} and v_{44} , the parameters for sparse categories of farmers and farm workers.

Table 1
Parameter estimates of the main effects logit model and the SDR logit model

Main Effects logit model				Simple Diagonal Reference Logit Model		
estimate	std error	estimate	std error	estimate	std error	
α_1	0 (contrast)	β_1	0 (contrast)	v_{11}	1.221	.068
α_2	-.694	β_2	-.706	v_{22}	-.137	.085
α_3	-.719	β_3	-.647	v_{33}	-.144	.105
α_4	-.810	β_4	-.119	v_{44}	.039	.183
α_5	-1.276	β_5	-1.528	v_{55}	-1.547	.065
α_6	-1.418	β_6	-1.575	v_{66}	-1.763	.070
α_7	-1.394	β_7	-1.359	v_{77}	-1.578	.265
<i>intercept</i>		1.240	.069	q	.457	.018

Example 3: Proportional asymmetry

The following model was described earlier in chapter 6. Unlike the diagonal reference model, this is not a well known design, but an exercise at implementing a nonlinear design in a log-linear model. Our objective was to extend the idea of a diagonal reference design to the interaction effects. The diagonal reference model specifies that the main effects of a model may be unequal, but that the row and column values are proportional to each other. Similarly, we wished to estimate an interaction effect design where each parameter in the lower triangle of the table was proportional to the its counterpart in the upper triangle of the table. We specified the design as:

$\eta_{ij} = \psi + \alpha_i + \beta_j + \theta_{ij}$ where
 $\theta_{ij} = (1+q)\gamma_{ij} + (1-q)\gamma_{ji}$ and
 γ_{ij} are symmetric interaction parameters with a specified contrast

This design was used in a loglinear model, so it assumes that the frequency variable $E(y_{ij}) = \exp(\eta_{ij})$ and that y_{ij} has a poisson distribution. The design is for use on a square table, so $i, j = 1$ to r . Beside the main effect parameters ψ , α , and β , there are $r(r-1)/2$ symmetry parameters γ_{ij} and a single asymmetry parameter q . If $q = 0$, then the model is equivalent to a model of quasi-symmetry. Otherwise, the parameters θ_{ij} will be asymmetric, but θ_{ij} parameters in the upper triangle will be $\frac{1+q}{1-q}$ their counterpart parameters θ_{ji} in the lower triangle of the table.

In principle, any contrast could be used for the symmetric interaction parameters γ_{ij} . However, if the deviation contrast is used, the restriction that θ_{ij} is proportional to θ_{ji} will only apply to the identifiable parameters, not to the redundant parameters. For the symmetric interaction parameters, we used the parametrization in Sobel, Hout and Duncan (1985). Each parameter corresponds with a log odds-ratio, of the ratio of the log odds of immobility in the origin category versus mobility, to the log odds of mobility versus immobility in the destination category. The design matrix is simple to specify: the design vector for γ_{ij} equals 1 for $row = i$ and $col = j$, or $row = j$ and $col = i$, and is 0 otherwise.

For data, we used a 4 by 4 table of husband's education by wife's education in the pre 1949 marriage cohort, from the Dutch 1971 census. The association in this table is asymmetric: a quasi symmetry model has an L^2 of 2513 with 3 *df*. The corresponding BIC value is 2472, so sample size is not the explanation. We wrote the following program (PROPASYM SAS) to estimate a proportional asymmetry model on these data:

```

/* data from the Dutch 1971 census: husband's education by wife's      */
/* education in the pre 1949 marriage cohort                             */

data one;
input freq @@;
edHusb=1+mod(int((_N_-1)/4),4);
edWife=1+mod(int((_N_-1)/1),4);

array xa{4};
array xb{4};
array xi{4,4} xi11 xi12 xi13 xi14
              xi21 xi22 xi23 xi24
              xi31 xi32 xi33 xi34
              xi41 xi42 xi43 xi44;

if edHusb=4 then xa4=1; else xa4=0;
if edWife=4 then xb4=1; else xb4=0;

do i=1 to 3;
  if edHusb=i then xa{i}=1; else xa{i}=0;
  xa{i}=xa{i}-xa4;
  if edWife=i then xb{i}=1; else xb{i}=0;
  xb{i}=xb{i}-xb4;
end;

do i=1 to 4;
  do j=1 to 4;
    if edHusb=i & edWife=j then xi{i,j}=1; else xi{i,j}=0;
  end;
end;
drop i j xa4 xb4 xi11 xi22 xi33 xi44;

cards;
  
```

```

475931    30462    6143    2154
116212    46791    9382    3163
21876     19069    8640    3429
17047     18743    12621   12054
;

proc nlin data=one nohalve sigsq=1;
parms constant=0 a1=0 a2=0 a3=0 b1=0 b2=0 b3=0
      i12=0 i13=0 i14=0 i23=0 i24=0 i34=0 q=0;

if _iter_=-1 | (_iter_=0 & _model_=0) then do;
  mu=0;
  der=1;
  _weight_=freq;
  _loss_=0;
  freq=log(freq);
end;
else do;
  pred=constant + a1*xa1 + a2*xa2 + a3*xa3 +
        b1*xb1 + b2*xb2 + b3*xb3 +
  i12*((1+q)*xi12+(1-q)*xi21) + i13*((1+q)*xi13+(1-q)*xi31) +
  i14*((1+q)*xi14+(1-q)*xi41) + i23*((1+q)*xi23+(1-q)*xi32) +
  i24*((1+q)*xi24+(1-q)*xi42) + i34*((1+q)*xi34+(1-q)*xi43) ;
  mu=exp(pred);
  der=mu;
  _weight_=1/mu;
  _loss_=(freq*log(mu)-mu)/_weight_;
end;
model freq=mu;

der.constant=der;
der.a1 =der*xa1 ;
der.a2 =der*xa2 ;
der.a3 =der*xa3 ;
der.b1 =der*xb1 ;
der.b2 =der*xb2 ;
der.b3 =der*xb3 ;
der.i12 =der*((1+q)*xi12 + (1-q)*xi21) ;
der.i13 =der*((1+q)*xi13 + (1-q)*xi31) ;
der.i14 =der*((1+q)*xi14 + (1-q)*xi41) ;
der.i23 =der*((1+q)*xi23 + (1-q)*xi32) ;
der.i24 =der*((1+q)*xi24 + (1-q)*xi42) ;
der.i34 =der*((1+q)*xi34 + (1-q)*xi43) ;
der.q =der*(i12*(xi12-xi21) + i13*(xi13-xi31) + i14*(xi14-xi41) +
      i23*(xi23-xi32) + i24*(xi24-xi42) + i34*(xi34-xi43)) ;

output out=two p=fitted;

data three; set two;
dev=2*freq*log(freq/fitted) - freq+fitted;

proc summary data=three;
var dev;
output out=four sum=;

data _null_; set four; file print;
* degrees of freedom = 16 units - 14 parameters = 2;
prob=1-probchi(dev,2);

put // 'Deviance is:' dev 8.3 ' with 2 df.'
    / 'prob=' prob 6.3;

```

In the first dataset `data one`, the table frequencies are read and the row and column factors `edHusb` and `edWife` are generated. Design vectors for the main effects, using the deviation contrast. Two sets of design vectors for the symmetric interaction parameters are also generated, one for parameters in the lower triangle of the table, and one for parameters in the upper triangle of the table. Added together, corresponding pairs of these design vectors will give the design vectors for symmetric interaction using the SHD contrast. In the model

statement however, the resulting design vector will be a weighted sum of the component pairs.

In the PROC NLIN program, most elements remains as they would be if linear predictors were used with a poisson error term and a log link function. As noted above, in the specification of the predictor terms, the parameter for symmetric interaction is multiplied by a resultant design vector, which is formed by adding the design vectors from the upper and lower triangles, using weights $1+q$ and $1-q$. And because the predictor terms have changed, the specification of the derivatives must also change. Since a log link function is used, the dependent variable is an exponential function of the predictor terms: $E(y) = \exp(\eta)$. The derivative of any parameter τ that is a predictor of η will therefore be equal to $\frac{d\eta}{d\tau} \cdot \exp(\eta) = \frac{d\eta}{d\tau} \cdot \exp(\eta)$.

The specification of the derivatives for the linear terms is straightforward: the derivative for any parameter is equal to its design vector. The derivatives of the symmetric interaction parameters γ_{ij} are equal to the resultant design vectors found by adding corresponding design vectors for the upper and lower triangle of the table with weights $1+q$ and $1-q$. The derivative of the parameter q is equal to the sum of symmetric interaction parameters, times the difference between the component design vectors in the upper and lower triangles of the table. After the PROC NLIN program, the fitted values are output to dataset two, where they are used to calculate the deviance in subsequent steps.

The program converged in 5 iterations. The L^2 of the model was 34.634 with 2 *df*. This is an immense improvement over quasi-symmetry (L^2 2513 with 3 *df*). However, the model is still not acceptable, either by the probability of the model or by its BIC value (7.4). The q parameter had a value of -.973. This means that parameters in the upper triangle of the table will be near zero, while parameters in the lower triangle will be quite high. Table 2 gives the parameter estimates and standard errors of the identifiable parameters of the model, while table 3 shows the full set of parameters. Note that in the full set of interaction parameters, values in the upper triangle are all almost zero. There are no barriers to men marrying wives with a higher education than themselves. The parameters in the lower triangle show that there are strong barriers to men marrying wives with less education than themselves. All parameters in the lower triangle are negative, showing that homogamy is much more likely than heterogamy, particularly at several removes from the diagonal.

Table 2
Parameter estimates and standard errors of a proportional asymmetry model

parameter	estimate	s.e.
ψ	10.577	.004
α_1	-.596	.042
α_2	-.197	.009
α_3	-.257	.016
β_1	3.092	.042
β_2	.371	.009
β_3	-1.232	.015
γ_{12}	-.917	.004
γ_{13}	-1.733	.007
γ_{14}	-2.522	.010
γ_{23}	-.423	.008
γ_{24}	-1.095	.009
γ_{34}	-.483	.009
q	-.973	.035

Table 3
Full set of parameters of a proportional asymmetry model
 $L^2 = 34.6$ with 2 df; BIC = 7.4

Husband's education	Wife's education				Row marginals
	Elementary	Lower secondary	Higher secondary	College	
Elementary	0	-.025	-.047	-.068	-.596
Lower secondary	-1.808	0	-.011	-.030	-.197
Higher secondary	-3.418	-.835	0	-.013	-.257
College	-4.976	-2.161	-.953	0	1.051
Column marginals	3.092	.371	-1.232	-2.232	10.577

Example 4: A power distance model

This model is a second example of how nonlinear designs can be developed. The point of departure is the so called distance model (Haberman, 1979). This loglinear model estimates for a square table a single interaction parameter ϕ , using as its design vector the absolute differences between the row and column factors.

$$\eta_{ij} = \psi + \alpha_i + \beta_j + \phi|i - j|$$

Noting that $E(y_{ij})$, the expected value of the dependent frequency variable is equal to $\exp(\eta_{ij})$, and that y_{ij} has a poisson distribution. The distance parameter therefore indicates how much lower mobility becomes (controlling for the marginals) after each step away from the main diagonal. This model is related to the crossings parameter model (Goodman, 1972; Hout, 1983): it fixes crossings parameters to be equal for all steps away from the diagonal. In terms of log odds-ratios⁶, it generates a pattern of equal values on the main diagonal of the table of log odds-ratios, and zero values off the main diagonal (see tables 4a and 4b).

A squared distance model can be derived from the distance model, by squaring the absolute difference design vector.

Table 4a
Distance design for a 5 by 5 table

0	1 ϕ	2 ϕ	3 ϕ	4 ϕ
1 ϕ	0	1 ϕ	2 ϕ	3 ϕ
2 ϕ	1 ϕ	0	1 ϕ	2 ϕ
3 ϕ	2 ϕ	1 ϕ	0	1 ϕ
4 ϕ	3 ϕ	2 ϕ	1 ϕ	0

Table 4b
Pattern of log odds-ratios

-2 ϕ	0	0	0
0	-2 ϕ	0	0
0	0	-2 ϕ	0
0	0	0	-2 ϕ

$$\eta_{ij} = \psi + \alpha_i + \beta_j + \phi|i - j|^2$$

The rationale for this would be that long distance mobility becomes less at a greater than linear rate. The squared distance model turns out to be equivalent to the uniform association model: it generates a pattern of equal values in all cells of the table of log odds-ratios (see tables 5a and 5b).

Table 5a
Squared distance design for a
5 by 5 table

0	1φ	4φ	9φ	16φ
1φ	0	1φ	4φ	9φ
4φ	1φ	0	1φ	4φ
9φ	4φ	1φ	0	1φ
16φ	9φ	4φ	1φ	0

Table 5b
Pattern of log odds-ratios

-2φ	-2φ	-2φ	-2φ
-2φ	-2φ	-2φ	-2φ
-2φ	-2φ	-2φ	-2φ
-2φ	-2φ	-2φ	-2φ

This raises the question of whether the distance model couldn't be generalized, by estimating as a parameter the power to which the distance design vector is raised. The higher the power parameter p , the greater the extent in which the principle of "the further, the fewer" applies.

$$\eta_{ij} = \psi + \alpha_i + \beta_j + \phi|i - j|^p$$

We estimated this model in the following program POWDIST SAS. The data were a 5 by 5 table of occupational mobility, from Featherman and Hauser, 1978.

```
data dist;
input freq @@;
row=1+mod(int((_n_-1)/5),5);
col=1+mod(int((_n_-1)/1),5);

array xa(4); /* row cat design vectors, deviation contrast */
array xb(4); /* col cat design vectors */
do i=1 to 4;
  if row=i then xa(i)=1;
  else if row=5 then xa(i)=-1;
  else xa(i)=0;
  if col=i then xb(i)=1;
  else if col=5 then xb(i)=-1;
  else xb(i)=0;
end;

dist=abs(row-col);

drop i;
cards;
1414 521 302 643 40
724 524 254 703 48
798 648 856 1676 108
756 914 771 3325 237
409 357 441 1611 1832
;

proc nlin data=dist sigsq=1 maxiter=25 nohalve;
parms intercpt=0 a1=0 a2=0 a3=0 a4=0 b1=0 b2=0 b3=0 b4=0 gam=0 pow=1;

if _iter_=-1 | (_iter_=0 & _model_=0) then do;
```

```

mu=0;
_loss_=0;
der=1;
_weight_=freq;
freq=log(freq);
end;
else do;
  pred=intercpt + a1*Xa1 + a2*Xa2 + a3*Xa3 + a4*Xa4
               + b1*Xb1 + b2*Xb2 + b3*Xb3 + b4*Xb4
               + gam*dist**pow;
  mu=exp(pred);
  der=mu;
  _weight_=1/mu;
  _loss_=(freq*log(mu)-mu)/_weight_;
end;

model freq=mu;

der.intercpt=der;
der.a1 =der*Xa1 ;
der.a2 =der*Xa2 ;
der.a3 =der*Xa3 ;
der.a4 =der*Xa4 ;
der.b1 =der*Xb1 ;
der.b2 =der*Xb2 ;
der.b3 =der*Xb3 ;
der.b4 =der*Xb4 ;
der.gam=der*dist**pow;
if dist=0 then der.pow=0;
else der.pow=der*gam*log(dist)*dist**pow;

output out=dset.powdist p=fitted;

data two; set dset.powdist;
dev=2*freq*log(freq/fitted) - freq+fitted;

proc summary data=two;
var dev;
output out=three sum=;

data _null_; set three; file print;
* degrees of freedom = 25 units - 11 parameters =14;
prob=1-probchi(dev,14);

put // 'Deviance is:' dev 8.3 ' with 14 df.'
    / 'prob=' prob 6.3;

```

In the first data statement, data `dist`, the data are read and the row and column factors are generated. Design vectors for the main effects using the deviation contrast are created, and the design vector for a linear distance model is defined. In the PROC NLIN program, the power parameter `pow` is initialized with the value of 1; a value of zero cannot be used, since zero to the power of zero is undefined. The specification of the predictor terms is straightforward.

The derivative of ϕ is easy to specify: $\frac{d\eta}{d\phi} = |i - j|^p$. As for the derivative of p , since $|i - j|^p =$

$\exp(\log(|i - j|^p)) = \exp(p \log(|i - j|))$, the derivative is $\frac{d\eta}{dp} = \log(|i - j|) \cdot \phi |i - j|^p$. After the

PROC NLIN program, the fitted values are output and used to calculate the deviance.

The program converged in 5 iterations. It had an L^2 of 1413.645 with 14 *df*, versus 1497.772 with 15 *df* for a linear distance model. The fit is inadequate, presumably because of high counts on the diagonal. The estimate of ϕ was -.622 (s.e. .017), versus -.475 (s.e. .007) in a linear distance model. The estimate for p was .744 (s.e. .024), indicating that long distance mobility does not become increasingly difficult. Short distance mobility is difficult, but each

subsequent step becomes relatively easier. The pattern of log odds-ratios (table 6b) bears this out. Since the distance parameter ϕ will usually be negative, there will be high positive odds-ratios on the diagonal of the table. Off diagonal log odds-ratios will be negative and will decrease in value, indicating that a subsequent step away from the main diagonal is slightly more likely than the present outcome. At further removes from the diagonal, the association becomes less and less.

Table 6a
Design from a power distance design for
a 5 by 5 table with $p=.744$

.000	1.000	1.675	2.265	2.805
1.000	.000	1.000	1.675	2.265
1.675	1.000	.000	1.000	1.675
2.265	1.675	1.000	.000	1.000
2.805	2.265	1.675	1.000	.000

Table 6b
Pattern of log odds-ratios

-2.000	.325	.085	.049
.325	-2.000	.325	.085
.085	.325	-2.000	.325
.049	.085	.325	-2.000

Example 5: The row and column model II (RCII)

Goodman's row and column model II (RCII) is another example of a nonlinear design used in a GLM-type model, in this case a loglinear model. The basic notion of the design is an extension of that of uniform association, which tests whether the association is equal in all subtables of the frequency table. The RCII model can be used to find the scale values for which this would be the case. The model can be specified for a table of row factor with r categories, by column factor with c categories, as:

$$\eta_{ij} = \psi + \alpha_i + \beta_j + \phi\sigma_i\omega_j$$

$$\text{where } \sum_{i=1}^r \sigma_i = \sum_{j=1}^c \omega_j = 0$$

$$\text{and } \sum_{i=1}^r \sigma_i^2 = \sum_{j=1}^c \omega_j^2 = 1$$

For $i = 1$ to r , $j = 1$ to c . Since this is an extension of a loglinear model, y_{ij} , the frequencies of the table, have a poisson error distribution, and a log link function is used, which means that the expected frequencies are the exponent of the predictor term: $E(y_{ij}) = \exp(\eta_{ij})$.

The first three terms model the marginal effects, but could be extended with a diagonal term, if necessary or desired. The interaction term $\phi\sigma_i\omega_j$ contains multiplicative parameters in an otherwise linear design. ϕ is an overall association term, and σ_i and ω_j are new scale values. If the row and column factors are rescaled using σ_i and ω_j , the table will have uniform association of the magnitude ϕ . The scale values have been normalized, making two values σ_i and σ_m redundant. Other restrictions are possible, as long as the interaction term contains $(r-2)(c-2)+1$ identifiable parameters.

There are two ways of estimating the RCII model using PROC NLIN. The first method directly estimates all parameters. In order to do this, the redundant σ_i and ω_j parameters must be

expressed in terms of the identifiable parameters for the model statement. In addition, the derivatives for units of η which are a function of redundant σ_i and/or ω_j parameters must be expressed in terms of identifiable parameters.

An alternative method is to impose only the restriction that the scale parameters σ_i and ω_j sum to zero. The model is not identifiable: there is no unique solution, but PROC NLIN will find a solution, using a generalized inverse. The fit is not affected by the use of this procedure, and the scale parameters can be normalized afterwards. The only differences are that standard errors of the parameter estimates are no longer available, and that this second alternative is slightly less accurate. On the other hand, this method is much easier to specify and therefore considerably more flexible. We discuss the method of direct estimation first, then show what modifications in the program are necessary for the generalized inverse method.

DIRECT ESTIMATION

The redundant parameters σ_i and σ_m can be derived from the identifiable parameters in the following fashion. Let p be the sum of the identifiable σ_i parameters, and let pSS be the sum of squares of the identifiable σ_i parameters. This means that $\sigma_i + \sigma_m + p = 0$, and $\sigma_i^2 + \sigma_m^2 + pSS = 1$, so:

$$\sigma_i = -\sigma_m - p \Rightarrow$$

$$(-\sigma_m - p)^2 + \sigma_m^2 + pSS = 1$$

$$\sigma_m^2 + 2p\sigma_m + p^2 + \sigma_m^2 + pSS = 1$$

$$2\sigma_m^2 + 2p\sigma_m + p^2 + pSS - 1 = 0$$

This can be solved as:

$$\begin{aligned}\sigma_m &= \frac{-2p \pm \sqrt{4p^2 - 8(p^2 + pSS - 1)}}{4} \\ &= \frac{-p \pm \sqrt{-p^2 - 2pSS + 2}}{2}\end{aligned}$$

$$\text{So } \sigma_m = \frac{-p + \sqrt{-p^2 - 2pSS + 2}}{2} \text{ and } \sigma_i = \frac{-p - \sqrt{-p^2 - 2pSS + 2}}{2} \text{ - or the other way around.}$$

The redundant parameters can switch places, and there is therefore no unique solution for finding redundant scale values from identifiable ones. In practise, the values of the row and column scales are ordered and shifts in value are expected, not wildly different new scales. So, if the categories of factor a are ordered from low to high, we can let

$$\sigma_1 = \frac{-p - \sqrt{-p^2 - 2pSS + 2}}{2} \text{ and } \sigma_r = \frac{-p + \sqrt{-p^2 - 2pSS + 2}}{2}.$$

Likewise,

$$\omega_1 = \frac{-q - \sqrt{-q^2 - 2qSS + 2}}{2} \text{ and } \omega_c = \frac{-q + \sqrt{-q^2 - 2qSS + 2}}{2}.$$

With these expressions for the redundant parameters, we are able to express the RCI model in the model statement in PROC NLIN. The next step is to determine what the derivative statements must be. Because a log link is being used, $\frac{dy_y}{d\tau} = \frac{d\eta_y}{d\tau} \cdot \exp(\eta_y) = \frac{d\eta_y}{d\tau} \cdot der$ for any parameter τ that is a predictor of η_y . Since the derivatives of η_y with respect to any of the linear parameters will evaluate to 1 for units that are a function of that parameter, 0 otherwise, we can focus on the derivatives with respect to $\phi\sigma_i\omega_j$. $\frac{d\eta_y}{d\tau} \cdot der$ evaluates to $\sigma_i\omega_j$; it is easy to specify because ϕ applies to all units of η_y .

$\frac{d\eta_y}{d\sigma_i}$ evaluates to $\phi\omega_j$ for $row=i$, and $\frac{d\eta_y}{d\omega_j}$ evaluates to $\phi\sigma_i$ for $col=j$. However, units 1 and r of row , and units 1 and c of col are a function of redundant parameters. The derivatives for these redundant parameters must be expressed in terms of the identifiable parameters. We will illustrate how this must be done for $\frac{d\eta_y}{d\sigma_i}$. It is easy to see that:

$$\frac{dp}{d\sigma_i} = 1 \text{ and } \frac{dpSS}{d\sigma_i} = 2\sigma_i,$$

and the rules of calculus specify that if $f(x) = \sqrt{g(x)}$, then $f'x = g'(x) \cdot \frac{1}{2\sqrt{g(x)}}$. Therefore, given that for $row=1$ and $col=j$,

$$\begin{aligned} \eta_y &= \dots + \phi\sigma_i\omega_j \\ &= \dots + \phi \frac{-p - \sqrt{-p^2 - 2pSS + 2}}{2} \omega_j \end{aligned}$$

it follows that

$$\begin{aligned} \frac{d\eta_y}{d\sigma_i} &= \frac{1}{2} \phi \omega_j \left\{ -1 - (-2p - 4\sigma_i) \cdot \frac{1}{2\sqrt{-p^2 - 2pSS + 2}} \right\} \\ &= \frac{1}{2} \phi \omega_j \left\{ -1 - \frac{-p - 2\sigma_i}{\sqrt{-p^2 - 2pSS + 2}} \right\} \\ &= \frac{1}{2} \phi \omega_j \left\{ \frac{-\sqrt{-p^2 - 2pSS + 2} + p + 2\sigma_i}{\sqrt{-p^2 - 2pSS + 2}} \right\} \\ &= \frac{1}{2} \phi \omega_j \left\{ \frac{-2\sigma_r + 2\sigma_i}{\sqrt{-p^2 - 2pSS + 2}} \right\} \\ &= \frac{\phi \omega_j (-\sigma_r + \sigma_i)}{\sqrt{-p^2 - 2pSS + 2}} \end{aligned}$$

In the same way, we can derive that for $row=r$ and $col=j$,

$$\frac{d\eta_{ij}}{d\sigma_i} = \frac{\phi\omega_i(\sigma_i - \sigma_r)}{\sqrt{-p^2 - 2pSS + 2}}$$

To summarize, the derivatives for σ_i are:

$$\begin{aligned}\frac{d\eta_{ij}}{d\sigma_i} &= \phi\omega_i, & \text{for row} = i \\ \frac{d\eta_{ij}}{d\sigma_i} &= \phi\omega_i \cdot \frac{-\sigma_r + \sigma_i}{\sqrt{-p^2 - 2pSS + 2}}, & \text{for row} = 1 \\ \frac{d\eta_{ij}}{d\sigma_i} &= \phi\omega_i \cdot \frac{\sigma_i - \sigma_r}{\sqrt{-p^2 - 2pSS + 2}}, & \text{for row} = r\end{aligned}$$

Similarly, the derivatives for ω_i are:

$$\begin{aligned}\frac{d\eta_{ij}}{d\omega_i} &= \phi\omega_i, & \text{for col} = j \\ \frac{d\eta_{ij}}{d\omega_i} &= \phi\omega_i \cdot \frac{-\omega_c + \omega_i}{\sqrt{-q^2 - 2qSS + 2}}, & \text{for col} = 1 \\ \frac{d\eta_{ij}}{d\omega_i} &= \phi\omega_i \cdot \frac{\omega_i - \omega_c}{\sqrt{-q^2 - 2qSS + 2}}, & \text{for col} = c\end{aligned}$$

PROGRAM FOR THE DIRECT ESTIMATION OF A QUASI ROW AND COLUMN MODEL II

For a sample program, we fit a quasi RCII model⁷. This model contains a special parameter d_i for each diagonal cell of the square table, in addition to the parameters of the RCII model.

$$\eta_{ij} = \psi + \alpha_i + \beta_j + d_i + \phi\sigma_i\omega_j$$

The reasoning is that if the high frequencies on the diagonal are taken into account, the RCII model applies to the table. As data we used a 5 by 5 mobility table taken from Featherman and Hauser (1978). The categories are: "upper nonmanual", "lower nonmanual", "upper manual", "lower manual", "farm". The row factor (`row` in the program) is father's occupation, the column factor (`col`) is son's first occupation.

We split the program in two sections. The first, DATDESQ SAS, reads the data and creates the design matrix and the necessary dummy variables for use in the derivatives statement. QRCII SAS then estimates the quasi RCII model.

```
title 'Design matrix for quasi-rcii model';

data dsset.datdesq;
input freq @@;
row=1+mod(int((_n_-1)/5),5);
col=1+mod(int((_n_-1)/1),5);

array xr(5); /* row cat dummy vars for the derivatives statement */
array xc(5); /* col cat dummies */
array xd(5); /* design vectors for the diagonal effects */
do i=1 to 5;
  if row=i then xr(i)=1; else xr(i)=0;
  if col=i then xc(i)=1; else xc(i)=0;
  if row=i and col=i then xd(i)=1; else xd(i)=0;
end;
```

```

/* deviation contrast parameters for the marginal effect parameters */
array xa(4);
array xb(4);
do i=1 to 4;
    xa(i)=xr(i)-xr5;
    xb(i)=xc(i)-xc5;
end;

drop i;
cards;
1414 521 302 643 40
724 524 254 703 48
798 648 856 1676 108
756 914 771 3325 237
409 357 441 1611 1832

```

The input statement reads only the frequency table itself. The row and column factors can then be calculated. The arrays *xr* and *xc* contain dummy variables for each category of the row and column variables respectively, for use in the derivatives statement. The array *xd* contains design vectors for the diagonal effects d_j . The *xr* and *xc* arrays are used to create design vectors with the deviation contrast *xa* and *xb*, for the row and column effects α_i and β_j .

The SAS dataset *dset.datdesq* contained data and design information for a quasi RCII model. This model was estimated in QRCII SAS:

```

proc nlin data=dset.datdesq sigsq=1 nohalve;
parms intercpt=0 a1=0 a2=0 a3=0 a4=0 b1=0 b2=0 b3=0 b4=0
    d1=0 d2=0 d3=0 d4=0 d5=0
    sig2=-.316 sig3=0 sig4=.316 ome2=-.316 ome3=0 ome4=.316 phi=0;
array sig(5) sig1-sig5;
array ome(5) ome1-ome5;

/* Calculate redundant sigma and omega parameters          */
/* prior to each iteration                                */

p=sig2+sig3+sig4;
pSS=sig2**2+sig3**2+sig4**2;
pSqrtDet=sqrt(-p**2-2*pSS+2);
sig1=(-p-pSqrtDet)/2;
sig5=(-p+pSqrtDet)/2;

q=ome2+ome3+ome4;
qSS=ome2**2+ome3**2+ome4**2;
qSqrtDet=sqrt(-q**2-2*qSS+2);
ome1=(-q-qSqrtDet)/2;
ome5=(-q+qSqrtDet)/2;

if _iter_=-1 | (_iter_=0 & _model_=0) then do;
    mu=0;
    _loss_=0;
    der=1;
    _weight_=freq;
    freq=log(freq);
end;
else do;
    pred=intercpt + a1*Xa1 + a2*Xa2 + a3*Xa3 + a4*Xa4
        + b1*Xb1 + b2*Xb2 + b3*Xb3 + b4*Xb4
        + d1*Xd1 + d2*Xd2 + d3*Xd3 + d4*Xd4 + d5*Xd5
        + sig{row}*ome{col}*phi;

    mu=exp(pred);
    der=mu;
    _weight_=1/mu;
    _loss_=(freq*log(mu)-mu)/_weight_;
end;

model freq=mu;

der.intercpt=der;

```

```

der.a1 =der*xa1 ;
der.a2 =der*xa2 ;
der.a3 =der*xa3 ;
der.a4 =der*xa4 ;
der.b1 =der*xb1 ;
der.b2 =der*xb2 ;
der.b3 =der*xb3 ;
der.b4 =der*xb4 ;
der.d1 =der*xd1 ;
der.d2 =der*xd2 ;
der.d3 =der*xd3 ;
der.d4 =der*xd4 ;
der.d5 =der*xd5 ;
der.sig2=der*phi*ome(col)*( xr2 +
(-sig5+sig2)/pSqrtDet *xr1 +
(sig1-sig2)/pSqrtDet *xr5 );
der.sig3=der*phi*ome(col)*( xr3 +
(-sig5+sig3)/pSqrtDet *xr1 +
(sig1-sig3)/pSqrtDet *xr5 );
der.sig4=der*phi*ome(col)*( xr4 +
(-sig5+sig4)/pSqrtDet *xr1 +
(sig1-sig4)/pSqrtDet *xr5 );
der.ome2=der*phi*sig(row)*( xc2 +
(-ome5+ome2)/qSqrtDet *xc1 +
(ome1-ome2)/qSqrtDet *xc5 );
der.ome3=der*phi*sig(row)*( xc3 +
(-ome5+ome3)/qSqrtDet *xc1 +
(ome1-ome3)/qSqrtDet *xc5 );
der.ome4=der*phi*sig(row)*( xc4 +
(-ome5+ome4)/qSqrtDet *xc1 +
(ome1-ome4)/qSqrtDet *xc5 );
der.phi =der*sig(row)*ome(col);

output out=dset.qrcii p=fitted;

data two; set dset.qrcii;
dev=2*freq*log(freq/fitted) - freq+fitted;

proc summary data=two;
var dev;
output out=three sum=;

data _null_; set three; file print;
* degrees of freedom = 25 units - 21 parameters = 4;
prob=1-probchi(dev,4);

put // 'Deviance is:' dev 8.3 ' with 4 df.'
/ 'prob=' prob 6.3;

```

The linear parameters are, as usual, initialized with the value of zero. The identifiable scale parameters σ_j and ω_j are given the normalized values of their category numbers. For the specification of the predictor term, both identifiable and redundant scale parameters σ_j and ω_j must be used. Therefore, the redundant scale values are calculated prior to each iteration. The predictor term itself can be expressed in a straightforward fashion.

The `_weight_` and `_loss_` variables are given values appropriate for a poisson error distribution, and `mu` is set to the inverse link function of the predictor term. The specification of the derivatives for the scale parameters is a bit more complicated than in previous examples, because different values must be specified for the category the parameter pertains to, and categories 1 and 5, the two redundant categories. This is done using the appropriate dummy variables.

The fitted values are output to the SAS dataset `dset.qrcii`, to be used in the calculation of the deviance statistics. The program converged in 8 iterations. The weighted SS, equal to the Pearson χ^2 , was equal to 23.78 with 4 *df*. The deviance was 24.13, with a *prob* < .001. That the model is not statistically acceptable is due to the large⁸ number of cases (19912).

Table 8
Parameter estimates of a quasi RCII model

d_i	s.e.	ϕ	s.e.	σ_i	s.e.	ω_j	s.e.
.086	(.254)	1.621	(.149)	-.680	—	-.748	—
.275	(.095)			-.325	(.064)	-.207	(.055)
.527	(.050)			.083	(.029)	.070	(.034)
-.004	(.079)			.471	(.039)	.410	(.049)
2.785	(.093)			.451	—	.474	—

ASSOC⁹, a special program for estimating association models, gave the same deviance and parameter estimates. The parameter estimates are presented in table 8.

Given these parameter estimates, we can say that there is a good deal of immobility in category 5 (farm), and to a much smaller degree in categories 2 and 3 (lower nonmanual and upper manual). Having taken immobility into account, there is a strong association between father's occupation and son's first occupation. The new scale values place categories 4 and 5 very close together - their rank order switches for origin status. There is evidently little social distance between lower non-manual workers and farmers (taking immobility into account). Possibly they could be treated as a single category as far as scale values are concerned, and distances between categories could be fixed to be identical. Note the large standard error for d_1 (.254) and for ϕ (.149).

PROGRAM FOR ESTIMATING A QUASI RCII MODEL, USING A GENERALIZED INVERSE

Specifying the redundant σ_i and ω_j scale parameters in terms of identifiable parameters, then specifying the derivatives is fairly complicated. It should be possible to let the computer handle such complex tasks. This can be done by incorrectly specifying the model, so that it is not identified. PROC NLIN then uses a generalized inverse to find a solution anyway. The model fit is not affected by this method, and parameters can be transformed afterward to the values they would have, if the proper restrictions had been imposed.

In this alternative model, we restricted the σ_i and ω_j parameters to sum to zero¹⁰, but did not restrict their sum of squares to equal 1. We let $\sigma_i = -\sum_{i=1}^4 \sigma_i$, and $\omega_j = -\sum_{j=1}^4 \omega_j$. Redundant

parameters were now much easier to specify. For the derivatives, $\frac{d\eta_{ij}}{d\sigma_i} = \phi\omega_j$, for $row = i$ and

$\frac{d\eta_{ij}}{d\sigma_i} = -\phi\omega_j$, for $row = 5$. Similarly, $\frac{d\eta_{ij}}{d\omega_j} = \phi\sigma_i$, for $col = j$ and $\frac{d\eta_{ij}}{d\omega_j} = -\phi\sigma_i$, for $col = 5$.

All effects except the scaled association term $\phi\sigma_i\omega_j$ are identified, and their estimates are not affected by this procedure (to three decimal points of accuracy). The estimates for ϕ , σ_i and ω_j are arbitrary, but since the fitted values and the other terms of the model are not affected, the scaled association term can be transformed to the values they would have had, us-

ing direct estimation. The estimates of σ_i and ω_j already have a sum of zero. Normalized scale parameters σ_i^* can be found by dividing σ_i by the square root of its sum of squares:

$$\sigma_i^* = \frac{\sigma_i}{\sqrt{\sum_{i=1}^5 \sigma_i^2}}$$

Likewise,

$$\omega_j^* = \frac{\omega_j}{\sqrt{\sum_{j=1}^5 \omega_j^2}}$$

By specifying that

$$\phi^* = \phi \sqrt{\sum_{i=1}^5 \sigma_i^2} \sqrt{\sum_{j=1}^5 \omega_j^2}$$

we ensure that $\phi^* \sigma_i^* \omega_j^* = \phi \sigma_i \omega_j$.

Our alternative program, QRCII2 SAS, was as follows:

```
proc nlin data=dset.datdesq sigsq=1 maxiter=25 nohalve
      g4 outest=pset.qrcii2;
parms  intercpt=0 a1=0 a2=0 a3=0 a4=0 b1=0 b2=0 b3=0 b4=0
      d1=0 d2=0 d3=0 d4=0 d5=0 phi=0
      sig1=-.632 sig2=-.361 sig3=0 sig4=.361
      ome1=-.632 ome2=-.361 ome3=0 ome4=.361;
array sig{5} sig1-sig5;
array ome{5} ome1-ome5;

sig5=-sig1-sig2-sig3-sig4;
ome5=-ome1-ome2-ome3-ome4;

if _iter_=-1 | (_iter_=0 & _model_=0) then do;
  mu=0;
  _loss_=0;
  der=1;
  _weight_=freq;
  freq=log(freq);
end;
else do;
  pred=intercpt + a1*Xa1 + a2*Xa2 + a3*Xa3 + a4*Xa4
        + b1*Xb1 + b2*Xb2 + b3*Xb3 + b4*Xb4
        + d1*Xd1 + d2*Xd2 + d3*Xd3 + d4*Xd4 + d5*Xd5
        + sig{row}*ome{col}*phi;

  mu=exp(pred);
  der=mu;
  _weight_=1/mu;
  _loss_=(freq*log(mu)-mu)/_weight_;
end;

model freq=mu;

der.intercpt=der;
der.a1 =der*Xa1 ;
der.a2 =der*Xa2 ;
der.a3 =der*Xa3 ;
der.a4 =der*Xa4 ;
der.b1 =der*Xb1 ;
der.b2 =der*Xb2 ;
der.b3 =der*Xb3 ;
der.b4 =der*Xb4 ;
```



```

der.d1 =der*Xd1 ;
der.d2 =der*Xd2 ;
der.d3 =der*Xd3 ;
der.d4 =der*Xd4 ;
der.d5 =der*Xd5 ;
der.sig1=der*phi*ome(col)*xa1;
der.sig2=der*phi*ome(col)*xa2;
der.sig3=der*phi*ome(col)*xa3;
der.sig4=der*phi*ome(col)*xa4;
der.ome1=der*phi*sig(row)*xb1;
der.ome2=der*phi*sig(row)*xb2;
der.ome3=der*phi*sig(row)*xb3;
der.ome4=der*phi*sig(row)*xb4;
der.phi =der*sig(row)*ome(col);

output out=dset.qrcii2 p=fitted;

data two; set dset.qrcii2;
dev=2*freq*log(freq/fitted) - freq+fitted;

proc summary data=two;
var dev;
output out=three sum=;

data _null_; set three; file print;
* degrees of freedom = 25 units - 21 parameters = 4;
prob=1-probchi(dev,4);

put // 'Deviance is:' dev 8.3 ' with 4 df.'
/ 'prob=' prob 6.3;

data _null_; set pset.qrcii2; file print;
if _type_='FINAL';
array sig(5) sig1-sig5;
array ome(5) ome1-ome5;
sig5=-sig1-sig2-sig3-sig4;
ome5=-ome1-ome2-ome3-ome4;
sqSSsig=sqrt(sig1**2+sig2**2+sig3**2+sig4**2+sig5**2);
sqSSome=sqrt(ome1**2+ome2**2+ome3**2+ome4**2+ome5**2);
phi=phi*sqSSsig*sqSSome;
put 'phi=' @12 phi 12.3;
do i=1 to 5;
sig(i)=sig(i)/sqSSsig;
ome(i)=ome(i)/sqSSome;
put 'sigma(' i 1.0 ' )' @12 sig(i) 12.3
@36 'omega(' i 1.0 ' )' @48 ome(i) 12.3;
end;

```

We used the PROC NLIN option g4 to use a “Moore-Penrose inverse”, since this gave slightly better estimates. We also specified that the estimates be written to an output data set pset.qrcii2 for use later in the program. We specified 4, rather than 3 σ , and ω , parameters and let σ_5 and ω_5 be equal to the negative sum of the remaining parameters. The redundant parameters could now be specified in a simple fashion prior to each iteration. For the rest, the only change was the specification of the derivatives. Since the row and column main effects also summed to zero, their design vectors could be used for the specification of the derivatives for σ_5 and ω_5 .

The deviance was calculated as before. In a final data step, we calculated the proper scaled association term values, using the data set of the estimates pset.qrcii2. This contained the estimates of the parameters for each estimate, the final parameter estimates, and the correlation matrix of the parameter estimates. Specifying if _type_='FINAL'; selects the case containing the final parameter estimates. The association parameters could then be transformed to the normalized values, and the results written to the output file.

The program converged in 8 iterations, as for the first program QRCII SAS. As expected, the program notes that "the Jacobian is singular", after the Summary Statistics. The weighted residual *SS* of the model was 23.783 with 4 *df*, versus 23.784 in QRCII SAS. The deviance was 24.112, versus 24.128 in QRCII SAS. The standard errors of ϕ and ω_1 were set to zero, and their correlations in the Asymptotic Correlation Matrix were missing values, showing that the program had imposed arbitrary restrictions to gain an additional 2 *df*. The transformed parameter estimates were equal to those of QRCII SAS up to 3 decimal points of precision.

There is therefore a small loss of precision in the use of the generalized inverse method, but this is compensated by the greater ease in specifying the model. This could be especially relevant if a three-way or higher order table is being analyzed. The simpler program structure of the generalized inverse method could help avoiding time-consuming programming mistakes.

Example 6: The multidimensional RCII model

Goodman (1985) extended his RCII model to a multidimensional model, which closely resembles a correspondence analysis model. The extension is straightforward. Let $t = \min(r-1, c-1)$ for an r by c table. The saturated multidimensional RCII model is:

$$\eta_{ij} = \psi + \alpha_i + \beta_j + \sum_{k=1}^t \phi_k \sigma_{ik} \omega_{jk}$$

$$\text{where } \sum_{i=1}^r \sigma_{ik} = \sum_{j=1}^c \omega_{jk} = 0,$$

$$\sum_{i=1}^r \sigma_{ik}^2 = \sum_{j=1}^c \omega_{jk}^2 = 1,$$

$$\text{and } \sum_{i=1}^r \sigma_{ik} \sigma_{ik'} = \sum_{j=1}^c \omega_{jk} \omega_{jk'} = 0 \text{ for } k \neq k'$$

The model assumes a poisson distribution of the frequencies y , and a log link function, which means that $E(y) = \exp(\eta)$.

The RCII model discussed above can be seen as a restricted submodel of the multidimensional RCII model, for which $t^* = 1$. If it does not fit, other submodels can be tried for which $t^* < t$.

The new scale values must have a mean of zero, a length of 1, and an inner product of zero, so axes are perpendicular to each other. The presence of squares and roots of parameters makes it very complicated to specify redundant parameters in terms of identifiable parameters, which is necessary to directly estimate parameters. An alternative could be to use simpler restrictions, e.g. to fix the lowest scale value to 0 and highest scale value to 1. The scales would still have to be orthogonal, but this restriction is relatively easy to deal with.

A second alternative is to not fully identify the model, but to let SAS find a solution using a generalized inverse, and to transform the parameters to orthonormal values afterwards. As in QRCII SAS, we specified only that σ_{ik} and ω_{jk} sum to zero. We then calculated a r by c matrix Z of interaction effect parameters, using

$Z = \Sigma\Phi\Omega'$ where:
 Σ is a r by t' matrix of σ_{ik} parameters,
 Ω is a c by t' matrix of ω_{jk} parameters,
 Φ is a t' by t' diagonal matrix of ϕ_k parameters

The expression $\Sigma\Phi\Omega'$ is the matrix notation for $\sum_{k=1}^t \phi_k \sigma_{ik} \omega_{jk}$, except that the result is an r by c matrix, rather than a column vector. Z could also be calculated by $z_{ij} = \log(\mu_{ij}) - \psi - \alpha_i - \beta_j$, where μ_{ij} are the fitted values, cross-classified by the row and column factors.

Scale parameters with orthonormal restrictions can now be found by the singular value decomposition (SVD) of Z . The singular value decomposition (SVD) of an m by n ($m \geq n$) matrix A finds matrices U , Q , and V , such that:

$A = UQV'$, where

Q is an n by n diagonal matrix,

U is an m by n matrix,

V is an n by n matrix, and

$U'U = V'V = I$, the identity matrix (Lammers, Peters, van der Weegen, 1989; SAS/IML 435-437).

Because the lower order effects are identified in our model, Z is also equal to $\Sigma^* \Phi^* \Omega^{*'} where $\Sigma^* \Sigma^* = \Omega^* \Omega^* = I$. Therefore, Q from the singular value decomposition of Z has zeros on diagonal elements $t'+1$ and higher. So with no loss of information, Φ^* is equal to the first t' rows/columns of Q , Σ^* is equal to the first t' columns of U , and Ω^{*} is equal to the first t' columns of V .$

This shows the differences between a correspondence analysis model and a multidimensional RCII model. In a correspondence analysis model, A contains the residuals of an loglinear model of independence. A is then approximated by taking the first w rows/columns of Q and the first w columns of U and V . In the multi-dimensional RCII model on the other hand, the overall, row, and column effects (modelling the relative sizes of the row and column categories) are estimated simultaneously with the association, and the estimated parameters

$\sum_{k=1}^t \phi_k \sigma_{ik} \omega_{jk}$ reproduce the association exactly. Advantages of the multi-dimensional RCII model are that it gives a measure of goodness of fit, and that it allows for special restrictions, e.g. equal values for certain categories.

PROGRAM FOR A 2 DIMENSIONAL RCII MODEL

In RCII2D SAS, we estimated a 2 dimensional RCII model, using the same data and design information created in DATDESQ SAS. Since the data are a 5 by 5 table, a saturated model would use 4 dimensions. The program was as follows:

```
proc nlin data=dset.datdesq sigsq=1 maxiter=25 nohalve
  g4 outest=pset.rcii2d;
parms  intercept=0 a1=0 a2=0 a3=0 a4=0 b1=0 b2=0 b3=0 b4=0
  sig11=-.632 sig21=-.361 sig31=0 sig41=.361
  ome11=-.632 ome21=-.361 ome31=0 ome41=.361 phi1=0
  sig12=.534 sig22=.267 sig32=-.535 sig42=-.267
  ome12=.534 ome22=.267 ome32=-.535 ome42=-.267 phi2=0;
array sig1(5) sig11 sig21 sig31 sig41 sig51;
array ome1(5) ome11 ome21 ome31 ome41 ome51;
array sig2(5) sig12 sig22 sig32 sig42 sig52;
```

```

array ome2{5} ome12 ome22 ome32 ome42 ome52;
sig51=-sig11-sig21-sig31-sig41;
ome51=-ome11-ome21-ome31-ome41;
sig52=-sig12-sig22-sig32-sig42;
ome52=-ome12-ome22-ome32-ome42;

if _iter_=-1 | (_iter_=0 & _model_=0) then do;
  mu=0;
  _loss_=0;
  der=1;
  _weight_=freq;
  freq=log(freq);
end;
else do;
  pred=intercpt + a1*Xa1 + a2*Xa2 + a3*Xa3 + a4*Xa4
               + b1*Xb1 + b2*Xb2 + b3*Xb3 + b4*Xb4
               + sig1(row)*ome1(col)*phi1
               + sig2(row)*ome2(col)*phi2;

  mu=exp(pred);
  der=mu;
  _weight_=1/mu;
  _loss_=(freq*log(mu)-mu)/_weight_;
end;

model freq=mu;

der.intercpt=der;
der.a1 =der*Xa1 ;
der.a2 =der*Xa2 ;
der.a3 =der*Xa3 ;
der.a4 =der*Xa4 ;
der.b1 =der*Xb1 ;
der.b2 =der*Xb2 ;
der.b3 =der*Xb3 ;
der.b4 =der*Xb4 ;
der.sig11=der*phi1*ome1(col)*xa1;
der.sig21=der*phi1*ome1(col)*xa2;
der.sig31=der*phi1*ome1(col)*xa3;
der.sig41=der*phi1*ome1(col)*xa4;
der.ome11=der*phi1*sig1(row)*xb1;
der.ome21=der*phi1*sig1(row)*xb2;
der.ome31=der*phi1*sig1(row)*xb3;
der.ome41=der*phi1*sig1(row)*xb4;
der.sig12=der*phi2*ome2(col)*xa1;
der.sig22=der*phi2*ome2(col)*xa2;
der.sig32=der*phi2*ome2(col)*xa3;
der.sig42=der*phi2*ome2(col)*xa4;
der.ome12=der*phi2*sig2(row)*xb1;
der.ome22=der*phi2*sig2(row)*xb2;
der.ome32=der*phi2*sig2(row)*xb3;
der.ome42=der*phi2*sig2(row)*xb4;
der.phi1=der*sig1(row)*ome1(col);
der.phi2=der*sig2(row)*ome2(col);

output out=dset.rcii2d p=fitted;

proc iml;
reset noname;
use dset.rcii2d;
read all var{freq fitted};
close;

dev=2*sum(freq*log(freq/fitted) - freq+fitted);
* degrees of freedom = 25 units - 21 parameters = 4;
prob=1-probchi(dev,4);
print 'Deviance is:' dev[format=8.3] ' with 4 df.',
      'prob=' prob[format=6.3];

use pset.rcii2d;
read all var{phi1 phi2
              sig11 sig21 sig31 sig41 ome11 ome21 ome31 ome41
              sig12 sig22 sig32 sig42 ome12 ome22 ome32 ome42 }
      where (_type_='FINAL');

```

```

close;
phi=diag(phi1 // phi2);
sig=(sig11 // sig21 // sig31 // sig41) ||
    (sig12 // sig22 // sig32 // sig42);
sig=sig // -sig(+, );
ome=(ome11 // ome21 // ome31 // ome41) ||
    (ome12 // ome22 // ome32 // ome42);
ome=ome // -ome(+, );

intrct=sig*phi*ome`;

call svd(sigStar,phiStar,omeStar,intrct);
sigStar=sigStar[,1:2];
phiStar=diag(phiStar[1:2, ]);
omeStar=omeStar[,1:2];

reset name;
print sigStar[format=8.3] phiStar[format=8.3] omeStar[format=8.3];

```

The program contains only a few modifications from QRCII2 SAS. For starting values of σ_{ik} and ω_{jk} , we used the orthonormalized linear and quadratic scale values¹¹. As in QRCII2 SAS, σ_{5k} and ω_{5k} were redundant, and equal to the negative sum of the remaining σ_{ik} and ω_{jk} parameters. We did not impose other restrictions. Redundant parameters in the program could be calculated prior to each iteration in a simple fashion. For the derivatives, $\frac{d\eta}{d\sigma_{ik}} = \phi_k \omega_{jk}$ for

$row = i$ and $\frac{d\eta}{d\sigma_{ik}} = -\phi_k \omega_{jk}$ for $row = 5$, for $k = 1, 2$. Similarly, $\frac{d\eta}{d\omega_{jk}} = \phi_k \sigma_{ik}$ for $col = j$ and $\frac{d\eta}{d\omega_{jk}} = -\phi_k \sigma_{ik}$ for $col = 5$. Multiplication by a deviation contrast design vector, of e.g.

`der*phi1*ome(row)`, therefore correctly specifies the derivatives.

We used PROC IML (interactive matrix language), to calculate the deviance and the normalized scale values. The statement `reset noname;` suppresses printing the matrix name. With use `dset.rcii2d;` we specify to use the SAS dataset containing fitted values to read information from. The variables `freq` and `fitted` are then read into n by 1 column vectors, under the same name. A scalar `dev` containing the deviance could then be calculated. Note that the hash “#” denotes elementwise multiplication, since in `proc iml`, the “*” indicates matrix multiplication. The function `sum` returns the sum of all elements of a matrix. With the deviance, and knowing the number of degrees of freedom, the probability can be calculated, and the information printed to the output.

The next step is to calculate the normalized scale values. The parameter estimates for ϕ_k , σ_{ik} , and ω_{jk} are in dataset `pset.rcii2d` in the case for which the variable `_type_` equals 'FINAL'. The parameter estimates for this case are read into scalars under the same name. These scalars are then concatenated into matrices, using “//” for vertical concatenation, and “||” for horizontal concatenation. So `phi=diag(phi1 // phi2);` denotes that the 2 by 2 diagonal matrix `phi` must be constructed by first vertically concatenating the scalars `phi1` and `phi2` into a 2 by 1 column vector, then transforming this into a 2 by 2 diagonal matrix. The estimates for σ_{ik} and ω_{jk} are concatenated into two 4 by 2 matrices `sig` and `ome`. The redundant parameters are equal to the negative sums over the rows of these matrices, e.g. `-sig(+, )`. This value is then vertically concatenated to the existing `sig` and `ome` matrices.

The full set of parameter estimates intrct is now calculated using $\text{sig}*\phi*\omega$. The singular value decomposition of intrct gives the desired orthonormal scale values, after the first two columns have been selected. The correct parameter estimates can now be printed.

The program converged after 11 iterations. The weighted SS was 163.61 with 4 df , the deviance was 157.47. Again, the program reported that "the Jacobian is singular", after the summary statistics. The standard errors for the estimates of ϕ_1 , σ_{11} , σ_{12} , σ_{42} , ω_{12} , and ω_{42} had the value of 0, showing that the program imposed extra constraints on these parameters. The output contains several pages containing the asymptotic correlation matrix, which in this case is particularly uninteresting; unfortunately, there is no way to suppress printing this information.

The normalized scale values are printed in table 9. The ϕ_1 parameter is much larger than the ϕ_2 parameter, which indicates that there is stronger association in the first dimension, than in the second. The σ_{ik} and ω_{ik} are quite similar. The first dimension seems to model the special situation of farmers, with their high degree of status inheritance. Farmers are set at a considerable distance from other occupations on the first dimension. On the second dimension, the categories are more or less evenly spaced, in the order upper nonmanual, farmer, lower nonmanual, upper manual, lower manual.

Table 9
Normalized scale values of a 2 dimensional RCII model

Sigma's		Phi's		Omega's	
-.429	.578	3.008	0	-.454	.651
-.324	.096	0	1.013	-.294	-.058
-.145	-.355			-.128	-.300
.070	-.649			.045	-.616
.828	.330			.830	.323

With a deviance of 157 for 4 df , the 2 dimensional RCII model is an improvement over the uni-dimensional RCII model, which would have a deviance of 686 with 9 df . The quasi RCII model has a much lower deviance however (24), with an equal number of degrees of freedom. This would indicate that for these data, it is better to model status inheritance separately, but that father's and son's occupation can be ordered on a single continuum. Before definitely drawing this conclusion, models with equal scale values for the row and column factors (the ERCII model) would have to be tested. A quasi RCII model with equal σ_i and ω_j parameters would have 7 df , but a 2 dimensional RCII model with equal σ_{ik} and ω_{jk} would have 9 df . Since our purpose here is to illustrate how such models could be programmed, rather than to find an adequate model, these models fall outside the scope of this paper. However, a 2 dimensional ERCII model will have an even higher deviance than the 2 dimensional RCII model, so even with its greater parsimony, it could not compete with a uni-dimensional quasi RCII model, which has a deviance of 39 with 7 df (Hout, 1983: 63). At the most, a 3 dimensional ERCII model might have a lower deviance, with an equal number of degrees of freedom. But even then, the substantively simpler uni-dimensional ERCII model would usually be preferable, since a 3 dimensional solution would be quite difficult to interpret.

Appendix A: Differentiation rules

Taken from: Freilich, Gerald, Frederick P. Greenleaf. (1976) "*Calculus. A Short Course with Applications to Business, Economics, and the Social Sciences.*" San Francisco: W.H. Freeman and Company.

ELEMENTARY OPERATIONS

Differentiation rule for powers (pp. 109)

$$\frac{d}{dx}\{x^r\} = rx^{r-1}$$

Special cases are $f(x) = x$, for which $f'(x) = 1$, and $f(x) = c$, for which $f'(x) = 0$ (since $c = cx^0$).

Derivatives of the special functions e^x , $\log x$, $\sin x$ and $\cos x$ (pp. 111)	
$y = e^x$	$\frac{dy}{dx} = e^x$
$y = \log x$	$\frac{dy}{dx} = \frac{1}{x}$
$y = \sin x$	$\frac{dy}{dx} = \cos x$
$y = \cos x$	$\frac{dy}{dx} = -\sin x$

COMBINATION RULES

Multiplication Rule (pp. 111)

$$\frac{d}{dx}\{kf(x)\} = k \cdot \frac{df}{dx}$$

The Addition Rule (pp. 112)

$$\frac{d}{dx}\{f(x) + g(x)\} = \frac{df}{dx} + \frac{dg}{dx}$$

The Product Rule (pp. 116)

$$\frac{d}{dx}\{f(x) \cdot g(x)\} = \frac{df}{dx} \cdot g(x) + f(x) \cdot \frac{dg}{dx}$$

The Quotient Rule (pp. 117)

$$\frac{d}{dx} \left\{ \frac{f(x)}{g(x)} \right\} = \frac{\frac{df}{dx} \cdot g(x) - f(x) \cdot \frac{dg}{dx}}{[g(x)]^2}$$

The Chain Rule (pp. 121)

If $y = f(u)$ and $u = f(g)$ are differentiable functions, their composite $y = h(x) = f(g(x))$ has derivative

$$h'(x) = f'(g(x)) \cdot g'(x)$$

Notes

¹ In addition, the SAS/STAT manual for version 6 contains a shorter version of the %GLIM macro (SAS/STAT User's Guide, Volume 2: 1168-1175).

² For the normal distribution, the variance is assumed to be 1, and the standard errors of the parameter estimates must therefore be multiplied by sqrt(mean deviance). For the gamma distribution, the variance is assumed to equal alpha, where $\alpha = (\mu^2)/\text{variance}$. The standard errors of the parameter estimates can be corrected by:

- 1) multiplying by sqrt(mean deviance)
- 2) multiplying by sqrt(mean Pearson residual squared)
- 3) dividing by sqrt(alpha)

³ The statements for `_Y_` are constructed in a data step prior to PROC NLIN and read in at the beginning of the second and subsequent iterations as TEXT2 SAS.

⁴ E and P are not specified in the %GLIM macro. Instead, the predictor statement `_Y_` successively transformed. The documentation for the macro specifies that a bernoulli distribution could be implemented by specifying that $\mu = P$, and that a geometric distribution could be implemented by $\mu = (1-P)/P$. These distributions are not otherwise implemented; it is unknown if the `_weight_` variable would require a different specification.

⁵ The diagonal reference model is usually specified as:

$$y_{ijk} = \mu_{ij} + \varepsilon_{ijk} \text{ where}$$

$$\mu_{ij} = p\mu_{ii} + (1-p)\mu_{jj}$$

We use different symbols to avoid conflicts with other model specifications.

⁶ The odds-ratio for a 2 by 2 table is the ratio for row category 1 and row category 2, of the odds of being in column category 1 versus column category 2 ("row" and "column" may be switched). It can be calculated as $\theta = \frac{f_{11}f_{22}}{f_{12}f_{21}}$, where f_{ij} is the cell frequency. Loglinear mobility

models are often formulated in terms of patterns of (log) odds-ratios.

⁷ We found that a program for an RCII model would not converge. After the first 30 iterations, the weighted loss oscillated between two values, and the corresponding two sets of parameter values did not change within 3 digits. The SAS/STAT manual warns that PROC NLIN will not always be able to solve the set of equations. When the program stopped, the deviance reported was 940 with 9 df, instead of the 685.5 found with a macro program in GLIM 3.77. The SAS/STAT manual suggests trying other algorithms if the program fails to converge, and after some experimentation, we found that the program would converge in `_loss_` was not

specified, the `nohalve` option was omitted, and `method=marquardt` was used. The program converged in 16 iterations and the deviance was now 562.6. We have little faith in this result. Our conclusion is that if the program does not converge, this should be taken as an indication that the model does not fit the data.

⁸ For data such as these, only a saturated model usually is acceptable, since sample fluctuations will naturally be very small. The BIC measure proposed by Raftery (1984) can be used as an alternative. BIC is derived from Bayesian statistics and compares the probability of a model with the probability of the saturated model. BIC can be approximated by:

$$\text{BIC} = L^2 - df \cdot \log(n)$$

Values less than zero are preferable to the saturated model. The bic value for the quasi rcii model was -15.47, which makes it an acceptable model, although alternatives (e.g. with equal row and column scale parameters) are better still.

⁹ ASSOC, including the fortran source code, is available for IBM-compatibles from Ruud Luijkx, Department of Sociology, Tilburg University, PO BOX 90.153, 500 LE Tilburg, The Netherlands, E-mail LUIJKX@KUB.NL.

¹⁰ A model could be estimated without even this restriction. However, it is then much more difficult to transform $\phi\sigma, \omega$ to their proper, normalized values.

¹¹ These values can be quite simply calculated using the PROC IML function `orpol`, for orthogonal polynomials.

Samenvatting

De doelstelling van dit proefschrift is een beeld te geven van de openheid van de Nederlandse samenleving wat betreft de godsdienst. Als indicator hiervoor wordt de godsdiensthomogamie gebruikt: de mate waarin mensen wel of niet een huwelijkspartner met dezelfde godsdienst kiezen. Uitgangspunt hierbij is dat de mate waarin huwelijken tussen personen uit verschillende groepen voorkomen iets zegt over de mate waarin contacten van alledaagse aard plaatsvinden. Immers, slechts een deel van de dagelijkse ontmoetingen tussen mensen uit verschillende groepen zullen uitgroeien tot vriendschapsrelaties en slechts een deel van die vriendschapsrelaties zullen uitgroeien tot gemengde huwelijken.

Om dit doel te verwezenlijken worden met behulp van loglineaire modellen vierkante tabellen geanalyseerd waarin de godsdienst van de man tegen de godsdienst van de vrouw is gekruist. Met deze modellen is het mogelijk om verschillen in contactgelegenheden ten gevolge van verschillen in de grootte van de godsdienstgroepen uit te schakelen. Bovendien kunnen hypothesen over de aard van de associatie tussen de godsdiensten van huwelijkspartners worden getoetst met behulp van loglineaire modellen met speciale restricties.

Dit proefschrift bestaat uit twee delen. In deel 1 staan de inhoudelijke analyses, waarin de volgende vragen worden beantwoord:

- Hoe ontwikkelde zich de godsdiensthomogamie in de loop van de twintigste eeuw?
- In hoeverre zijn theoretische verklaringen voor de toenemende openheid van de samenleving daadwerkelijk in staat om veranderingen in de godsdiensthomogamie over de tijd of om variaties in de godsdiensthomogamie tussen provincies te verklaren?
- Hoe sterk is de godsdiensthomogamie in vergelijking met de opleidingshomogamie, een andere dimensie van de openheid van de samenleving?
- Hoe sterk is de godsdiensthomogamie in Nederland in vergelijking met die in Duitsland?

Deel 2 is het methodologische gedeelte van dit proefschrift. Hierin worden de modelleringsstechnieken ('design techniques') voor loglineaire modellen besproken die in deel 1 worden gebruikt. Deel 2 is nogal abstract van opzet. De modelleringsstechnieken worden in sommige hoofdstukken dan ook besproken in het kader van 'Gegeneraliseerde Lineaire Modellen'. Dit type model omvat naast het loglineaire model ook andere statistische modellen met categorische variabelen, zoals variantie analyse, probit en logit modellen. Ook wordt er ingegaan op het toepassen van deze modelleringsstechnieken bij het analyseren van mobiliteit van vader op zoon. In deel 2 komen eveneens vier vragen aan de orde:

- Hoe kan een loglineair model worden gecreëerd dat informatie geeft over zowel homogamie als heterogamie?
- Hoe kunnen restricties worden opgelegd aan de parameters van een bestaand model om zuiniger modellen af te leiden? De aandacht gaat hier in het bijzonder uit naar het opleggen van restricties aan parameters die niet direct worden geschat, maar achteraf worden berekend uit de min som van andere parameters.

- Hoe kunnen modellen om schommelingen in de trends glad te strijken worden geïmplementeerd binnen modellen voor categorische data?
- Hoe kunnen niet-lineaire modellen worden geïmplementeerd binnen modellen voor categorische data?

Deel 1

In *hoofdstuk 1* wordt een overzicht gegeven van de theoretische en methodologische problemen die in deel 1 en 2 aan de orde zullen komen. Het begint met een uiteenzetting van de relaties tussen vragen over kerkelijk gemengde huwelijken en sociologische theorieën over stratificatie, secularisering, verzuiling en modernisering. Dit wordt gevolgd door een uiteenzetting van de methoden die zijn gebruikt om de mate van homogamie te bepalen. De eenvoudige statistieken uit het verleden worden geplaatst naast de meer recentelijk toegepaste loglineaire modellen en de voordelen van loglineaire modellen worden aangegeven. Verder worden de redenen besproken om nieuwe modellen te ontwikkelen voor dit project, in plaats van uit te gaan van bestaande modellen voor mobiliteitsonderzoek. Hoofdstuk 1 wordt afgesloten met een korte bespreking van de overige hoofdstukken van dit proefschrift.

Hoofdstuk 2, getiteld '*Religious assortative marriages in the Netherlands 1938-1983*', verscheen in 1991 in de 'Review of Religious Research'. Hierin wordt getoetst of er tussen 1938 en 1983 een trend aanwezig was naar grotere secularisatie van de Nederlandse samenleving. Hierbij wordt de mate van waarin godsdiensthomogamie afneemt gebruikt als indicator voor de mate van secularisatie. Door het gebruik van loglineaire modellen kan er worden gecontroleerd voor verschillen in grootte van de kerkelijke gezindtes. Door de analyses voor de jaren 1938, 1963 en 1983 per provincie te herhalen, kan er bovendien worden gecontroleerd voor de ongelijke geografische spreiding van de kerkelijke gezindtes in Nederland. Blau's macro-sociologische theorie over relaties tussen groepen wordt gebruikt om de toegepaste onderzoekstechnieken een theoretische fundamente te geven. Deze theorie wordt aangevuld met een specificatie van de mechanismen waarlangs macro-sociologische factoren zoals industrialisatie en urbanisatie een invloed kunnen hebben op individuele beslissingsprocessen, die al dan niet in een homogame huwelijk resulteren.

Godsdiensthomogamie onder de gereformeerden en katholieken blijkt een gelijksoortige trend te volgen: min of meer constant tot het einde van de vijftiger jaren, een sterke afname in de zestiger jaren en een meer geleidelijke afname na 1973. De mate van homogamie onder de hervormden daarentegen schommelt alleen maar, zonder een duidelijke trend te vertonen. Deze uitkomsten vormen een gedeeltelijke bevestiging van de voorspelling dat godsdienst minder saillant is geworden in de Nederlandse samenleving in de zestiger en zeventiger jaren. De analyses per provincie tonen aan dat voor de jaren 1938 en 1963 een analyse op landelijk niveau tot een belangrijk verlies van informatie leidt. De godsdiensthomogamie blijkt een stuk lager te zijn in de provincies Noord-Holland, Zuid-Holland en Utrecht, die worden gekenmerkt door relatief hoge niveaus van urbanisatie en industrialisatie.

Hoofdstuk 3 heeft als titel *Modernization and religious assortative marriage: explanatory models for regional variations in the Netherlands, 1938-1986*'. Hierin worden kerkelijk gemengde huwelijken in Nederland geanalyseerd, zowel per provincie als per categorie van gemeentegrootte. De volgende twee vragen worden beantwoord:

1. Leidt een analyse op landelijk niveau, doordat geen rekening wordt gehouden met de ongelijke spreiding van de kerkelijke gezindtes, tot een vertekend beeld van de godsdiensthomogamie in Nederland?
2. In welke mate kunnen verschillende aspecten van modernisering (o.a. de toename van gemeentegrootte) de verschillen in godsdiensthomogamie tussen provincie en over de tijd verklaren?

Vraag 1 is reeds gedeeltelijk beantwoord in hoofdstuk 2. In hoofdstuk 3 wordt een meer afdoend antwoord gezocht, door parameters uit een analyse op landelijk niveau te vergelijken met parameters uit een analyse op provinciaal niveau.

Vraag 2 betreft de empirische houdbaarheid van verschillende verklaringen voor trends en variaties in de godsdiensthomogamie. In hoofdstuk 2 werd de hypothese naar voren gebracht dat variaties in de mate van homogamie tussen provincies samenhangen met aspecten van modernisering, zoals urbanisatie, (ruimtelijke) mobiliteit, de economische structuur. Deze hypothese wordt in hoofdstuk 3 getoetst door variabelen met betrekking tot deze en andere aspecten van modernisering op te nemen als covariaten in loglineaire modellen voor godsdiensthomogamie per provincie en over de tijd. De uitgevoerde analyse van godsdiensthomogamie voor vier categorieën van gemeentegrootte en over de tijd vormt een nog betere toets van de invloed van urbanisatie op kerkelijk gemengde huwelijken.

Uit de analyses op landelijk niveau blijkt dat de homogamie in de loop der tijd afneemt, maar dat het patroon van aantrekking en afwijzing tussen de gezindtes constant over de jaren is. De analyses per provincie wijzen uit dat godsdiensthomogamie sterk samenhangt met zowel provincie als jaar van huwelijk en dat het eerder gevonden patroon van aantrekking en afwijzing ook constant is over de provincies. Parameters voor godsdiensthomogamie uit een analyse op het landelijk niveau zijn bijna hetzelfde als overeenkomstige parameters uit een analyse op provinciaal niveau. Vraag 1 kan dus voor Nederland ontkennend worden beantwoord.

Uit de verklarende analyses blijkt dat drie covariaten goed in staat zijn de verschillen in godsdiensthomogamie tussen provincies en over de tijd te verklaren:

- migratie per vierkante kilometer,
- de beroepsstructuur (het percentage van de beroepsbevolking dat werkzaam is in de sectoren landbouw, nijverheid, handel en verkeer, overige dienstverlening),
- het gemiddelde inkomen per hoofd van de bevolking.

Zoals voorspeld is de godsdiensthomogamie lager in provincies waar de migratie hoger is. Homogamie blijkt hoger te zijn in provincies waar agrarische beroepen belangrijk zijn en lager waar de dienstensector prominent is. Provincies waar het gemiddelde inkomen hoger is worden gekenmerkt door minder godsdiensthomogamie.

Deze analyses worden aangevuld met een analyse van kerkelijk gemengde huwelijken per categorie van gemeentegrootte en over de tijd. Hoewel uit de analyse met covariaten bleek dat variabelen voor urbanisatiegraad en bevolkingsdichtheid geen belangrijke verklarende factoren zijn, wordt wel een sterke samenhang gevonden tussen gemeentegrootte en godsdiensthomogamie. Het patroon van aantrekking en afwijzing tussen de gezindtes is constant over de categorieën van gemeentegrootte en over de tijd. De godsdiensthomogamie blijkt echter te variëren met gemeentegrootte, jaar van huwelijk en gemeentegrootte/jaar combinaties. De godsdiensthomogamie is lager naarmate de gemeente waarin het huwelijk wordt gesloten groter is. Met name katholieke homogamie wordt tussen 1938 en 1962 sterk beïnvloed door de gemeentegrootte.

Hoofdstuk 4, getiteld 'Religion and education as dimensions of the choice of marriage partner: single trait and dual trait analyses', werd in januari 1993 gepresenteerd bij de Nederlands-Israelische ontmoeting over Sociale Stratificatie in Haifa. Hoofdstuk 4 bevat een gelijktijdige analyse van opleidings- en godsdiensthomogamie, aan de hand van een 5-weg tabel van de godsdienst van de man tegen de godsdienst van de vrouw, tegen opleiding van de man tegen de opleiding van de vrouw, per huwelijkscohort. De data zijn afkomstig uit de volkstelling van 1971. Door een gelijktijdige analyse uit te voeren werd een antwoord verkregen op de volgende vragen:

- (a) Is er sprake van dubbele homogamie, d.w.z. doen mensen bijzondere moeite om een huwelijk te sluiten dat zowel qua godsdienst als qua opleiding homogaaam is?
- (b) Op welke manier beïnvloedt religie de opleidingshomogamie en op welke manier beïnvloedt opleiding de godsdiensthomogamie?
- (c) Leidt een gelijktijdige analyse van godsdienst- en opleidingshomogamie waarin gecontroleerd wordt voor de associatie tussen godsdienst en opleiding tot andere resultaten dan twee afzonderlijke analyses?
- (d) Hoe ontwikkelt zich de relatieve sterkte van godsdienst- en opleidingshomogamie in de loop der tijd?

In de analyses worden geen aanwijzingen gevonden voor het bestaan van dubbele homogamie. Godsdiensthomogamie blijkt sterker te zijn dan opleidingshomogamie, maar laat een neerwaartse trend zien in de zestiger jaren, terwijl opleidingshomogamie een licht stijgende trend vertoont. In de gelijktijdige analyses blijken de parameters voor homogamie lager uit te vallen in vergelijking met afzonderlijke analyses, omdat gecontroleerd wordt voor de associatie tussen godsdienst en opleiding. Opleidingshomogamie hangt samen met de gezindte van de vrouw en is lager als de vrouw gereformeerd is of lid van de 'overige denominaties'. Godsdiensthomogamie hangt samen met zowel de opleiding van de man als opleiding van de vrouw. Er blijkt een lagere neiging tot godsdiensthomogamie naarmate de opleiding vrouw hoger is. Godsdiensthomogamie blijkt echter alleen substantieel lager te zijn als de man lid is van de 'overige denominaties'.

Hoofdstuk 5, getiteld 'Religiously mixed marriages in Germany (1901-1986) and the Netherlands (1914-1986)', is een Engelse bewerking van een Duitstalig artikel 'Die Mischehe in Deutschland (1901-1986) und den Niederlanden (1914-1986)'. In dit artikel worden trends in godsdiensthomogamie onder katholieken, protestanten, joden, en 'overigen' in Duitsland en Nederland met elkaar vergeleken tussen 1901 resp. 1914 en 1986. De trend van godsdiensthomogamie in Nederland wordt ook onderzocht voor de periode 1941-1986 in een meer uitgebreid analyse met zes categorieën (katholiek, hervormd, gereformeerd, overigen, joods, geen). Tenslotte wordt speciale aandacht geschonken aan de situatie van de joden tijdens de opkomst van het Nationaal Socialisme in Duitsland (1927-1936) en vlak voor en tijdens de beginjaren van de Tweede Wereldoorlog in Nederland (1935-1941).

Homogamie blijkt in zowel Duitsland als in Nederland het hoogst te zijn onder de joden. De neiging tot homogamie onder katholieken en protestanten was vóór de Tweede Wereldoorlog in Duitsland ongeveer even hoog als in Nederland. Na de Tweede Wereldoorlog was de homogamie onder de katholieken in Duitsland een stuk lager, terwijl de vooroorlogse daling onder de Duitse protestanten zich voortzette. In Nederland daarentegen steeg de homogamie onder zowel katholieken als de protestanten. De gedifferentieerde analyse wijst uit dat de toename van protestantse homogamie in Nederland het gevolg is van de hoge godsdiensthomogamie onder de gereformeerden. De homogamie onder de hervormden

was laag en bleef dat tijdens de gehele periode 1941-1986. In Nederland neemt de homogamie onder katholieken en gereformeerden af in de 60er jaren.

De analyse van joodse homogamie in Duitsland in de periode 1927-1936 laat zien dat deze sterk stijgt vanaf 1933. Tot dat jaar bleef de joodse neiging tot homogamie echter constant. Joodse homogamie in Nederland bleef ook constant van 1935 tot 1941. Er zijn dus geen aanwijzingen dat antisemitisme in beide landen tot meer homogamie onder de joden leidde voordat de Nationaal Socialisten daadwerkelijk aan de macht kwamen.

Deel 2

Deel 2 van dit proefschrift gaat over modellerings technieken (design techniques) voor modellen met categorische onafhankelijke variabelen. Deel 2 begint met *hoofdstuk 6*, getiteld '*Design techniques for equal/unequal main effects and symmetric/asymmetric interactions*'. Dit artikel verscheen in 1992 in de bundel '*Statistical Modelling – 6th International Workshop on Statistical Modelling*', onder redactie van P.G.M. van der Heijden e.a. Het begint met een uitleg van de toepassing van contrasten om modellen met categorische onafhankelijke variabelen te identificeren en hoe dezelfde technieken kunnen worden toegepast om restricties op te leggen aan een bestaand model. In een uiteenzetting over modellen voor verschillen in de hoofdeffecten wordt het 'halfway/difference' model van Hope vergeleken met het alternatieve 'size/marginal shift' model van Sobel, Hout en Duncan. Verder wordt kort ingegaan op het niet-lineaire diagonaal referentie model van Sobel, die eveneens voor dit doel wordt gebruikt. Vervolgens wordt gekeken naar het opsplitsen van interactie effecten in symmetrische en 'skew symmetric' componenten en de wijze waarop het gebruikte contrast conclusies over de aard van de asymmetrieën kan beïnvloeden. Het hoofdstuk wordt afgesloten met een nieuw niet-lineaire model voor asymmetrische interactie effecten, het 'proportional asymmetry' model.

Hoofdstuk 7, getiteld '*Design matrix techniques for generalized linear models and their applications to mobility models*', werd in juni 1991 in Praag gepresenteerd op de conferentie van de ISA onderzoekscommissie voor Sociale Stratificatie. In hoofdstuk 7 wordt wat dieper ingegaan op het gebruik van contrasten en het opleggen van restricties dan in hoofdstuk 6 gebeurde. In mobiliteitsmodellen worden echter eenvoudigere en snellere methodes toegepast om zuinige modellen te creëren. Deze methoden maken vaak geen onderscheid tussen restricties die altijd nodig zijn om het model te identificeren en restricties die op grond van inhoudelijke overwegingen worden opgelegd. Dit kan leiden tot onbepaaldheid van het model, d.w.z. dat modellen met verschillende substantieve implicaties toch dezelfde fit hebben.

Dit wordt gevolgd door een uitleg over hoe log odds-ratios gezien kunnen worden als parameters met het opeenvolgend simpel contrast (difference contrast). Dit verduidelijkt het probleem van onbepaaldheid in sommige modellen. Twee alternatieve modellen worden gepresenteerd die beiden uitgaan van het deviatie contrast (de vaak gebruikte restrictie dat parameters een som van nul hebben). Deze modellen vertalen de achterliggende ideeën van twee modellen die met het probleem van onbepaaldheid kampen, het 'levels' model en het afstandsmodel, tot restricties op deviatie contrast parameters. Het eerste alternatief model legt een 'levels' restrictie op aan parameters, hetgeen inhoudt dat een gelijkheidsrestrictie wordt opgelegd aan bepaalde groepen parameters. Het tweede model vertaalt het achterliggende idee van het afstandsmodel tot een afstandsrestrictie op deviatie contrast parameters, waardoor deze met een vaste waarde toenemen met elke stap vanaf de diagonaal.

Hoofdstuk 8, getiteld 'Redefining interaction parameters using the deviation contrast, for use in the analysis of square tables', geeft nieuwe methoden aan om vierkante tabellen te analyseren met modellen die uitgaan van het deviatie contrast. De interactie term van een loglineair model voor een vierkante tabel kan worden gezien als de uitwerking van drie aspecten van partnerkeuze: (a) de neiging tot homogamie, (b) de sociale afstanden tussen de categorieën, (c) verschillen in de sociaal afstanden tussen de categorieën voor mannen dan voor vrouwen. Hoofdstuk 8 beschrijft methodes om de interactie term te herdefiniëren naar subtermen die betrekking hebben op deze aspecten. Een nieuw element is het gebruik van een 'symmetric deviances' subterm om de sociale afstanden tussen categorieën te meten. De transformaties die hier worden besproken kunnen worden toegepast op parameters met elke type restrictie, maar de aandacht gaat hier uit naar parameters met het deviatie contrast.

Na een beschrijving van de transformaties wordt een voorbeeld gegeven aan de hand van een tabel van kerkelijk gemengde huwelijken in Nederland in 1956. Dit wordt gevolgd door een bespreking van de problemen van de grootte van de tabel en door een specificatie van de regels die nodig zijn om nog zuiniger modellen af te leiden. In de appendix worden voorbeeldprogramma's gegeven die laten zien hoe de besproken modellen kunnen worden geschat met de statistische pakketten SAS en SPSS.

Hoofdstuk 9, getiteld 'Using SAS macros and PROC IML to create special designs for generalized linear models', verscheen in 1992 in 'SEUGI '92. Proceedings of the SAS® European Users Group International Conference, May 19-22, 1992'. In de SAS voorbeeldenbibliotheek staat een programma met een set van macros om het programma GLIM te emuleren. Hoofdstuk 9 beschrijft een set van macros (GLIMMAT) die de mogelijkheden hiervan uitbreiden, o.a. de mogelijkheid contrasten voor verschillende model termen op te geven en de mogelijkheid om de design matrix vóór het schatten van het model te manipuleren met commando's van de SAS matrix programmeertaal IML (Interactive Matrix Language).

Als voorbeeld voor het gebruik van deze macros bij het ontwikkelen van nieuwe modellen wordt het opleggen van een voortschrijdende gemiddelde restrictie aan parameters met het opeenvolgend simpel contrast uiteengezet. Met deze restricties kunnen schommelingen in trendparameters worden glad gestreken. De macros en bijbehorende programma's worden beschreven in Appendix A. De GLIMMAT macros zijn verkrijgbaar via e-mail, door de tekst 'get glimmat package' te sturen naar 'listserv@uicvm' op bitnet of 'listserv@uicvm.cc.uic.edu' op internet. De macros zijn ook verkrijgbaar via FTP (user 'anonymous', e-mail adres als password) naar 'uicvm.uic.edu'. Het bestand 'glimmat.\$package' bevat informatie over welke bestanden relevant zijn.

Hoofdstuk 10, getiteld 'Models for status inconsistency and mobility: a comparison of the approaches by Hope and Sobel with the mainstream square additive model', zal binnenkort verschijnen in Quality & Quantity. Hoofdstuk 10 gaat over de analyse van effecten van status inconsistentie of mobiliteit op een afhankelijke variabele. Het gebruikelijke 'square additive' baseline model wordt vergeleken met alternatieve modellen door Hope (1971, 1975) en Sobel (1981, 1985). Beide auteurs beweren dat het 'square additive' model ook status inconsistentie effecten bevat. Een vergelijking van het 'square additive' model met het 'halfway/difference' model van Hope en het diagonaal referentie model van Sobel toont aan dat de effecten die worden blootgelegd in de modellen van Hope en Sobel betrekking hebben op verschillen van de effecten van de status variabelen op de afhankelijke variabele. Deze verschillen in saillantie zijn daarom anders dan de niet-additieve status inconsistentie effecten die zouden worden gevonden bij gebruik van het 'square additive' model als baseline. Versies van het diagonaal referentie model met minder restricties, zoals de DM-1 end DM-2 modellen en een recent

model van Weakliem (1992) worden ook vergeleken met het oog op additieve versus niet-additieve componenten en symmetrie van de effecten.

Deel 2 wordt afgesloten met *hoofdstuk 11*, getiteld '*Specifying link functions and error distributions for categorical models using nonlinear designs*'. Hoofdstuk 11 beschrijft aan de hand van een programma uit de SAS voorbeeldenbibliotheek hoe Gegeneraliseerde Lineaire Modellen (GLM's) kunnen worden geschat met het SAS niet-lineaire regressie programma PROC NLIN. Dit kan op een eenvoudige manier worden uitgebreid door niet-lineaire modeltermen op te nemen. Hoofdstuk 11 bevat een aantal voorbeeldprogramma's, zoals het diagonaal referentie model van Sobel (1981, 1985) binnen een logit model, en uni- en multi-dimensionele versies van het log-multiplicatieve rij/kolom model II van Goodman (1979, 1985).

References

- Agresti, Alan. (1990). *"Categorical Data Analysis."* New York: Wiley.
- Aitkin, Murray, Dorothy Anderson, Brian Francis, John Hinde. (1989). *"Statistical modelling in GLIM."* Oxford: Clarendon Press.
- Alschuler, Lawrence R. (1973). *"Status equilibration, reference groups, and social fields."* General Systems 18: 99-118.
- Bank, Jan. (1978). *"Opkomst en ondergang van de Nederlandse Volksbeweging."* Deventer: Van Loghum Slaterus.
- Barron, Milton L. (1952). *"Research on intermarriage: A survey of accomplishments and prospects."* American Journal of Sociology 57: 249-255.
- Bax, Erik H. (1988). *"Modernization and cleavage in Dutch society. A study of long term economic and social change."* Dissertation for the degree of doctor of Economy. Groningen: Universiteitsdrukkerij.
- Bealer, R., F.K. Willits, G.W. Bender. (1963). *"Religious exogamy: a study of social distance."* Sociology and Social Research 48: 69-79.
- Becker, Gary S. (1981). *"A treatise on the family."* Cambridge, Mass.: Harvard University Press.
- Besanceney, Paul H. (1970). *"Interfaith marriages: who and why."* New Haven, Conn.: College & University Press.
- Blalock, Hubert M. (1966). *"The identification problem and theory building: the case of status inconsistency."* American Sociological Review 31: 52-61.
- Blalock, Hubert M. (1967). *"Status inconsistency and interaction: some alternative models."* American Journal of Sociology 73: 305-315.
- Blasi, Anthony J., Michael Cuneo. (1986). *"Issues in the sociology of religion: A bibliography."* New York: Garland.
- Blau, Peter M. (1977). *"Inequality and heterogeneity: a primitive theory of social structure."* New York: Free Press.
- Blau, Peter M., Joseph E. Schwartz. (1984). *"Crosscutting social circles. Testing a macrostructural theory of intergroup relations."* New York: Academic Press.
- Blau, Peter M., Otis Dudley Duncan. (1967). *"The American occupational structure."* New York: Wiley.
- Bock, R. Darrell. (1975). *"Multivariate statistical methods in behavioral research."* New York: McGraw-Hill.
- Bossard, James H., Eleanor S. Boll. (1957). *"One marriage, two faiths. Guidance on interfaith marriages."* New York: Ronald Press.
- Bouma, D.H. (1963). *"Religiously mixed marriages; denominational consequences in the Christian reformed church."* Marriage and Family Living 25: 428-432.
- Brunkow, Robert de. (1983). *"Religion and Society in North America: an annotated bibliography."* Santa Barbara: Clio.

- Burchinal, Lee G., Loren E. Chancellor. (1963). "Survival rates among religiously homogamous and interreligious marriages." *Social Forces* 41: 353-362.
- C.B.S. "Bevolking der gemeenten van Nederland op ..." 's-Gravenhage: Staatsuitgeverij.
- C.B.S. "Inkomensverdeling: ...: regionale gegevens." 's-Gravenhage: Staatsuitgeverij.
- C.B.S. "Maandstatistiek van de bevolking en de volksgezondheid." 's-Gravenhage: Staatsuitgeverij.
- C.B.S. "Regionaal statistisch zakboek ..." 's-Gravenhage: CBS-Publikaties.
- C.B.S. (1930). "Volkstelling 31 December 1930." 's-Gravenhage: Algemeene Landsdrukkerij.
- C.B.S. (1947). "12e Volkstelling annex woningtelling 31 mei 1947." 's-Gravenhage: Staatsdrukkerij- en Uitgeverijbedrijf.
- C.B.S. (1960). "13e Volkstelling annex woningtelling 31 mei 1960." 's-Gravenhage: Staatsdrukkerij.
- C.B.S. (1971a). "14e Volkstelling annex woningtelling, 28 februari 1971." 's-Gravenhage: Staatsdrukkerij.
- C.B.S. (1971b). "Inventarisatie van regionaal-statistische gegevens 1946-1970." 's-Gravenhage: Staatsuitgeverij.
- C.B.S. (1982a). "Een schatting van de aantallen Islamieten en Hindoes in Nederland, 1971-1981." Centraal Bureau voor de Statistiek: Maandstatistiek Bevolking 82/1.
- C.B.S. (1982b). "Kerkelijke gezindten in Nederland, 1971-1981." Centraal Bureau voor de Statistiek: Sociaal-cultureel Kwartaalbericht 82/4.
- C.B.S. (1988). "Kerkelijke gezindten in 1988." Centraal bureau voor de statistiek: Sociaal-culturele berichten 1988-11.
- C.B.S. (1989). "1899-1989 : negentig jaren statistiek in tijdreeksen." 's-Gravenhage: SDU uitgeverij/CBS-publikaties.
- Cahnman, Werner J. (ed.) (1963). "Intermarriage and Jewish life. A symposium." New York: Herzl and Jewish Reconstruction Press.
- Dahrendorf, Ralf. (1965). "Gesellschaft und Demokratie in Deutschland." München: Piper.
- De Graaf, Nan Dirk. (1985). "Husbands' and wives' occupations: Comment on Hout." *American Journal of Sociology* 90: 1078-1083.
- De Graaf, Nan Dirk. (1991). "Distinction by consumption in Czechoslovakia, Hungary, and the Netherlands." *European Sociological Review* 7: 267-290.
- De Graaf, Nan Dirk, Harry Ganzeboom. (1990). "Statusgroepen en cultuurdeelname. (Status group effects on culture consumption)." *Mens en Maatschappij* 65: 219-244.
- De Graaf, Nan Dirk, Anthony Heath. (1992). "Husbands' and wives' voting behaviour in Britain: Class dependent mutual influence of spouses." *Acta Sociologica* 35: 311-322.
- De Graaf, Nan Dirk, Wout Ultee. (1987). "Intergenerationele mobiliteit en politieke verhoudingen." *Acta Politica* 22: 1-37.
- De Graaf, Nan Dirk, Wout C. Ultee. (1990). "Individual preferences, social mobility and electoral outcomes." *Electoral Studies* 9: 108-131.
- De Graaf, Nan Dirk, Paul Nieuwbeerta, Anthony Heath. (1992). "Intergenerational class mobility and political preferences in Germany, the Netherlands, Britain and the United States." Paper to be presented at the ASA meeting in Pittsburgh, 19-24 August 1992.
- Dekker, Gerard. (1965). "Het kerkelijk gemengde huwelijk in Nederland." Meppel: Boom.
- Dekker, Gerard. (1992). "De stille revolutie. De ontwikkeling van de Gereformeerde Kerken in Nederland tussen 1950 en 1990." Kampen: J.H.Kok.

- Drehse, Volker. (1980). "Selected bibliography referring to German sociology of religion and Church after 1945." *Social Compass* 27: 101-158.
- Duffhues, Ton, Albert Felling, Jan Roes. (1985). "Bewegende patronen: een analyse van het landelijk netwerk van katholieke organisaties en bestuurders 1945-1980." Baarn: Ambo.
- Duncan, Otis Dudley. (1966). "Methodological issues in the analysis of social mobility." Pp. 51-97 in: Neil J. Smelser, Seymour Martin Lipset (eds.), *Social structure and mobility in economic development*, Chicago, Aldine Publishing Company.
- Eisinga, Rob, Albert Felling, Jan Peters, Peer Scheepers. (1992). "Social and cultural trends in the Netherlands 1979-1990. Documentation of national surveys on religious and secular attitudes in 1979, 1985 and 1990." Amsterdam: Steinmetz Archive.
- Erikson, Robert, John H. Goldthorpe. (1992). "The Constant Flux. A Study of Class Mobility in Industrial Societies." Oxford: Clarendon Press.
- Featherman, David L., Robert M. Hauser. (1978). "Opportunity and change." New York: Academic Press.
- Featherman, David L., Frank Lancaster Jones, Robert M. Hauser. (1975). "Assumptions of social mobility research in the U.S.: The case of occupational status." *Social Science Research* 4: 329-360.
- Felling, Albert, Jan Peters. (1988). "Der Säkularisierungsprozeß in den Niederlanden zwischen 1966 und 1985." S. 98-139 in: Heinz Otto Luthe und Heiner Meulemann (Hg), *Wertwandel-Faktum oder Fiktion?*, Frankfurt am Main: Campus.
- Felling, Albert, Jan Peters, Osmund Schreuder. (1986). "Geloven en leven. Een nationaal onderzoek naar de invloed van religieuze overtuigingen." Zeist: Kerckebosch.
- Felling, Albert, Jan Peters, Osmund Schreuder. (1987). "Religion im Vergleich: Bundesrepublik Deutschland und Niederlande." Frankfurt am Main: Lang.
- Felling, Albert, Jan Peters, Osmund Schreuder. (1991). "Dutch religion. The religious consciousness of the Netherlands after the cultural revolution." Nijmegen: Instituut voor Toegepaste Sociale Wetenschappen.
- Festinger, Leon. (1954). "A theory of social comparison processes." *Human Relations* 7: 117-140.
- Finn, Jeremy D. (1974). "A general model for multivariate analysis." New York: Holt, Rinehart and Winston, Inc.
- Freilich Gerald, Frederick P. Greenleaf. (1976). "Calculus. A short course with applications to business, economics, and the social sciences." San Francisco: W.H. Freeman and Company.
- Ganzeboom, Harry, Paul de Graaf. (1983). "Beroepsmobiliteit tussen generaties in Nederland in 1954 en 1977." *Mens en Maatschappij* 58: 28-52.
- Ganzeboom, Harry B.G., Paul M. de Graaf. (1984). "Intergenerational occupational mobility in the Netherlands in 1954 and 1977." Pp. 71-90 in: B.F.M. Bakker, J. Dronkers, H.B.G. Ganzeboom (eds.), *Social stratification and mobility in the Netherlands*, Amsterdam: Siswo.
- Ganzeboom, Harry B.G., Paul M. de Graaf. (1989). "Internationale opleidingsmobiliteit in Nederland van geboortecohorten 1891-1960." *Sociale Wetenschappen* 32: 263-278
- Ganzeboom, Harry B.G., Ruud Luijkx, Donald J. Treiman. (1989). "International class mobility in comparative perspective." Pp. 3-84 in A.L. Kalleberg (Ed.) *Research in Social Stratification and Mobility. Volume 8*. Greenwich: JAI Press.

- Ganzeboom, Harry, Ruud Luijkx, Jos Dessens, Paul de Graaf, Nan Dirk de Graaf, Wim Jansen, Wout Ultee. (1987). *"Intergenerationele klassenmobiliteit in Nederland tussen 1970 en 1985."* Mens en Maatschappij 62: 17-43.
- Geschwender, James A. (1967). *"Continuities in theories of status inconsistency and cognitive dissonance."* Social Forces 46: 160-171.
- Glenn, Norval D. (1982). *"Interreligious marriage in the United States: patterns and recent trends."* Journal of Marriage and the Family 44: 555-566.
- Glenn, Norval D. (1984). *"A note on estimating the strength of influences for religious endogamy."* Journal of Marriage and the Family 46: 725-726.
- Goddijn, W., H. Smets, G. van Tillo. (1979). *"Opnieuw: God in Nederland."* Amsterdam: De Tijd.
- Goddijn, Walter. (1973). *"De beheerste kerk: uitgestelde revolutie in Rooms-Katholiek Nederland."* Amsterdam: Elsevier.
- Goldthorpe, John H. (1980). *"Social mobility and class structure in modern Britain."* Oxford: Clarendon Press.
- Goode, William J. (1982). *"The Family."* Englewood Cliffs, New Jersey: Prentice-Hall, Inc.
- Goodman, Leo A. (1968). *"The analysis of cross-classified data: Independence, quasi-independence, and interactions in contingency tables with or without missing entries."* Journal of the American Statistical Association, pp. 1091-1131.
- Goodman, Leo A. (1972). *"Some Multiplicative Models for the analysis of cross-classified data."* Pp. 649-696 in: L. Lecam et al. (eds.), *Proceedings of the Sixth Berkeley Symposium on Mathematical Statistics and Probability*. Berkeley: University of California Press.
- Goodman, Leo A. (1979). *"Multiplicative models for the analysis of occupational mobility tables and other kinds of cross-classification tables."* American Journal of Sociology 84: 804-819.
- Goodman, Leo A. (1981). *"Criteria for determining whether certain categories in a cross-classification table should be combined, with special reference to occupational categories in an occupational mobility table."* American Journal of Sociology 88: 114-134.
- Goodman, Leo A. (1984). *"The analysis of cross-classified data having ordered categories."* Cambridge, Mass.: Harvard University Press.
- Goodman, Leo A. (1985). *"The analysis of cross-classified data having ordered and/or unordered categories: association models, correlation models, and asymmetry models for contingency tables with or without missing entries."* The Annals of Statistics 13: 10-69.
- Gordon, Albert I. (1964). *"Intermarriage: Interfaith, Interracial, Interethnic."* Boston: Beacon.
- Haberman, Shelby Joel. (1979). *"Analysis of qualitative data."* New York: Academic Press.
- Halman, Loek, Felix Heunks, Ruud de Moor, Harry Zanders. (1987). *"Traditie, secularisatie en individualisering."* Tilburg: Tilburg University Press.
- Hayes, Bernadette C. (1991). *"Religious identification and marriage patterns in Australia."* Journal for the Scientific Study of Religion 30: 469-478.
- Heath, Anthony. (1981). *"Social Mobility."* London: Fontana.
- Heer, David M. (1962). *"The trend of interfaith marriages in Canada: 1922-1957."* American Sociological Review 27: 245-250.
- Heer, David M. (1974). *"The prevalence of black-white marriage in the United States, 1960 and 1970."* Journal of Marriage and the Family 36: 246-258.

- Hendrickx, John. (1992). "Using SAS macros and PROC IML to create special designs for Generalized Linear Models." pp. 634-655 in: SAS Institute, SEUGI '92. Proceedings of the SAS® European Users Group International Conference, May 19-22, 1992.
- Hendrickx, John, Jan Lammers. (1991). "Design matrix techniques for generalized linear models and their applications to mobility models." Paper to be presented at the conference of the ISA Research Committee for Social Stratification in Prague, June 18-21, 1991.
- Hendrickx, John, Jan Lammers. (1992). "Design techniques for equal/unequal main effects and symmetrical/asymmetrical interactions." Pp. 149-158 in: P.G.M. van der Heijden, W. Jansen, B. Francis, G.U.H. Seeber (eds.), Statistical Modelling - 6th International Workshop on Statistical Modelling, July 15-19, 1991, Utrecht, The Netherlands. Amsterdam: Elsevier Science Publishers.
- Hendrickx, John, Jan Lammers, Wout Ultee. (1989). "Kerkelijk gemengde huwelijken in Nederland 1946-1986." pp 40-57 in: I. Gadourek, J.L. Peschar (eds.), "De Open Samenleving", Deventer: Van Loghum Slaterus.
- Hendrickx, John, Jan Lammers, Wout Ultee. (1991). "Religious assortative marriage in the Netherlands 1938-1983." Review of Religious Research 33: 123-145.
- Hendrickx, John, Jan Lammers, Wout Ultee. (1993). "Religion and Education as dimensions of the choice of marriage partner: single trait and dual trait analyses." Paper to be presented at the Dutch-Israeli Workshop on Social Stratification, Haifa, January 29-31, 1993.
- Hendrickx, John, Nan Dirk de Graaf, Jan Lammers, Wout Ultee. (1993). "Models for status inconsistency and mobility: a comparison of the approaches by Hope and Sobel with the mainstream square additive model." Quality and Quantity 27: 335-352.
- Herberg, Will. (1955). "Protestant, Catholic, Jew: An Essay in American Religious Sociology. [rev. ed 1960]" New York: Doubleday.
- Homan, Roger. (1986). "The sociology of religion: a bibliographical survey." New York: Greenwood Press.
- Hope, Keith. (1971). "Social mobility and fertility." American Sociological Review 36: 1019-1032.
- Hope, Keith. (1975). "Models for status inconsistency and social mobility effects." American Sociological Review: 40: 322-343.
- Hope, Keith. (1981). "Vertical mobility in Britain: a structured analysis." Sociology 15: 19-55.
- Hope, Keith. (1982). "Vertical and nonvertical class mobility in three countries." American Sociological Review 47: 99-113.
- Hope, Keith. (1991). "Design matrix analysis." Quality and Quantity 25: 333-344.
- House, James S. (1978). "Facets and flaws of Hope's diamond model." American Sociological Review 43: 439-442.
- Hout, Michael. (1982). "The association between husbands' and wives' occupations in two-earner families." American Journal of Sociology 88:397-409
- Hout, Michael. (1983). "Mobility tables." Beverly Hills: Sage Publications.
- Hout, Michael, Andrew M. Greeley. (1987). "The center doesn't hold: church attendance in the United States, 1940-1984." American Sociological Review 52: 325-345.
- Hunt, Richard A., Morton B. King. (1978). "Religiosity and marriage." Journal for the Scientific Study of Religion 17: 399-406.
- Jackson, Elton F. (1962). "Status consistency and symptoms of stress." American Sociological Review 27: 469-480.

- Jackson, Elton F., Peter J. Burke. (1965). "Status and symptoms of stress: additive and interaction effects." *American Sociological Review* 30: 556-564.
- Jackson, Elton F., Richard F. Curtis. (1972). "Effects of vertical mobility and status inconsistency: a body of negative evidence." *American Sociological Review* 37: 701-713.
- Johnson, Robert Alan. (1980). "Religious assortative marriage in the United States." New York: Academic Press.
- Jørgensen, B. (1983). "Maximum likelihood estimation and large-sample inference for generalized linear and nonlinear regression models." *Biometrika* 70: 19-28.
- Kalmijn, Matthijs. (1991a). "From family origins to individual destinations: the changing nature of homogamy in the United States. A dissertation submitted in partial satisfaction of the requirements for the degree of Doctor of Philosophy in Sociology." Los Angeles: University of California.
- Kalmijn, Matthijs. (1991b). "Shifting boundaries: trends in religious and educational homogamy." *American Sociological Review* 56: 786-800.
- Kennedy, Ruby Jo Reeves. (1944). "Single or triple melting-pot? Intermarriage trends in New Haven, 1870-1940." *American Journal of Sociology* 49: 331-339.
- Kennedy, Ruby Jo Reeves. (1953). "Single or triple melting-pot? Intermarriage in New Haven, 1870-1950." *American Journal of Sociology* 58: 56-59.
- Kerr, C., J.T. Dunlop, F. Horbison, C.A. Myers. (1960). "Industrial man and industrial society." Cambridge, Mass: Harvard University Press.
- Kerr, Clark. (1983). "The future of industrial societies, convergence or continuing diversity?" Cambridge, Mass: Harvard University Press.
- Klages, Helmut. (1985). "Wertorientierungen im Wandel." Frankfurt am Main: Campus.
- Kruijt, J.P. (1957). "Sociologische beschouwingen over zuilen en verzuiling." *Socialisme en Democratie* 14: 11-29.
- Kruijt, J.P. (1959). "The influence of denominationalism on social life and organizational patterns." *Archives de sociologie des religions* 4: 105-111.
- Kruijt, J.P., W. Goddijn. (1961). "Verzuiling en ontzuiling als sociologisch proces." In: den Hollander, A.N.J., E.W. Hofstee, J.A.A. van Doorn, E.V.W. Vercruijse (red.), *Drift en koers, een halve eeuw sociale veranderingen in Nederland*, pp. 227-263. Assen: Van Gorcum.
- Lammers, Jan. (1984). "Tabelanalyse volgens multiplicatieve modellen gezien vanuit een causaal perspectief." Doctoral dissertation. Nijmegen: Instituut voor Toegepaste Sociologie.
- Lammers, Jan, Vincent Peters, Theo van der Weegen. (1989). "Visuele analyse van een kruistabel. De techniek van correspondentie analyse." Nijmegen: SWI-reeks.
- Landis, Judson T. (1949). "Marriages of mixed and non-mixed religious faith." *American Sociological Review* 14: 401-407.
- Landis, Judson T., Mary G. Landis. (1953). "Building a successful marriage." New York: Prentice Hall.
- Larson, Lyle E., J. Walter Goltz. (1989). "Religious participation and marital commitment." *Review of Religious Research* 30: 387-400.
- Leeuwen, Bertulf van. (1959). "Het gemengde huwelijk. Pastoraal-sociografisch onderzoek naar de huwelijken van katholieken met niet-katholieken in Nederland." Assen: Van Gorcum.
- Lenski, Gerard E. (1954). "Status crystallization: a non-vertical dimension of social status." *American Sociological Review* 19: 405-413.

- Lenski, Gerard E. (1956). "*Social participation and status crystallization.*" American Sociological Review 21: 458-464.
- Lenski, Gerard E. (1961). "*The religious factor. A sociological study of religion's impact on politics, economics, and family life.*" New York: Doubleday & Co.
- Lenski, Gerhard, Jean Lenski, Patrick Nolan. (1991). "*Human societies : an introduction to macrosociology (6th edition).*" New York: McGraw-Hill.
- Lijphart, Arend. (1968). "*The politics of accommodation: Pluralism and democracy in the Netherlands.*" Berkeley: University of California Press.
- Lipset, Seymour Martin, Reinhard Bendix. (1959). "*Social mobility in industrial society.*" Berkeley: University of California Press
- Long, J. Scott. (1984). "*Estimable functions in log-linear models.*" Sociological Methods & Research 12: 399-342.
- Luckmann, Thomas. (1963). "*Das Problem der Religion in der modernen Gesellschaft.*" Freiburg i.Br.: Rombach.
- Luijckx, Ruud. (1985). "*Structural difference parameters. Some recent developments.*" Paper presented at the annual meeting of the Research Committee on Social Stratification and Mobility (I.S.A.) at Harvard University, September 2-4, 1985.
- MacDonald, K.I. (1981). "*On the formulation of a structural model of the mobility table.*" Social Forces 60: 557-571.
- Mare, Robert D. (1991). "*Five decades of educational assortative mating.*" American Sociological Review 56: 15-32.
- McCullagh, P., J.A. Nelder. (1983). "*Generalized linear models.*" London: Chapman and Hall.
- McCutcheon, Allan L. (1988). "*Denominations and religious intermarriage: trends among white Americans in the twentieth century.*" Review of Religious Research 29: 213-225
- Merton, Robert K. (1941). "*Black-white intermarriage in the United States.*" (Originally in: International Journal of Sociology of the family 1 (special issue): 49-58). Pp. 217-250 of: R.K. Merton, (1976), Sociological ambivalence and other essays. New York: The Free Press.
- Middendorp, Cees. (1979). "*Ontzuiling, politisering en restauratie in Nederland: Progressiviteit en conservatisme in Nederland in de jaren 60 en 70.*" Meppel: Boom.
- Müller, Karl-Valentin. (1950). "*Das Konnubium als Maß der psychischen und sozialen Einwurzelung von Flüchtlingsgruppen.*" Raumforschung und Raumordnung 10: 72-74.
- NAG. (1985). "*The GLIM System Release 3.77 Manual.*" Oxford: Numerical Algorithms Group Ltd.
- Nelder, J.A., R.W.N. Wedderburn. (1972). "*Generalised linear models.*" Journal of the Royal Statistical Society, ser. A, 135: 370-384.
- Nisbet, Robert A. (1966). "*The Sociological Tradition.*" New York: Basic Books.
- Noelle-Neumann, Elisabeth, Renate Köcher. (1987). "*Die verletzte Nation.*" Stuttgart: Deutsche Verlags-Anstalt.
- Noll, Heinz-Herbert, Erich Wiegand (Hg). (1993). "*System Sozialer Indikatoren für die Bundesrepublik Deutschland. Zeitreihen 1950-1991.*" Mannheim: ZUMA.
- Pagnini, Deanna L., S. Philip Morgan. (1990). "*Intermarriage and social distance among U.S. immigrants at the turn of the century.*" American Journal of Sociology 96: 405-432.
- Pennings, Paul. (1991). "*Verzuiling en ontzuiling: de lokale verschillen : opbouw, instandhouding en neergang van plaatselijke zuilen in verschillende delen van Nederland na 1880.*" Kampen: Kok

- Peters, Jan, Osmund Schreuder. (1987). *"Katholiek en Protestant. Een historisch en contemporair onderzoek naar confessionele culturen."* Nijmegen: ITS.
- Peters, Jan, Osmund Schreuder. (1989). *"Konfessionelle Kulturen in den Niederlanden."* S. 113-138 in: H.F. Daiber (Hg), *Religion und Konfession*. Hannover: Lutherische Verlagshaus.
- Pöntinen, Seppo. (1982). *"Models and social mobility research: a comparison of some log-linear models of a social mobility matrix."* *Quality and Quantity* 16: 91-107.
- Post, Harry. (1989). *"Pillarization: An analysis of Dutch and Belgian society."* Aldershot: Avebury.
- Raftery, Adrian E. (1986). *"Choosing models for cross-classifications: comment on Grusky and Hauser, ASR, February 1984."* *American Sociological Review* 51: 145-146.
- Rao, C.R. (1973). *"Linear statistical inference and its applications (2nd ed)."* New York: Wiley.
- Resnik, Reuben B. (1933). *"Some sociological aspects of intermarriage of Jew and non-Jew."* *Social Forces* 12: 94-102.
- Righart, Hans. (1986). *"De katholieke zuil in Europa."* Meppel: Boom.
- Rijsman, J.B., H.A.M. Wilke (red). (1980). *"Sociale vergelijkingsprocessen: theorie en onderzoek."* Deventer: Van Loghum Slaterus.
- Rodman, Hyman. (1965). *"Technical note on two rates of mixed marriage."* *American Sociological Review* 30: 776-778.
- Rother, Karl. (1950). *"Konnuptialindex und Korrelationskoeffizient."* *Mitteilungsblatt für Mathematische Statistik* 2: 184-190.
- SAS Institute Inc. (1989). *"SAS/IML Software. Usage and Reference, Version 6, First Edition."* Cary, NC: SAS Institute Inc.
- SAS Institute Inc. (1989). *"SAS/STAT User's Guide, Version 6, Fourth Edition, Volume 2."* Cary, NC: SAS Institute Inc.
- Schmidtchen, Gerhard. (1972). *"Zwischen Kirche und Gesellschaft."* Freiburg i.Br.: Herder.
- Schmidtchen, Gerhard. (1973). *"Gottesdienst in einer rationalen Welt."* Freiburg i.Br.: Herder.
- Seber, G.A.F. (1977). *"Linear regression analysis."* New York: Wiley.
- Sigelman, Lee. (1977). *"Review of the polls. Multi-nation surveys of religious beliefs."* *Journal for the Scientific Study of Religion* 16: 289-294.
- Sixma, Herman, Wout Ultee. (1983). *"Trouwpatronen en de openheid van een samenleving. De samenhang tussen de opleidingsniveaus van (huwelijks)partners in Nederland tussen 1959 en 1977."* *Mens en Maatschappij* 58: 109-131.
- Sixma, Herman, Wout C. Ultee. (1984). *"Marriage patterns and the openness of society."* Pp. 91-108 in: B.F.M. Bakker, J. Dronkers, H.B.G. Ganzeboom (eds.), *Stratification and Mobility in the Netherlands*, Amsterdam: Siswo
- Slomczynski, Kazimierz M. (1989). *"Effects of status-inconsistency on the intellectual process: The United States, Japan, and Poland."* Pp. 148-166 in: Kohn, M.L. (ed.), *Cross-national research in sociology*. London: Sage Publications.
- Slotkin, J.S. (1942). *"Jewish-Gentile intermarriage in Chicago."* *American Sociological Review* 7: 34-39.
- Smits, Jeroen, Wout Ultee, Jan Lammers. (1993). *"Het verband tussen de beroepsposities van huwelijkspartners in acht landen van de Europese Gemeenschap, 1975-1989."* *Mens en Maatschappij* 68: 39-58.

- Sobel, Michael E. (1981). "*Diagonal mobility models: a substantively motivated class of designs for the analysis of mobility effects.*" American Sociological Review 46: 893-906.
- Sobel, Michael E. (1983). "*Structural mobility, circulation mobility and the analysis of occupational mobility: a conceptual mismatch.*" American Sociological Review 48: 721-727.
- Sobel, Michael E. (1985). "*Social mobility and fertility revisited: some new models for the analysis of the mobility effects hypothesis.*" American Sociological Review 50: 699-712.
- Sobel, Michael E., Gerhard Arminger. (1989). "*Probit adding and averaging models: modelling household fertility decisions.*"
- Sobel, Michael E., Michael Hout, Otis Dudley Duncan. (1985). "*Exchange, structure, and symmetry in occupational mobility.*" American Journal of Sociology 91: 359-372.
- Sociaal en Cultureel Planbureau. (1988). "*Sociaal en Cultureel Rapport 1988.*" Rijswijk: Sociaal en Cultureel Planbureau.
- Sorenson, Ann Marie. (1989). "*Husbands' and wives' characteristics and fertility decisions: a diagonal mobility model.*" Demography 26: 125-135.
- SPSS Inc. (1988). "*SPSS-X User's Guide, 3rd Edition.*" Chicago: SPSS Inc.
- Suls, Jerry M., Richard L. Miller (eds.). (1977). "*Social comparison processes - theoretical and empirical perspectives.*" London: Wiley.
- Thurlings, J.M.G. (1971). "*De wankende zuil. Nederlandse katholieken tussen assimilatie en pluralisme.*" Deventer: Van Loghum Slaterus.
- Ultee, Wout C., Ruud Luijkx. (1990). "*Educational heterogamy and father-son occupational mobility in 23 industrial nations: General societal openness or compensatory strategies of reproduction?*" European Sociological Review 6: 125-149.
- Vugt, Joos van, Ben van Son. (1988). "*Nog eens: godsdienst en kerk in Nederland, 1945-1986: een geannoteerde bibliografie van sociaal-wetenschappelijke en historische literatuur.*" Hilversum: Gooi & Sticht.
- Weakliem, David. (1992). "*Does social mobility affect political behavior?*" European Sociological Review 8: 153-165.
- Weber, Max. (1921). "*Gesammelte Aufsätze zur Religionssoziologie.*" Tübingen: Mohr.
- Whitt, Hugh P. (1983). "*Status inconsistency: a body of negative evidence or a statistical artifact?*" Social Forces 62: 201-233.
- Wilson, Bryan R. (1967). "*Religion in secular society.*" London: Watts.
- Wilson, Kenneth L. (1979). "*Status inconsistency and the Hope technique I: the grounds for a resurrection.*" Social Forces 57: 1229-1247.
- Wilson, Kenneth L., Louis A. Zurcher. (1976). "*Status inconsistency and participation in social movements: an application of Goodman's hierarchical modeling.*" The Sociological Quarterly 17: 520-533.
- Yamaguchi, Kazuo. (1990). "*Some models for the analysis of asymmetric association in square contingency tables with ordered categories.*" Pp. 181-212 in: C. Clogg (ed.), Sociological Methodology 1990, Washington, DC: American Statistical Association.
- Zeegers, G.H.L., G. Dekker, J.W.M. Peters. (1967). "*God in Nederland.*" Amsterdam: Van Duijn.
- Ziegler, Rolf. (1985). "*Bildungsexpansion und Partnerwahl.*" S. 85-106 in: Stefan Hradil, "Sozialstruktur im Umbruch", Opladen: Leske Verlag + Budrich GmbH.
- Zimmerman, Ekkart. (1985). "*Almost everything you always wanted to know about status inconsistency (but were afraid to measure).*" Social Behavior and Personality 13: 193-214.

Zurcher, Louis A., Kenneth L. Wilson. (1979). "*Status inconsistency and the Hope technique II: a linear hypothesis about status enhancement, status detracting, and satisfaction with membership.*" *Social Forces* 57: 1248-1664.

Curriculum Vitæ

John Hendrickx was born in St. Catharines, Canada, on February 8, 1958. He moved to the Netherlands in 1972, where he completed high school, graduating from atheneum-B in 1978. He started studying sociology at the University of Nijmegen in 1979, and obtained his Masters degree (doctoraal) in 1988, with a specialization in Research Methodology. He became a graduate student at the University of Nijmegen in 1989, where he did research on religious assortative marriage in the Netherlands and Germany in the 20th century.

By studying patterns of assortative marriage, sociologists can gain valuable insights in the openness of society. Part 1 of this book analyzes religious assortative marriage in the Netherlands, in order to monitor tensions between religious groups in the course of the twentieth century. Through the use of special loglinear models, the patterns of assortative marriage can be broken down into meaningful components, and hypotheses on modernization and openness of society can be tested.

Part 2 examines design techniques of categorical data as used in the analysis of mobility and assortative marriage. Contrasts and their relationship to the interpretation of parameters and the implications for creating designs with special restrictions are discussed. New designs using the deviation contrast are derived on this basis.

John Hendrickx studied sociology at the University of Nijmegen. This book presents the results of a four year research project on religious assortative marriage.

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