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# The long-term relationship between land use and employment on industrial sites in the Netherlands

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## Abstract
Popular forecasting models for long-term planning of industrial sites assume a strong linear relationship between employment and land use. New Dutch panel data for 1997-2008 were used to test this assumption. In a linear model, employment alone does not suffice to predict land use. Non-linear models show a relationship at municipal and industrial sites level, but not for regions. However, the relationship is strongly biased by unobserved heterogeneity. For planning purposes and prediction, additional explanatory variables are necessary to tackle this problem. The findings do not support the use of simple linear models for the planning of industrial sites.

JEL classifications: C23, O18, R12, R14
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## 1. Introduction

Like in many Western countries, industrial sites in the Netherlands play an important role in the country's economic development as they accommodate a great share of economic activities and employment (LOUW and BONTEKONING, 2007; DE VOR and DE GROOT, 2011). This share has increased to about one-third of national employment in 2006 (WETERINGS et al., 2008). For many firms, industrial sites are an attractive location to settle (LOUW and BONTEKONING, 2007) and firms on these sites grow faster than firms located elsewhere (WETERINGS et al., 2008). Local policy makers see industrial sites as a strategic asset to meet local economic objectives, i.e. stimulating local entrepreneurship, employment and competitiveness (DE VOR and DE GROOT, 2010). This explains why policy makers at the national, regional and local level have traditionally accommodated all potential demand for industrial land (LOUW et al., 2003; VAN DER KRABBEN and VAN DINTEREN, 2010).
In the Netherlands, the process of developing a land-use plan and preparing industrial sites for building assumes between six and eight years (LOUW, 2000; LOUW et al., 2003). Once the area is developed and industrial real estate has been established, the land use has a near permanent character, as urban redevelopment is very time-consuming and expensive. Therefore it is important that policy makers have a good estimate of the land needed in the coming decades. To this end, various forecasting models of the long-term demand for industrial sites have been developed in the Netherlands and other Western countries (VAN AALST et al., 1985; CPB, 2002; TRAA and DECLERCK, 2007). KNOBEN and TRAA (2008) compare the different long-term forecasting methods currently in use and identify the *employment based method* as the single best candidate. This method links future spatial demand for industrial sites to long-term employment forecasts for these sites, assuming a strong and robust linear relationship between employment and land use. Although this method is widely implemented to forecast long-term demand for industrial sites, its underlying assumption has to date been insufficiently assessed: The theoretical arguments supporting linearity have been rather limited and the empirical findings tend to suggest that the relationship is less strong than one would hope (IKE et al., 1984; VAN AALST et al., 1985; ZEILSTRA, 1998; SCHUUR, 1998; LOUW et al., 2004; KNOBEN and TRAA, 2008). Newly available panel data for the period 1997-2008 enable the monitoring of employment and land use at the level of individual industrial sites over a 12-year period. This, for the first time, makes it possible to test the relationship between employment and land use on industrial sites.
This paper contributes to the spatial planning of industrial sites by providing new empirical evidence on the long term relationship between employment and land use on these sites. Improvement of the planning of industrial sites meets the current policy concern about oversupply of industrial land and a high rate of deteriorating industrial sites in the Netherlands (LAGENDIJK, 2001; LOUW et al., 2004; VROM-RAAD, 2006; GORDIJN et al., 2007; PBL, 2009; DE VOR and DE GROOT, 2011). In 2006, industrial sites occupied about 2,1% of the total land use of the Netherlands (PBL, 2009) and this urban land use category is the strongest growing of all (PBL, 2009). The total net area allocated to industrial sites has increased with about 10,000 hectares (25%) between 1997 and 2008 (BECKERS et al., 2012). As a consequence, land for industrial greenfield locations is debated in the Netherlands for its cost of open space, its local environmental impact, its limited aesthetic quality and its negative effect on the redevelopment potential of brownfield locations. This resulted in a national policy programme restricting

new regional supply (VROM, 2009). Recently, policy on industrial sites was transferred to Dutch provinces (IenM, 2011), but most provincial authorities share this concern.
The paper begins with a section on the planning of industrial sites to explain the purpose of long-term planning and to compare the employment based method with alternative methods applied to industrial sites planning in the Netherlands and other countries. In the next section, the paper discusses the relationship between employment and land use and factors at different spatial levels that affect this relationship. This is followed by a description of the newly available data used to assess the relationship between employment and land use, and the methodology. Thereafter, the paper focuses on the discussion of the empirical results. This is followed by the paper's conclusions and a discussion of policy implications.

## 2. Planning of industrial sites

Various methods are used in the Netherlands and other Western countries to make long-term forecasts for land use of industrial sites (IKE et al., 1984; VAN AALST et al., 1985; BCI, 2000; BONNY and KAHNERT, 2005; MVG, 2004; STOGO, 2007). KNOBEN and TRAA (2008) provide an overview and discuss their advantages and disadvantages. The *employment based method* is currently by far the most popular and widely used method of all (KNOBEN and TRAA, 2008). This method computes the future spatial demand of industrial sites by multiplying employment forecasts with a land use parameter reflecting the average lot size per worker.
Other instrumental variables to predict industrial land use have been tried occasionally, such as real estate value (VAN DER VEGT and POOT, 1996) and production output (CPB, 1997), but with little success or limited scope. Land use corresponding to economic dynamics may be determined by many factors, including the type of activity, the production process, the organisation of transport logistics, the type of accommodation, land supply and land prices, and land use regulation and environmental policies. Moreover, the relationship between employment and land use is likely subject to time lags and an asymmetric response to economic expansion and decline. For prediction purposes this complex relationship is usually reduced to a simple projection model with employment volume as a proxy for general economic development, a categorization into economic sectors to account for land use differentials related to the type of activity, and a regionalization to catch land market effects (SCHUUR, 1998).
Perhaps the most important advantage of the employment based method over alternative methods is that reliable regional employment data is available for longer periods of time in many countries. In addition, the employment based method is built around the intuitive relationship between employment and land use and rather transparent in design. In the policy context of Dutch land use planning, where many private and public stakeholders have to come to a political agreement on the supply of new industrial sites, these are important assets. Such land use forecasts are accepted more easily and therefore more effective (SCHUUR, 1999).
An international literature review reveals that the most sophisticated application of the employment based method is currently found in the Netherlands. It is also applied to long-term industrial sites forecasting in Belgium and Germany, but in a less detailed fashion as data availability in these countries is less favourable (KNOBEN and TRAA, 2008). In the Netherlands, the employment based method is implemented in three

steps: First, annual forecasts of regional (NUTS-3 level[1]) employment per sector are derived from four national economic scenario's until 2040. Second, the share of total employment on industrial sites is forecasted per region and sector. Third, forecasts of sector and region-specific land use parameters are made and then multiplied by the corresponding future employment scenarios per region (ARTS et al., 2005; BECKERS et al., 2012). The land use parameters play a central role in translating the employment forecasts to space demand. The underlying assumption is that each worker needs a certain amount of space to carry out his or her task. This need of space may vary by economic activity, geographic location and in time, but within these dimensions the relationship between employment and land use is assumed to be robust and linear: i.e. each extra worker in the logistics sector on industrial sites in region A requires the same square metres of additional lot size.

While the employment based method is generally considered superior over other existing methods for long-term spatial forecasting of industrial sites, this method has since long been criticized. This critique has focused particularly on the theoretical assumption of a linear relationship between employment and land use, given the large spread of the land use parameters (IKE et al., 1984; VAN AALST et al., 1985; ZEILSTRA, 1998; LOUW et al., 2004) and the assumptions regarding the future development of these parameters (KNOBEN and TRAA, 2008).

## 3. The relationship between employment and land use

IKE et al. (1984) and other researchers thereafter doubt that the relationship between employment and land use on industrial sites is linear as the underlying processes that link these variables are far more complex. The authors point out that other, non-linear relationships such as an exponential relationship are more plausible or even that no statistically significant relationship between the variable might be found at all. At the micro level, a linear relationship seems unlikely given internal scale-effects: Many studies have pointed out that larger firms require less space per worker than smaller firms (BAK, 1961; VAN STEEN, 1997; ZEILSTRA, 1998). As firms grow, they have more options to make efficient use of central facilities, production technology, logistics, storage, and e.g. parking space (economies of scale). However, findings by VAN STEEN (1997) and ZEILSTRA (1998) suggest that firms in the beginning of their life cycle tend to use relatively little space as many entrepreneurs cannot find adequate firm space. At the macro level the linear relationship may be less problematic as developments in the variables are determined by the simultaneous effects of firms which start up, grow, decline and close down (KNOBEN and TRAA, 2008). Given the debate on the functional form of the relationship between employment and land use, this paper tests both linear and non-linear (logarithmic, first-differences) model specifications as explained further below.

VAN AALST et al. (1985) suggest that a time lag exists between these variables as employment changes do not immediately imply land market transactions. Instead it is likely that growing firms first opt for more intensive use of their existing space before

[1] According to the standardized regional classification system of Eurostat, the Netherlands is subdivided into forty NUTS-3 level regions, which are based on administrative structures and regional labour markets and mobility. Map A1 in the appendix shows where these regions are located.

they relocate or expand. On the other hand, shrinking firms likely let go of employees first before they vacate their buildings. When analysing the relationship between employment and space at the firm level, this would suggest using models with time lags. In this regard, especially the inclusion of employment time lags seems relevant, as findings by VAN OORT et al. (2007, p.68) show that the employment growth of relocated firms two years before moving more than doubles the employment growth of firms that do not relocate. This finding holds for all sectors. At the macro-level, however, there is little evidence for a time lag in the relationship as KNOBEN and TRAA (2008) show. Nonetheless, in line with the findings of VAN OORT et al., this study tests for the existence of time delay effects of the employment variables on land use by running specifications including one and two-year employment time lags.
The relationship between employment and land use is highly complex as it is affected by a multitude of factors that are identified in the literature. These factors can be grouped by their level of aggregation: starting at the firm level, the regional level, and finally the macro level.

### 3.1. Factors at the firm level

At the firm level, a distinction can be made between firm size and life cycle stage - as were already discussed above, the nature of economic activities, and production methods and processes. Firm size may not only be relevant as a volume indicator, e.g. to account for scale effects, but also in terms of a growth indicator (first differences), to account for the relationship between employment size and land use to be asymmetric for growing and shrinking firms. The latter hypothesis is tested in this study by trying models with control variables for regions with shrinking sectoral employment. Firm size and life cycle information of firms could not be included in the analyses due to lack of reliable long-term data.
Various studies have found that the nature of economic activities on industrial sites determines to a large extent their demand for space. Most of these studies have looked into land use differences between classified sectors of economic activities finding higher land use parameters for industry and logistics than for services sectors (VAN AALST et al., 1985; ZEILSTRA, 1998; ARTS et al., 2005; BONNY and KAHNERT, 2005; WETERINGS et al., 2008; HOW-TO ADVISORY, 2006; ROGER TYM & PARTNERS, 2002[2]). It is argued that production processes in the industry and logistics sectors are more capital intensive and thus require more space per worker for storage and production than in the services sectors. Moreover, workers in the services sector tend to be housed in multiple floor office buildings, which proportionally reduces per head land use. Other studies confirm that storage and physical production activities require more space per worker than service- and sales-oriented activities (THOMPSON, 1997; ZEILSTRA, 1998). Although many studies underline the importance of distinguishing between economic activities to predict land use accurately, the difficulty seems to be to find the optimal grouping of activities. LOUW et al. (2004) and others question the accuracy of the forecasts generated by the employment based method as the spread of the land use parameters used in the model is very large. In fact, the data on land use characteristics of 11.483 individual firms, collected for the Dutch national planning of industrial sites and grouped into 27 business classes, show a very large within group variation of the

[2] This study as well as the other UK and US-based studies cited in this section investigate floor space per worker rather than lot size per worker. Despite this difference, their findings are informative here.

land use per worker, indicating a little robust relationship between employment and land use at firm level (CPB, 2002: p.155). Some firms may use hundreds of times more land per worker than others within the same business class. KNOBEN and TRAA (2009) study the relationship at the aggregation level of industrial sites, using time series employment data for Dutch industrial sites between 1999 and 2006. They conclude that employment is a promising land use predictor at this level, but due to heterogeneity they do not find significant effects when grouping the data into business classes. In the current study, grouping is limited to five broad economic sectors: industry, logistics, consumer services, business and financial services, and government and care. This is the maximum detail given the data and model options available for the analysis.
Differences in production methods and processes explain why land use varies between firms and why it changes over time. Technological developments such as automation may make production processes more capital intensive, which for reasons explained above affects spatial demand (SERPLAN & ROGER TYM, 1997). Also, the implementation of the 'new working' concepts (i.e. teleworking, working from home), Just-In-Time and Just-In-Place logistics, and changing work practises (organisational restructuring, outsourcing) likely affect firm land use, but how is unclear from the literature (LEMPA, 1990; ZEILSTRA, 1998). CPB (2002) distinguishes two long term trends: a positive trend in labour productivity, leading to a decrease in land use per worker, and a negative trend in spatial productivity (production per hectare), having an upward effect on this land use parameter.

### 3.2. Factors at the regional and national levels

A large number of geographical factors influence the land use parameter. The location of the industrial site and thereby its distance to urban centres and core economic areas determines the scarcity and price of building space for commercial purposes. This in turn, determines how intensively space is used (PBL, 2009). BAK (1961), VAN STEEN (1997) and ZEILSTRA (1998) have shown that land use on industrial sites is more intensive in regions with higher land prices. Many studies distinguish between regions to capture inequalities between the regionally functioning employment and industrial land markets (HOW-TO ADVISORY, 2006; BONNY & KAHNERT, 2005). Studies from the Netherlands have found that land use parameters are lowest in the Randstad, the economical heartland of the Netherlands where land is scarce and pricy, followed by the Intermediary Zone, and highest in the Periphery (ZEILSTRA, 1998; CPB, 2002; ARTS et al., 2005; WETERINGS et al., 2008; KNOBEN and TRAA, 2008, KNOBEN and TRAA, 2009; PBL, 2009)[3]. To account for the above regional differences in land use, this study analyses the relationship between employment and land use separately for the three regions Randstad, Intermediary Zone and Periphery as well as for each of the underlying 40 Dutch NUTS-3 regions.[4] Moreover, several additional regional characteristics were added to the analyses to reduce regional heterogeneity in the land use parameters: Control variables for urbanised regions, population density, employment density values (VAN OORT, 2004), and for regions with high employment share in services sectors (above 40%).

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[3] The regional grouping varies slightly between studies, but generally the Randstad includes the provinces of North-Holland, South-Holland, and Utrecht, and the Intermediary Zone consists of the provinces bordering the Randstad.
[4] Map A1 in the appendix shows the regional groupings used in this study.

The existing government policy has impact on the land use behaviour of firms. In The Netherlands, planning, development and supply of land for industrial sites is a responsibility of municipal authorities. Excess supply by neighbouring municipalities competing for regional employment since long had a pressing effect on land prices and stimulated demand (DE VOR, 2011). Moreover, LEMPA (1990) and ZEILSTRA (1998) stress the impact of environmental regulations, which are, however, hardly measurable and thus left aside in this study.
Finally, the macroeconomic situation affects the land use parameter as firms are more flexible in altering their employment volume than their building stock and land use. For instance, in times of economic decline, firms tend to reduce their employee numbers but only sell their real estate later, if ever. As a consequence, the land use parameter may temporarily rise in times of economic decline (THOMPSON, 1997; ZEILSTRA, 1998).

## 4. Data and methodology

A new panel database created by the PBL Netherlands Environmental Assessment Agency makes it possible to follow sectoral employment and land use of all industrial sites in the Netherlands over a 12-year period from 1997-2008. The panel database is created by merging two datasets using address information and geographical projection: the national IBIS monitoring database with quantitative and qualitative information on planned and existing industrial sites (ARCADIS and STEC GROEP, 2009), and the LISA database containing employment details on all individual firms in the Netherlands (STICHTING LISA, 2008). The IBIS database contains annual information on net area of issued land per industrial site as well as some geographical and other characteristics of these sites, which are used for the analyses.[5] From these the following variables are derived: Location (municipality, region of the country) and percentage issued of net area of the site. As the quality of the IBIS database has been widely criticized in recent years (TRAA and HAMERS, 2007; LOUW et al., 2004), major corrections and quality checks were carried out to make the data suitable for analysis (BECKERS et al., 2012).[6] Next, the national LISA database is used, whereby firm locations are projected geographically on the industrial sites in IBIS.[7] This way it is possible to determine which firms were located on industrial sites in the period 1997-2008 and track employment and space use developments at the level of individual industrial sites. This panel database, enables, for the first time, a study of the relationship between land use and sectoral employment at the level of individual industrial sites. The following variables are derived from the panel database: annual employment on industrial site for five economic sectors (industry, logistics, consumer services, business and financial services, government and care), the employment share of regions (NUTS-3) working in services sectors, dummy variables for regions where sectoral employment is shrinking.[8]

[5] Sites with less than one hectare gross area are not included in IBIS. IBIS data on seaport areas are not reliable. Therefore, small industrial sites and seaport areas are excluded from this study's analysis.

[6] As a result of the data corrections the national net area issued on industrial sites reduced by up to five per cent in some years.

[7] For this purpose GIS methods are used as well as complementary address information.

[8] Employment is defined as the number of workers employed for at least 12 hours per week.

Also, some regional variables are computed that are used in the analyses. These variables are based on public information from the Netherlands Bureau of Statistics (NETHERLANDS BUREAU OF STATISTICS, 2011). These are: population density of regions, the employment density value of regions, and a dummy for urbanized regions.[9]

The combined LISA-IBIS database complemented by additional information from the Netherlands Bureau of Statistics allows us to test statistically whether employment is a meaningful indicator to forecast long-term business spatial needs. The analyses will be performed on different spatial levels, as the underlying processes that affect this relationship likely vary by scale (OPENSHAW, 1984). As the land use behaviour on industrial sites can vary greatly even between sites located in the same municipality, analysis at the lowest possible level seems appealing. However, if employment is to be used as an instrumental variable for the long-term demand for industrial sites, the planning of which is coordinated in The Netherlands by provinces and some highly urbanized regions (NUTS-3), the regional level serves this purpose better. Furthermore, the NUTS-3 level comes closest to the spatial structure of the Dutch labour and commercial land markets (BONGAERTS et al., 2004; FRENKEN et al., 2007; PBL, 2009). Finally, the relationship can be studied at the municipal level, which might be a meaningful spatial compromise. In Dutch policy on industrial sites municipal governments play an important role: they decide on legal zoning plans, but also have a monopoly on the issuing of commercial land and a financial interest in site development through real estate taxation (SCHUUR, 2004; PBL, 2009).

This paper focuses on the use of employment variables as predictors of land use and tests whether a promising forecasting model for the Netherlands can be built using the newly available data on 1997-2008. For reasons given before, other predictors for industrial land use are hardly employed in long term planning of industrial sites and therefore are not considered here. As discussed in the literature review above, the relationship between employment and land use could be described by a linear regression model, but also non-linear specifications seem plausible. Therefore, this study experiments with three different model types, which are shown in their formal form in Equations 1-3. The linear model relates total land use (net area issued) to sector employment, assuming a fixed land use per worker. The logarithmic model relates the natural logarithms of both the dependent and independent variables.[10] As a consequence, the regression parameters are to be interpreted as elasticities, the underlying assumption being that a relative change in employment matches a fixed relative change in land use. While the first two models describe the relationship between the total stocks of employment and land use on industrial sites, reflecting the concept behind traditional planning models, model three assumes proportionality between the changes in these variable over time (flows). The latter, first-differences, model relates the absolute changes, allowing for the annual issue of new land being linear on annual employment growth, irrespective of stock size. The land use effect of a thousand new workers is the same, whether on a large or a small industrial site.

Linear model: $$L_{r,t} = \alpha_r + \sum_{s=1}^{5} \beta_{r,s} E_{r,s,t} \qquad (1)$$

[9] The variable definitions follow the terminology used by the Netherlands Bureau of Statistics.

[10] To avoid losing observations with no sectoral employment in the process of the logarithmic transformation, the constant of 0.5 is added to all sectoral employment values in line with SEN and SOOT (1981).

Logarithmic model: $\ln(L_{r,t}) = \alpha_r + \sum_{s=1}^{5} \beta_{r,s} \ln(E_{r,s,t})$ (2)

First-differences model: $L_{r,t} - L_{r,t-1} = \alpha_r + \sum_{s=1}^{5} \beta_{r,s} (E_{r,s,t} - E_{r,s,t-1})$ (3)

where:

$L_{r,t}$ = land use (net area issued) on industrial site per region (r) and year (t);

$E_{r,s,t}$ = employment on industrial site per region (r), sector (s) and year (t);

$\alpha_r$ , $\beta_{r,s}$ = regression parameters per region (r) and sector (s).

Initially, the regression parameters are estimated for each of the forty NUTS-3 regions separately to adequately capture the regional differences between labour markets and commercial land markets. Next, as prior research for the Netherlands has consistently shown that land use parameters differ between the three comprehensive regions Randstad, Intermediary Zone and Periphery (ARTS et al., 2005; WETERINGS et al., 2008; KNOBEN and TRAA, 2008), regression parameters are also estimated for each of these three regions separately.[11]

For each model type in formulas 1-3 a number of specifications is estimated with an intercept using ordinary least squares (OLS). They differ with regard to the employment sectors distinguished. Some sectors contribute significantly more to land use on industrial sites than others. In particular, service industries which tend to be accommodated in multi-level office buildings will show a linear relationship between employment and floor space rather than land use, and employment in this sector probably adds little to the explanation of land use. An intercept reflects the assumption that individual firms may have land use, even if hardly any workers are employed.

Finally, a fixed effects specification (FE) is applied to test whether unobserved heterogeneity due to local and regional characteristics influences the regression results.[12] Fixed effects may correct for geographical differences or local policy factors which affect the relationship under test. However, as it is uncertain what these fixed effects actually entail, in the long run they cannot simply be assumed fixed, leaving the resulting estimates not usable for prediction of future land use.

## 5. Empirical results

Table A1 in appendix A provides an overview of the various regression models that were estimated and the standard statistical criteria that were applied to test these models (KENNEDY, 2003; GREENE, 2008). The table indicates how each model performs with regard to these criteria. The models differ with respect to the three spatial levels of data used in the regressions, the two levels on which the parameters are estimated, the three model types, and the number of employment sectors included as explanatory variables.

[11] For the sake of simplicity, the above formulas suggest that all regressions are based on aggregate data at the regional NUTS-3 level. However, technically equivalent formulas were also estimated with data at the spatial levels of individual industrial sites and municipalities.

[12] The latter is the equivalent to a model with dummy variables for each industrial site, municipality or NUTS-3 region depending on the spatial level of data aggregation. Industrial site, municipality, NUTS-3 region dummies are used in the models using data at the industrial site level, the municipal level and the NUTS-3 regional levels respectively.

As can be seen in Table A1, only few model specifications satisfy the statistical criteria. In particular, the models defining a double log relationship between employment and land use at the level of industrial sites seem promising.

## 5.1. The linear relationship between employment and land use

As can be seen in Table A1 in appendix A, none of the linear regression models meet the statistical evaluation criteria as the residuals are correlated with the explanatory variables. In other words, the above analyses based on employment and land use data of the period 1997-2008 do not support the existence of a linear relationship between these variables when using employment as only predictor. This may either suggest that additional unobserved factors bias the linear relationship between employment and land use, or that the relationship between these variables is non-linear, or that employment and land use are not related at all.

As for reasons explained above, this research does not consider alternative predictors of land use other than employment, so the first option is left unexplored. Instead, the following section investigates whether a non-linear relationship exists between employment and land use.

## 5.2. The non-linear relationship between employment and land use

The non-linear relationship between employment and land use was explored by estimating two types of regression models, namely the logarithmic model and one with first-differences. As can be seen in Table A1 in appendix A, none of the models with first-differences and only two logarithmic model specifications meet the statistical evaluation criteria. The two logarithmic model specifications that do meet the criteria describe the relationship at the level of the three comprehensive regions Randstad, Intermediary Zone, and Periphery. The outcomes of these regressions are discussed in the following two sections.

*Logarithmic regression results at the level of individual industrial sites*

The first logarithmic model specification that passes the evaluation criteria describes the relationship between employment and land use at the level of individual industrial sites and yields useful regression outcomes for the comprehensive regions of the Randstad, Intermediary Zone, and Periphery. Table 1 presents the regression findings for this specification with intercept and the five broad employment sectors as explanatory variables using OLS. All coefficients are significant at the 5% level. The OLS outcomes are in line with expectations: coefficients are larger for employment in industry and logistics than for services, as land use in the in the former, more capital intensive sectors is more elastic to employment dynamics. Similarly, coefficients in the Randstad region are generally smaller than in the other two regions, because the higher land prices in this region will make land use respond more to employment variations. Two exceptions are found: the logistics sector coefficient in the Periphery is actually slightly smaller than in the Randstad, and the business and financial services sector coefficient in the Intermediary Zone is smaller than in the Randstad. Regarding the business and financial services sector, this may be caused by their preference for office buildings, which are much higher in the urbanized Randstad. As a consequence, a greater share of the employment dynamics will be absorbed in floor space instead of land use. For the logistics sector this may be due to the particular logistic activities in major seaports like Rotterdam and Amsterdam. The coefficients should be interpreted as elasticities, i.e. a 1% increase in employment in the industry corresponds with 0.14% more land use in the Randstad, 0.21% in the Intermediary Zone, and 0.23% in the Periphery. By running the model in the fixed-effects specification[13] it is possible to show what the coefficients

[13] This is the equivalent of the OLS specification with dummy variables for each industrial site.

would have looked like when controlling for the time-invariant unobserved characteristics of sites. The fixed-effects outcomes show that the OLS employment coefficients of all sectors except for consumer services are greatly biased upwards. In other words, land use responds much less to employment changes than is suggested by the OLS estimates, once controlling for other, unknown, characteristics of industrial sites. For prediction of future land use on industrial sites, the OLS coefficients can therefore be little trusted. On the other hand, using the coefficients estimated with fixed-effects is no viable option either as it is unclear which characteristics of industrial sites actually constitute these fixed-effects, and consequentially, it cannot be assumed that these characteristics that were time-invariant over the period 1997-2008 will not change in the long-run. Also, the fixed-effects results show that the employment variables actually explain a far smaller share of the variation in spatial demand than is suggested by the R-squared in the OLS regressions, once controlling for unobserved characteristics. This share reduces to 14.8%, 21.7% and 19.7% in the Randstad, Intermediary Zone and Periphery, respectively, as indicated by the within r-square figures. In other words, developments in land use are by and large driven by characteristics that are not part of the model. This makes the regression estimates unsuitable for long-term forecasting of land use, the purpose of this study.

Table 1. Regression results at the level of individual industrial estates for three comprehensive regions, logarithmic specification

| | Randstad | | Intermediary Zone | | Periphery | |
|---|---|---|---|---|---|---|
| | **OLS** | **FE** | **OLS** | **FE** | **OLS** | **FE** |
| **ln employment industry** | .144*** | .045*** | .209*** | .071*** | .232*** | .061*** |
| | (.015) | (.007) | (.013) | (.007) | (.016) | (.009) |
| **ln employment logistics** | .176*** | .044*** | .213*** | .050*** | .165*** | .059*** |
| | (.014) | (.008) | (.012) | (.007) | (.013) | (.008) |
| **ln employment consumer services** | .039** | .043*** | .062*** | .054*** | .070*** | .065*** |
| | (.016) | (.007) | (.013) | (.007) | (.015) | (.008) |
| **ln employment business and financial services** | .039*** | .025*** | .029** | .046*** | .048*** | .037*** |
| | (.014) | (.006) | (.013) | (.005) | (.012) | (.006) |
| **ln employment government and care** | .026** | .011** | .041*** | .014*** | .049*** | .022*** |
| | (.012) | (.005) | (.009) | (.004) | (.015) | (.006) |
| **constant** | .391*** | 1.35*** | .189*** | 1.28*** | .351*** | 1.21*** |
| | (.059) | (.056) | (.047) | (.046) | (.045) | (.042) |
| **n** | 9705 | 9705 | 14991 | 14991 | 11779 | 11779 |
| **R-squared** | .493 | .474 | .621 | .588 | .625 | .596 |
| **within R-squared** | | .148 | | .217 | | .197 |

Notes: * p<10%; ** p<5%; *** p<1% (White's heteroskedasticity-consistent standard deviations in brackets).

*Logarithmic regression results at the level of municipalities*

The second logarithmic model specification that passes the evaluation criteria describes the relationship between employment and land use at the level of municipalities and yields useful regression outcomes for the comprehensive regions of the Randstad, Intermediary Zone, and Periphery. Table 2 presents the regression findings for this specification with intercept and the two most important employment sectors (industry and logistics) as explanatory variables using OLS. All coefficients are significant at the 5% level. The OLS outcomes for the industry sector are in line with expectations: the coefficient in the Randstad is the smallest and the one in the Periphery is the largest. The logistics sector shows the same contrasting pattern as was found at the level of individual sites in the prior section. A 1% increase in employment in industry corresponds with 0.42% additional land use in the Randstad, 0.54% in the Intermediary Zone, and 0.56% in the Periphery. However, the fixed-effects results show that the OLS coefficients are greatly biased upwards due to the variables' correlation with unobserved characteristics of municipalities. Moreover, the OLS specification overestimates the explanatory effect of employment considerably as is indicated by the within R-squared figures. Again, neither the coefficients estimated with fixed-effects nor the OLS coefficients can be used for forecasting.

Table 2. Regression results at the level of municipalities for three comprehensive regions, logarithmic specification

| | Randstad | | Intermediary Zone | | Periphery | |
|---|---|---|---|---|---|---|
| | **OLS** | **FE** | **OLS** | **FE** | **OLS** | **FE** |
| **ln employment industry** | .421*** | .155** | .542*** | .185*** | .564*** | .150*** |
| | (.061) | (.061) | (.035) | (.067) | (.049) | (.055) |
| **ln employment logistics** | .410*** | .105** | .302*** | .176*** | .173*** | .147*** |
| | (.053) | (.041) | (.032) | (.033) | (.053) | (.039) |
| **constant** | -1.81*** | 2.01*** | -1.53*** | 1.82*** | -.593** | 2.37*** |
| | (.262) | (.429) | (.150) | (.414) | (.231) | (.379) |
| **n** | 1614 | 1614 | 2065 | 2065 | 1340 | 1340 |
| **R-squared** | .818 | .815 | .880 | .874 | .851 | .825 |
| **within R-squared** | | .097 | | .188 | | .144 |

Notes: * p<10%; ** p<5%; *** p<1% (White's heteroskedasticity-consistent standard deviations in brackets)

### 5.3. Spatial differentiation

The above bias may be due to a regionalization that does not account well for geographical heterogeneity in economic structure, particularly for differences in regional land markets that affect the land use of firms. To test this hypothesis, some explanatory variables which may reflect land market differentials better, identified in the above literature review, were added one-by-one to the regression models in Tables 1 and 2: interaction terms between the sectoral employment variables and a dummy for regions with high employment share in services sectors (above 40%), interaction terms between the sectoral employment variables and a dummy for regions with shrinking sectoral employment, interaction terms between the sectoral employment variables and a dummy for urbanized regions, employment density values of regions (VAN OORT, 2004), and population density values of regions. Unfortunately, the regressions with additional regional characteristics yield no useful outcomes. Most coefficients of the additional variables are insignificant at the 5% level, or lead to insignificant sectoral employment coefficients. Concluding, the inclusion of additional variables to test for land market heterogeneity in the regressions presented in Tables 1 and 2 indicates that this heterogeneity does probably not explain the poor fit of the relationship between land use and employment at the observation levels tested.

### 5.4. Time lags in the relation between employment and land use

Another explanation for the poor relationship between employment and land use on industrial sites may derive from the fact that they do not change simultaneously. A relocation may generate a growth jump or the growth jump may cause the relocation (VAN AALST et al., 1985). In this regard, especially the inclusion of employment lags seems relevant, as findings by VAN OORT et al. (2007, p.68) show that employment growth of relocated firms two years before moving more than doubles employment growth of firms not moving. To analyse possible time-delay effects in employment, the original regression models from Tables 1 and 2 were estimated with one and two-year time-lags of the sectoral employment variables. The findings do not provide evidence suggesting the existence of such time-delay effects. The coefficients of these time-lag terms are hardly significant and do not improve the original model quality. This is in line with findings by KNOBEN and TRAA (2008), who study the relationship at the macro-level and find no evidence of the presence of a time lag effects.

## 6. Conclusions, policy implications and research agenda

The findings of this study are policy relevant, as popular long-term forecasting models for planning policy are traditionally using employment forecasts to predict land use on industrial sites. Given this long tradition, it is rather surprising that the relationship between employment and land use has never been empirically assessed. Given new time-series data on sectoral employment development that is merged on the industrial site level with land use data for The Netherlands, for the first time, this analysis is made possible.

The relationship between employment and land use is studied on three different observation levels and parameters are estimated for the forty NUTS-3 regions as well as the three comprehensive regions Randstad, Intermediary Zone and Periphery. The findings of this paper, based on models with employment as only predictor, do suggest that a positive relationship between employment and land use exists at the levels of municipalities and individual industrial sites, but that this relationship is logarithmic and not linear. However, the findings also demonstrate that the relation between land use and employment is insufficiently robust to consider employment a reliable indicator to forecast the long term future demand for industrial sites. Once controlling for unobserved heterogeneity regarding location and site characteristics and local policy effects by means of fixed-effects estimation, outcomes at both spatial scale levels show that the employment coefficients become much smaller as compared to those in the OLS model. This indicates that the OLS coefficients are greatly biased upwards. Also, once controlling for unobserved characteristics, the employment variables actually explain a small share of the variation in spatial demand. For the purpose of using regression coefficients as input in long-term forecasting models, it therefore seems essential to identify these unknown factors to use them in the planning of industrial sites. Experimentation with time lag effects and with other regionalization - to better account for geographic land market differences - did not change this conclusion.

This study finds no evidence supporting linearity in the above relationship when using models with employment as only predictor. Future research could make a relevant contribution by investigating the source of the large bias in the coefficients and by adding relevant explanatory variables to the regressions that help diminish it.

A final remark concludes this paper. Like all forecasting methods based on historical evidence, the employment based method implicitly assumes that historical causal structures persist in the future. In the case of The Netherlands this assumption may no longer hold. After a post-war period of nearly uninterrupted growth, the next decades may show an unprecedented reduction of population and employment in some Dutch regions (PBL, 2011). This may also lead to structural changes in labour and land markets. Employers may adapt their location choice and land use behaviour to the new market circumstances, with unclear effects on the long term demand for industrial sites. For this reason, understanding the land use and land markets in foreign regions that have already encountered a similar population decline, may be more important for the prediction of future demand for industrial sites than understanding the historical relationship between employment and land use in The Netherlands itself.


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## Appendix A

The following standard set of statistical evaluation criteria is used to assess the quality of the regression models (based on KENNEDY, 2003; GREENE, 2008):

1. The model error term has a symmetric probability distribution function with expected value of zero;
2. The standard deviation of the model error term is constant regardless of the values of the independent variables;
3. The value of the model error term associated with any particular value of the dependent variable is autonomous of the error term associated with any other value of the independent variable (criteria 1-3 are assessed by means of residual plots);
4. There is no multicollinearity among the independent variables (the variance inflation factor is lower than 10);
5. All coefficients are statistically significant at the 5% level (a model is not rejected on the basis of this criterion only);
6. The prediction power of the model (R-squared) is at least 10%.

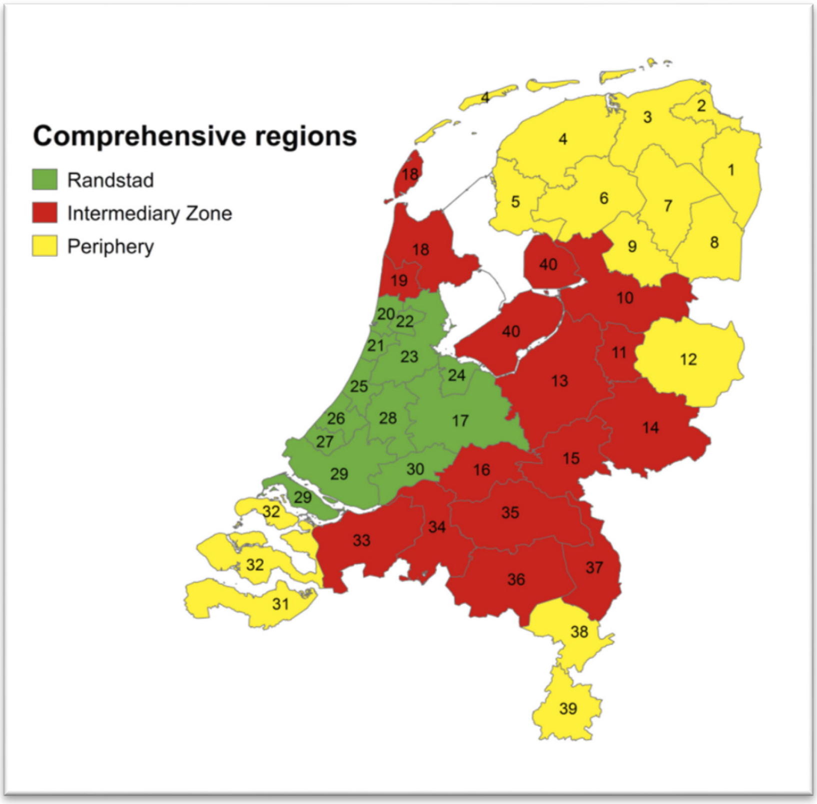
The table shows how the regression models perform. The codes in the table indicate which criteria are violated. Models that meet all criteria are marked.

Tabel A1. Quality of regression models with sectoral employment, OLS specification with intercept

| spatial level of data | parameter estimated per | type of model | number of employment sectors as independent variables | | | |
|---|---|---|---|---|---|---|
| | | | 5 sectors | 4 sectors | 3 sectors | 2 sectors |
| NUTS-3 region | NUTS-3 region | linear | 12345 | 12345 | 12345 | 12345 |
| | | logarithmic | 12345 | 12345 | 12345 | 12345 |
| | | first-differences | 1235 | 1235 | 1235 | 1235 |
| | Randstad, Intermediary Zone, Periphery | linear | 12345 | 12345 | 12345 | 12345 |
| | | logarithmic | 12345 | 12345 | 12345 | 12345 |
| | | first-differences | 1235 | 1235 | 1235 | 1235 |
| Municipality | NUTS-3 region | linear | 12345 | 12345 | 12345 | 1235 |
| | | logarithmic | 12345 | 12345 | 12345 | 1235 |
| | | first-differences | 1235 | 1235 | 1235 | 1235 |
| | Randstad, Intermediary Zone, Periphery | linear | 12345 | 12345 | 1235 | 1235 |
| | | logarithmic | 12345 | 12345 | 235 | |
| | | first-differences | 12356 | 12356 | 12356 | 12356 |
| Industrial site | NUTS-3 region | linear | 1235 | 1235 | 1235 | 1235 |
| | | logarithmic | 1235 | 1235 | 1235 | 235 |
| | | first-differences | 12356 | 12356 | 12356 | 12356 |
| | Randstad, Intermediary Zone, Periphery | linear | 235 | 235 | 235 | 23 |
| | | logarithmic | | | | |
| | | first-differences | 12356 | 12356 | 12356 | 12356 |

Note: All regression outcomes are corrected for heteroscedasticity and clustering of observations at the level of industrial sites, municipalities, NUTS-3 regions depending on the spatial level of data.

Map A1. Map of the three comprehensive regions and the forty NUTS-3 level areas used in this study




Notes: The grouping of the three comprehensive regions is based on employment density values of 2008, which measure the concentration of employment in an area. The indicator was developed by Van Oort (2004). Source: LISA 2008, own calculations.

The forty NUTS-3 level areas are as follows: 1Oost-Groningen, 2 Delfzijl en omgeving, 3 Overig Groningen, 4 Noord-Friesland, 5 Zuidwest-Friesland, 6 Zuidoost-Friesland, 7 Noord-Drenthe, 8 Zuidoost-Drenthe, 9 Zuidwest-Drenthe, 10 Noord-Overijssel, 11 Zuidwest-Overijssel, 12 Twente, 13 Veluwe, 14 Achterhoek, 15 Arnhem/Nijmegen, 16 Zuidwest-Gelderland, 17 Utrecht, 18 Kop van Noord-Holland, 19 Alkmaar en omgeving, 20 IJmond, 21 Agglomeratie Haarlem, 22 Zaanstreek, 23 Groot-Amsterdam, 24 Het Gooi en Vechtstreek, 25 Agglomeratie Leiden en Bollenstreek, 26 Agglomeratie 's-Gravenhage, 27 Delft en Westland, 28 Oost-Zuid-Holland, 29 Groot-Rijnmond, 30 Zuidoost-Zuid-Holland. 31 Zeeuwsch-Vlaanderen, 32 Overig Zeeland, 33 West-Noord-Brabant, 34 Midden-Noord-Brabant, 35 Noordoost-Noord-Brabant, 36 Zuidoost-Noord-Brabant, 37 Noord-Limburg, 38 Midden-Limburg, 39 Zuid-Limburg, 40 Flevoland.