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Innovation in SMEs: An Empirical Investigation of the Input-Througput-Output-Performance Model

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Abstract
Small and medium-sized firms have gained increasing attention in the innovation literature. Exactly how innovation occurs in these firms is still rather unknown. This study was conducted on a large number (N=1303) of small manufacturing and service firms in the Netherlands. In these organizations a conversion model that consisted of input, throughput, output and performance indicators was tested. The results clearly support the input-throughput-output model. The relation between output and financial performance was not supported. However, when extending the basic model with contextual variables, type of industry and firm size, we did find some support for the relationship between innovation output and financial performance in larger firms. Finally, we did not find substantial differences in the input-throughput-output model between manufacturing firms and service firms.

Keywords: Innovation, small and medium-sized firms, input-throughput-output-performance model, manufacturing vs. services

Innovation in SMEs: An Empirical Investigation of the Input-Throughput-Output-Performance Model

1. Introduction

Developing new products is a crucial, but risky undertaking (Calantone et al., 1995; Simon et al., 2002). Firms need to innovate, at least on occasion, to gain competitive advantage. The rate at which they innovate has been linked to performance (Soni et al., 1993; Geroski, 1995; Banbury and Mitchell, 1995). Firms, therefore, spend a great deal of time and energy developing the capability to innovate and one of the main ways they innovate is new product development.

Although the research on innovation tends to focus primarily on large firms, innovation is at least as important for small firms. The strategic position of a small company depends on its ability to offer high-quality products and services that fit the needs of the market. Therefore, a permanent flow of product innovations is significantly important to small firms (Simon et al., 2000).

In this paper we focus on the innovative activities of small firms. Innovation in small firms differs considerably from innovation in large firms (Rothwell, 1991; Rothwell and Dodgson, 1994; Hadjimanolis, 2000). Small firms react more quickly to changing market requirements than large firms. Their size makes them more internally flexible because they are free of the bureaucratic inertial forces that plague larger firms. Behavioural advantages, such as internal flexibility and responsiveness, are the main keys to success for small firms that engage in innovative activities. Large firms generally enjoy resource advantages (Rothwell & Dodgson, 1994), but suffer from being notoriously slow to react to changes in their environment.

In this paper, while acknowledging that all sources of innovation are important to the success of firms, we exclusively concentrate on product innovation. Product innovation can be one of the sources of competitive advantage, helping firms to adapt to changing environments (Eisenhardt & Tabrizi, 1995). Besides, in small firms it can be expected that process innovations offer less added value than product innovations (Acs & Audretsch, 1990).

For many small firms, new product development tends to be a haphazard process: it simply 'happens'. In these small firms the innovation process is mostly *ad hoc*; not the output of a formal, structured process. This applies to service and low-tech manufacturing firms in particular (see, for instance, Acs and Audretsch, 1990). In this context, Sundbo (1997) discusses two systems of organizing innovation activities. In the expert system a firm establishes special resources just for the purpose of innovation. This system usually organizes innovation in separate R&D departments. It is often found in high-tech manufacturing industries and large financial ser-vice firms. The other system is the so-called empowerment system. It implies that many people in a firm are responsible for innovation, and at the same time these employees are not necessarily innovation experts. This system is often found in SMEs. Because innovation in SMEs is rather unstructured, many models for new product development (such as the influential activity-stage model presented by Booz et al., 1982) do not seem to provide an adequate description of the innovation process (see for instance Kelly and Storey, 2000; Sundbo, 1997). Given the relative paucity of knowledge about innovation in SMEs and the suggestion in the literature that complex process models of innovation do not readily apply to SMEs, we turn to a well established model of innovation, commonly referred to the conversion model, to help develop a basic understanding about how SMEs innovate and how their innovation is related to performance.

Employing what has been termed the conversion model (cf. Twiss, 1980; Saren, 1984; Soni et al., 1993; Wakasugi & Koyata, 1997; Patterson, 1998), in this paper we examine the relationships between innovation input, throughput and output in small firms. Additionally, we investigate if having innovative outputs is related to higher firm performance. The conversion model proposes that financial resources, human knowledge and labor is transformed into new or improved products, services, work processes, etc. In this paper we concentrate on the innovation activities that managers choose instead of the resource levels they possess as we try to further our understanding of the organization attributes of successful innovation in small firms. The ultimate innovative results (output) also depend on the degree of innovation in the internal organization (throughput), in which the innovative inputs are transformed into innovative outputs. The transformation process itself is not described in detail: it is considered as a black box so there is little focus on the actual innovation processes themselves. We do, however, open the black box a bit by considering two contextual variables that are expected to influence the input-throughput-output-performance relationships: type of industry (our sample consists of both manufacturing and service firms) and size of the firm.

In the following section we argue that investing more in innovative inputs is associated with larger investments in innovative throughput and, in turn, investing more in innovative throughput lead to more innovative outputs. In the third section we elaborate on the variables in our model and develop hypotheses. The fourth section discusses our method and data analysis. Subsequently the results of our empirical study are presented. The final part of the paper includes a brief discussion and conclusions. Furthermore, we point at the limitations of our paper and indicate some promising areas for future research.

2. Model and hypotheses

A large body of literature in economics has focused on the relationship between innovation inputs, throughputs and outputs (see for instance Kleinknecht, 1993, 1996; Geroski, 1995; Brouwer & Kleinknecht, 1999; Sterlachini, 1999). These traditional conversion models have proven to be valuable research instruments helping to increase our understanding of the innovation cycle. Although these models were predominantly product oriented in the beginning, useful adjustments were made to include market research and thus customer needs (Twiss, 1980). The central message of these models is still valuable for managers today: firms that invest more in innovative inputs and throughputs are able to achieve higher levels of innovative output compared to firms that refrain from these investments. This means that firms can actively influence their innovative output by investing in inputs and throughputs. Although, the effect of small firms in innovation has been studied (e.g. Brouwer & Kleinknecht, 1996), the conversion model has not been tested empirically for small firms.

Figure 1 shows the model that was tested. Central to this model are the innovation inputs, throughput, outputs, and the financial performance of small firms. Two contextual variables, type of industry and firm size, intervene in these relationships. We will next discuss the model and develop hypotheses.

-- INSERT FIGURE 1 ABOUT HERE --

Central Constructs

The four central constructs in our model are discussed below. The conversion model of innovation suggests that more innovation inputs are associated with more innovation throughput, which in turn produces more innovation outputs. The model also suggests that innovation outputs are associated with firm performance. We discuss inputs, throughput, outputs and performance in turn.

Before discussing each of the central constructs it is important to note that in this study we investigate both services and manufacturing companies. However, there is a potential risk in comparing these two distinct classes of industry (Hoffman et al., 1998). Previous studies that included both manufacturing and service companies have not fully realized the impact of the traditional innovation measures, such as R&D expenditures and patents, on their results. Many of these studies did not explicitly distinguish between manufacturing and services, whereas their development and dynamics are very different. This often led to the use of indicators that were used to study both industries. Yet, these indicators were developed on the basis of the manufacturing based literature. Comparing service firms with manufacturing companies requires indicators that can be measured to a similar extent for both these firms. Sterlacchini (1999) put forward a similar argument demonstrating that traditional R&D indicators are not adequate for studying innovation in non-R&D intensive industries and small firms. So with care to consider the impact of our model on both services and manufacturing firms simultaneously we proceed with our model.

Innovation Input The innovation literature provides us with several indicators of innovation intensity. Traditionally, and perhaps still, the most popular input indicator is R&D effort, which consists of R&D expenditures (Cohen & Levin, 1989; Acs & Audretsch, 1990; Hitt et al., 1991; Kleinknecht, 1993, 1996, 2000; Wakasugi & Koyata, 1997; Hadjimanolis, 2000; Acs et al., 2002; Romijn & Albaladejo, 2002) and the number of employees dedicated to R&D (Scherer, 1965; Schmookler, 1966; Felder et al., 1996; Hadjimanolis, 2000). However, there are several drawbacks to using these indicators in an empirical study covering both manufacturing and services. Innovation also requires non-R&D activities, such as trial production, market research, commercial activities and the acquisition of patents and licenses (Brouwer, 1997). These are often not taken into account when estimating R&D expenditures. At first glance, the number of employees dedicated to R&D seems a better measure for services sectors. However, the fact that different systems to organize innovation are present has a devastating effect on the suitability of this indicator. In more ‘industrialized’ firms, such as financial services, the number of people involved in the development process is but a mere fraction of the employees involved in innovative activities in manufacturing. In others types of firms, innovation is a collaborative effort that needs the involvement of multiple employees (cf. Clark & Fujimoto, 1991; Cooper & Kleinschmidt, 1995; Tidd et al., 1997; Tushman & O’Reilly III, 1997; Cooper, 1999). However, the actual involvement of employees in the development process does not include the quality of the employment input. The level of skills of employees is often seen as a pre-condition for high innovative performance (Warner, 1994; Wood, 1997; Tidd et al., 1997). However, small firms will not be able to match wages, career development opportunities or job security present in large firms, which means that they are disadvantaged in the market for highly skilled employees (Freel, 2000b). Additional training is a means to increase the skill level of the employees in small firms.

Innovation Throughput Throughput indicators refer to the transformation process in an innovation trajectory. The following throughput indicators are frequently used in innovation studies: co-operation, continuous renewal efforts (and the explicit documentation of these efforts in company strategy) and the use of external information (Gupta & Wilemon, 1990; Rothwell, 1991; Kleinknecht & Reijnen, 1991; Davenport, 1993; Dodgson, 1994; Tidd et al., 1997; Freel, 2000b; Hadjimanolis, 2000; Bougrain & Haudeville, 2002; Tether, 2002).

Many firms have developed their new products without forming formal co-operative arrangements with external parties (Tether, 2002). However, the increasing complexity of new technologies creates a need for further co-operation between firms (Bougrain & Haudeville, 2002; Hanna & Walsh, 2002; Tether, 2002). A variety of reasons for the growth in the number of innovation alliances can be found in the literature, but the dominant reason remains the lack of resources (Dodgson, 1994; Tether, 2002; Hanna & Walsh, 2002). This is particularly true for small firms. Due to the scarcity of material resources, small firms collaborate with other parties (Kleinknecht & Reijnen, 1991), which increases their innovation success rates (Bougrain & Haudeville, 2002).

Internal renewal activities have also been referred to as throughput indicators (Den Hertog & Brouwer, 2000). These activities are a means to accelerate the development of new products (Gupta & Wilemon, 1990). Firms undergoing a major restructuring often revise their core business processes, such as manufacturing, customer acquisition and product development (Davenport, 1993). The reengineering of these processes can have a positive impact on the transformation process needed to deliver new products. These renewal activities are more easily adopted in small firms than in large firms. Changing small firms is often easier due to the scale of the organization (Davenport, 1993). It is important, however, to be aware of the need for continuous renewal efforts (cf. Imai, 1986). This awareness can be found in the use of company documents explicitly stating the companies' search for improvement. Continuous renewal efforts that are part of the written strategy (meaning that they have been documented) of the firm are likely to lead to more innovation outputs (Hadjimanolis, 2000). A clear vision and strategy concerning the role that innovation plays in business development are widely regarded as being beneficial and provide direction for the activities that an organization will develop in the future (e.g. Drew, 1995; Ennew & Wright, 1990; Hodgson, 1986; Rothwell, 1992; Thwaites, 1992). A focus on continuous renewal may prove helpful in aligning innovative efforts (Amabile, 1988; King & Anderson, 2002). Continuous attention on renewal stimulates workers and serves as a beacon for action. Other studies have shown that leaders expressing a clear vision were more successful in R&D and were able to increase innovative outputs (Hounsell, 1992; Shin, 1997).

A third throughput indicator, the use of external information, has frequently been related to successful innovations (Rothwell, 1977, 1991). Empirical evidence also demonstrates that small firms that are aware of this and use more external information perform significantly better (Lybaert, 1998). These firms have an above average scientific interest and are characterized by active gathering of information and a high frequency of contacts with suppliers. According to Cooper and Kleinschmidt (1995), the extent to which a company is knowledgeable of its environment is a critical success factor in the success of product innovations. Nagel (1992) and Sneep (1994) claim that an external network (consisting of relations with universities, competitors and advisers) increases the innovative ability of a firm. However, external information does not only come from research institutes or competitors, it also comes from customers. The innovative success of a company is strongly dependent on meeting customer needs (Twiss, 1992). Firms that are able to understand customer needs by conducting market research are likely to be more successful in innovative activities (Cooper, 1979, 1984; Davison et al., 1989; De Brentani, 1991, 2001; Edgett, 1994; Edgett & Parkinson, 1994).

Innovation Output Although various indicators have been described in the literature, three indicators for innovative output have received the most attention: number of patents, new product announcements, and the number and degree of newness of new products (Griliches, 1984; Hitt et al., 1991; Brouwer & Kleinknecht, 1999; Kleinknecht, 1996, 2002; Wakasugi & Koyata, 1997; Ahuja & Katila, 2001; Acs et al., 2002; Garcia & Calantone, 2002; Romijn & Albaladejo, 2002). The first output indicator is the number of patents (Griliches, 1984; Acs & Audretsch, 1990; Hitt et al., 1991; Brouwer & Kleinknecht, 1999; Ahuja & Katila, 2001; Acs et al., 2002). Patent application is an important means for a firm to protect its own knowledge (Wakasugi & Koyota, 1997). A second well-known output indicator refers to new product/service announcements from trade and technical journals (Acs and Audretsch, 1993; Wakasugi & Koyata, 1997; Brouwer & Kleinknecht, 1999; Kleinknecht, 2000). The announcements are typically based on trade and technical journals and are used in a series of studies on the relationship of firm size, market structure and innovation (Acs and Audretsch, 1993). From empirical tests it may be concluded that the innovation output variable new product/service announcements ads insights to innovation research (Brouwer & Kleinknecht, 1999). The third set of output indicators relate to new products. New products are the most obvious indicator of innovation output, since this is the goal of every product innovation process (Wakasugi & Koyata, 1997; Patterson, 1998; Romijn & Albaladejo, 2002). An important aspect in this indicator is the degree of newness of the new product. Two levels in newness have been identified: macro and micro (Garcia & Calantone, 2002). The macro-level refers to products that are new to the world, market or industry. On a micro-level, new products are new to the firm or the customer.

Financial performance Whether firms that invest more in innovation inputs and throughputs actually outperform competitors that invest less remains uncertain. In the end, innovative activities must result in better firm performance compared to companies that do not innovate. Developing new incremental or radical products should lead to better financial performance (Banbury & Mitchell, 1995; Calantone et al., 1995). Yet, the empirical support for this notion is mixed. Firms engaging in sustained innovation activities have been found to be more profitable and grow faster than firms who refrain from these activities (Geroski & Machin, 1992; Soni et al., 1993; Freel, 2000a). In contrast, Hoffman et al. (1998) argued that although innovation is widespread, it is not related to increased firm performance.

On the basis of the previous arguments, we will investigate if the conversion model – extended with performance measures – is empirically supported for small firms. We hypothesize the following

H1: Small firms investing in more innovation input activities also invest in more innovation throughput activities.

H2: Small firms investing in more innovation throughput activities produce more innovation outcomes.

H3: The financial performance of small firms is related to the rate of innovation output.

Contextual variables

We consider two attributes of context in our model: type of industry and firm size. These attributes have been identified in the innovation literature as important factors that affect innovation. We believe that the impact of these attributes is present in all the relationships between the central constructs in the model.

Type of industry The innovation literature suggests that the innovative activities of service and manufacturing firms are quite different. Service firms tend to have lower innovation outputs than manufacturing firms (Kleinknecht, 2000). Kleinknecht (2000), using Pavitt's (1984) taxonomy of sectors, found that high technological opportunity sectors (science-based, scale-intensive, and specialized suppliers) are more successful innovators than low technological opportunity sectors (supplier-dominated manufacturers). Service firms had an even lower degree of innovation outputs than the low technological sectors. On the basis of the previous arguments, we expect this to be the result of an overall lower degree of input and throughput indicators. However, we do not expect that the relationships between the input, throughput and output variables differ in relative terms. Therefore, we hypothesize the following:

H4a: The level of input, throughput and output variables is higher in manufacturing firms when compared with service firms.

H4b: The relationships between input, throughput and output variables are similar across industries.

Firm size A great deal of research has addressed the relationship between firm size and innovation. Schumpeter (1942) argued that large firms are more innovative than small firms. Economies of scale are an important determinant for the innovativeness of large firms (Acs & Audretsch, 1990). Large firms have more opportunities to develop and introduce radical new products, especially due to their financial and technical capabilities (Chandy & Tellis, 2000). However, the empirical literature provides mixed results. It has been argued that small firms are better able to adapt rapidly to market changes. Large firms tend to be more bureaucratic, which renders them resistant to change (Acs & Audretsch, 1990; Soni et al., 1993; Rothwell & Dodgson, 1994; Dougherty & Heller, 1994). When we merely look at the input, throughput and output attributes of innovation we expect some major differences between large and small firms. For instance, larger firms are able to attract more qualified personnel and have more resources available to invest in additional training programmes (Hoffman et al., 1998). Larger firms also tend to formalize their renewal activities, which results in more throughput activities (Hoffman et al., 1998). In general, large firms invest more in innovation inputs and throughputs than small firms (Wakasugi & Koyata, 1997; Hadjimanolis, 2000). Thus, we expect the following:

H5a: The relationship between innovation inputs and innovation throughput is more positive for larger firms.

H5b: The relationship between innovation throughput and innovation output is stronger for larger firms.

H5c: The relationship between innovation output and financial performance is more positive for larger firms.

4. Method

Sample

The sample population we consider consists of all small companies in the Netherlands. When defining a small company, one often takes the number of employees of a company as a guideline. In the Netherlands, a small company is defined as a company with no more than 100 employees. This is a major difference with many other countries, where a small company is defined as a company with a maximum of 250 employees and/or on the basis of the total turnover (sales). We have collected our data by means of a sample of 2,002 small firms. This initial sample was drawn from a database that is managed by the Dutch Chambers of Commerce. This database contains all small firms in the Netherlands. Various strata were identified to ensure coverage over sector and size classes (see below).

The data were collected in March 2002 by means of computer assisted telephone interviewing (CATI). The Dutch economic research firm EIM provided assistance. This firm's major objective is to collect information about the knowledge, attitude and opinion of entrepreneurs about various (government) policy-related issues. The person who is in charge of daily business completed the interview. Thus, all respondents were managers responsible for day-to-day business processes – usually the entrepreneur, and otherwise a general manager. We tried to contact a respondent at least five times before he/she was marked as a non-respondent.

Response

Eventually, 1.303 persons have completed our questionnaire, a response rate of 65%. Another 173 persons could not be contacted (busy, answering machines, no answer at all) and 526 persons refused to co-operate. Our sample covers all sectors of the Dutch economy. It can be defined by sector (manufacturing, construction, trade & repairs, lodging & meals, transport, business services, financial services, or other services) and size class (0-9 employees, 10-49 employees, or 50-99 employees). For sector and size class, strata were identified to ensure good coverage. In the appendix table A1 we have shown how our sample is distributed over these contextual variables.

Non-response bias was assessed by running chi-square tests, which compared our respondents with non-respondents. These tests revealed significant differences for sector (p=.000). This could easily be caused by a relatively large number of categories (eight) in combination with a large sample size (Churchill, 1999). Further analysis revealed that - compared to the other sectors - manufacturing, construction, trade & repairs and transport firms were slightly over-represented. The chi-square test on size class revealed no significant difference with non-respondents ($p = .215$), suggesting that non-response bias is unlikely to be present here. Finally, we have looked at the firms' ownership structure by comparing respondents and non-respondents' distribution over three types of firms: entrepreneurs, partnerships and corporations. Again, we found no significant difference with non-respondents ($p = .862$).

Measures

In order to make a correct comparison between various sectors, measures for innovation should be universally applicable. For this reason we have excluded measures that are sector specific, such as the expenditures on R&D and the possession of patents. Innovative inputs, throughputs and outputs were measured with a number of simple dichotomous questions. Our motivation to do so was twofold (see also Churchill, 1999). First, because respondents are asked for actual facts, it decreases the risk of common-method variance. Second, it makes the questionnaire easier to complete resulting in higher response rates. Telephone surveys are recognized to be less suitable for questions with multiple answers (Churchill, 1999). All measures were developed using insights from the literature (as discussed in theoretical background section and below). The full questionnaire is presented in the appendix (table A2). Confirmatory factor analysis was used to verify that the theoretically derived measures were represented in the data.

Input Innovation inputs are often measured by the total expenditures on R&D as a percentage of a firm's total sales (Kleinknecht, 2000). The main advantage of this indicator is that it is relatively easy to measure, especially for large firms. The extensive use of this indicator also improves the comparability of the different studies. However, several weaknesses of this indicator have been identified (see Cohen & Levin, 1989; Kleinknecht, 2000; Acs et al., 2002). First, R&D related inputs make for a minority of innovation expenditures, varying from 15-50 percent depending on the sector being studied (Felder et al., 1996). Second, R&D data tend to underestimate innovations in services. Most service firms do not have an R&D department or a separate R&D budget (Sundbo, 1997), which makes it difficult to ascertain the total amount of expenditures on innovative activities. Comparing R&D expenditures across sectors or industries does therefore not seem to be a very fruitful exercise. Finally, the small scale and, often, informal R&D activities in smaller companies are often underestimated and therefore excluded by this indicator (Santarelli & Sterlacchini, 1990; Kleinknecht & Reijnen, 1991; Sterlacchini, 1999; Kleinknecht 2000). Smaller firms, by nature, are expected to have a lower degree of R&D expenditures than larger firms (Felder et al., 1996). This is partly due to the fact that service firms use a different system to organize innovation activities (Sundbo, 1997). Even within a study of small firms, there can be a considerable range in size, which will again lead to difficulties in comparing the R&D expenditures for these firms.

Another traditional and easy to measure input indicator is the number of employees dedicated to R&D (Felder et al., 1996; Hadjimanolis, 2000). This indicator is better suitable for service firms. However, it also has several weaknesses. For instance, the total number of employees dedicated to R&D is probably higher in large firms than in small firms. This would call for a relative number of employees dedicated to R&D. But this only solves the problem of this indicator to a limited extent. The distinction between services and manufacturing requires further adaptation of this indicator. Again, the fact that different systems to organize innovation are present has a devastating effect on the suitability of this indicator. Therefore, we choose to examine if employees in small firms are actually involved in the development process. The main advantage of this indicator is that it will be comparable across sectors and industries. Yet, we also need to take into account the quality of the employment input. Additional training is a means to increase the skill level of the employees in small firms. Therefore our second input indicator was based on additional education and training programmes used to enhance the skills of employees.

Thus, innovative input was measured with two items: co-workers being involved in renewal efforts in their daily work (I1), and co-workers attending training funded by the company in the past year (I2). These two items were added to create the input measure used in our analysis. Neither of these measures was correlated more than 0.5 with the throughput measure.

Throughput Throughput indicators relate to organizational means to improve the transformation process, which subsequently leads to increased numbers of innovative outputs. Inter-firm cooperation was identified as an important determinant of increased outputs (Bougrain & Haudeville, 2002; Tether, 2002). Although this indicator seems to be suitable for both small and large firms, it is doubtful that this indicator can be measured in service firms. However, empirical evidence with respect to service firm co-operation is lacking. At first glance most services do not seem to require complex technologies. However, there are examples of new services using highly complex technologies that were developed in close co-operation. In the Netherlands, for instance, four banks jointly developed an electronic wallet (Chipknip). Therefore we decided to include this throughput indicator. It will provide us with empirical evidence on the usefulness of this indicator in service firms.

Next, we tried to obtain information on continuous renewal efforts that are part of the written strategy (meaning that they have been documented). Improved or renewed work processes are likely to lead to more innovation outputs (Hadjimanolis, 2000). We were interested in this indicator since it allowed us to measure whether or not enduring renewal is part of the business strategy. Furthermore, we measured whether or not enduring renewal activities were formally documented.

Firms that use external information in their innovative efforts are more likely to succeed (Rothwell, 1991). We measured this indicator in two distinct ways. Firstly, we tried to ascertain whether small firms use external networks to exchange information. Measuring the use of universities, suppliers and competitors in information exchange provides more insight in the innovative ability of firms (Nagel, 1992; Sneep, 1994). Secondly, we wanted to know whether small firms engaged in collecting customer information. Firms were asked whether they performed market research themselves or if they outsourced this activity to another firm.

Thus, innovative throughputs were measured with six items: renewal and/or improving internal work processes in the past three years (P1), enduring renewal is a part of the business strategy (P2), enduring renewal is written down (for instance in the business plan) (P3), use of an external network to exchange information (for instance with universities, suppliers, competitors, etc.) (P4), co-operation with other companies to develop innovative projects (P5), and performing or outsourcing market research (P6). The item of a documented continuous renewal effort was conditional. Respondents only judged this item if they indicated that enduring renewal was part of their business strategy. If not, their answer was supposed to be negative (coded as 0). The six items were summed to form the throughput measure. The measure exhibits sufficient validity (cronbach's coefficient alpha= .77).

Output Output indicators have been measured in numerous studies (Brouwer, 1997; Brouwer & Kleinknecht, 1999; Kleinknecht, 1996, 2000; Acs et al., 2002; Romijn & Albaladejo, 2002). Patents are often used as intermediate output measures of innovation (Brouwer, 1997). The advantages are first the abundance of publicly available information, with, second, the minor disturbances in these series. The relative importance of patents can be assessed by using citation analysis. In a survey, the number of patents can be easily asked. However, there are several problems with this indicator. Firstly, patents are strategically used to prevent competitors from appropriating the innovation (Kleinknecht, 2000). Secondly, many (service) innovations cannot be patented or are just not patented, especially in small firms (Kleinknecht, 2000; Acs et al., 2002; Romijn & Albaladejo, 2002). Thirdly, patenting or not will also depend on how high imitation costs are relative to innovation. Thus, when we use patents as output indicator we tend to underestimate the innovative efforts in service firms and in small firms in general. Therefore we did not include this measure in our study.

New product/service announcements are a relatively ‘new’ indicator (Brouwer, 1997). Kleinknecht and Bain (1993) and Kleinknecht (2000) ascribe several advantages to this indicator. Firstly, it is a direct measure of the innovation output. Secondly, it is relatively cheap to collect this information, bypassing any non-response problem and any privacy problems. Thirdly, it is possible to split these data by type of innovation (differentiation, imitation, etc.), degree of complexity, etc. Fourthly, data from small firms can also be covered easily. Fifthly, a broad coverage of sectors (including services) and inter-sectoral flows can easily be realized. Despite these advantages there are still some problems with this indicator (Kleinknecht & Bain, 1993; Kleinknecht, 2000). The first disadvantage with this indicator is the troublesome inter-country and inter-industry comparison. The number of (adequate) journals covered determines the number of counted innovations. The comparison via ratios remains possible, but standard statistical procedures (e.g. sample and raising factors) are not applicable. Furthermore, the process innovations probably remain under-reported in such technical and trade journals. Finally, not all new products are announced in trade and technical journals. Again, service firms in particular and small firms in general are less likely to announce their new products in these journals (Brouwer & Kleinknecht, 1996). Therefore, we decided not to include this indicator.

The most direct measure of innovation output is the new product. We believe that this indicator is the most useful one for our study in small manufacturing and service firms. Service firms are perfectly capable of indicating whether they have developed new products. Furthermore, the distinction between micro or macro level innovations is suitable for both services and manufacturing.

Thus, innovative output was measured with three items: having launched products and/or services new for the company in the past three years (O1), new for the sector (O2), and new for the Netherlands (O3). The latter two items were conditional on the first: respondent were only asked to indicate newness to the sector and the Netherlands if they had product innovations new to their own firm. If not, their answers were assumed to be negative.

We are interested in the extent to which the input and throughput choices influence the level of innovative output so we added the values for each of the three output items to create our output measure. We suggest that products that are new to the sector are more innovative than those that are new to the company and those that are new to the country reflect even more radical innovation. We also check our results by substituting the first output measure (having launched products and/or services new for the company in the past three years) in our analyses and found little difference in the results.

Performance Performance is measured as return on sales. Returns measures are a common measure of performance in the management literature (Hitt, et al 1997). They are uncommonly employed in the research on small and medium sized firms because the financial performance of these firms is not publicly available. Our research presents a unique window on the performance impacts of innovation in these firms. Respondents were asked what their turnover (sales) and profits were for both 2000 and 2001. We divided the profits by sales to determine the return on sales (ROS). We have responses on these items from 651 of the 1303 firms. The performance measure was self-reported giving us some concerns on the validity of the responses at the upper and lower ranges. After we trimmed the data, removing the top 2.5% and bottom 2.5% we found that the ROS measure had a mean and standard deviation that closely matches returns measures used in other research (Hitt, et al. 1997). The analyses that consider performance used the 618 observations that remained following the trimming.

Controls We employ a few control variables in our models. Industry dummies (manufacturing, construction, trade & repairs, lodging & meals, transport, business services, financial services, or other services) are included in most of the models (except the ones testing the differences between manufacturing and services) to control for mean differences across industries. We also include size (number of employees) as a control. It enables us to test the hypotheses 5A, 5B and 5C. Finally, we will control for ownership structure by including dummy variables for two of the three ownership forms (entrepreneurial, partnership, corporation).

5. Results

The correlation matrix and descriptive statistics for the variables used in the analysis are presented in table 1.

-- INSERT TABLE 1 ABOUT HERE --

In order to test the hypotheses, we estimated a series of OLS regression models. Table 2 presents the results of the regression models that test hypotheses 1-3. Hypothesis 1 states that firms using more innovation inputs will also use more innovation throughput techniques. We test this hypothesis by regressing input on throughput with controls for size, industry, and ownership structure. The results of this model are presented in model 1 of table 2. Hypothesis 1 is supported as the coefficient for input is statistically significant (t=22).

-- INSERT TABLE 2 ABOUT HERE --

Hypothesis 2, which suggests that firms that invest in more innovation throughput attributes will produce more innovation output is tested in model 2 (table 2). In the regression of throughput on output the coefficient for throughput is statistically significant (t=11). Thus, hypothesis 2 is confirmed. We also estimated another specification of this model employing a dichotomous measure of output: 1, if any new products had been introduced; else, 0. We then computed a logistic regression model, with this variable as the dependent measure, which produced very similar results to the model 2 in table 2. Hypothesis 3, suggesting that innovation output is related to firm performance is tested in model 3 and does not receive significant support. The coefficient for output is not significant (t=0.18).

In sum, the results show support for the first two stages of the input-throughput-output-performance model but not for the third link, which connects innovation output with firm performance.

We then turned our attention to investigating hypotheses 4a and 4b, which suggest that the input-throughput-performance model behaves differently for manufacturing firms than it does for service firms. Hypothesis 4a posits that there is a mean difference in input, throughput, and output between manufacturing and service firms. To test hypothesis 4a we computed the t-tests (table 3) for the difference of means. Although the average scores for input, throughput and output are slightly higher for manufacturing firms, we found that in each case there was no significant difference between manufacturing and service firms. Thus, hypothesis 4A is not confirmed.

-- INSERT TABLE 3 ABOUT HERE --

We test hypotheses hypothesis 4b (which is actually a set of three hypotheses) by comparing the regression models between manufacturing firms and service firms. These results are presented in table 4. Comparing the regression coefficients in the throughput=input model, the output=throughput model and the performance=output model shows that the regression parameters are remarkably similar across these models. The t-statistics are all not significant. Thus we also do not find support for hypothesis 4b.

-- INSERT TABLE 4 ABOUT HERE --

The final set of hypotheses suggests that size has an impact on the relationships between innovation practices and innovation outcomes. We have tested these hypotheses by estimating a series of OLS regression models including interaction effects with firm size (table 5). We find no significant impact of size on the relationship between input and throughput. The coefficient for the interaction term between size and input is insignificant (t=1) in model 1. We do find a significant coefficient (t=2.5) for the interaction term between size and throughput in model 2. This term adds significantly to the performance of the model with an F-statistic= 4.1. We find similar results for the interaction term between output and size in the regression model 3 with performance as the dependent variable. Again, the interaction term adds significantly to the base model (F= 5.92). With significance in two of the three interaction terms we find support for hypothesis 5b and 5c. This supports the notions that for larger SMEs the relationship between innovation throughputs and innovation outputs is higher than for small SMEs and the output for performance link is more positive for larger SMEs.

We also examined (results are available from the authors) the direct impact of inputs on outputs. Although the conversion model suggests a linear relationship of input-throughput-output we also estimated a model relating both input and throughput to output simultaneously. In this model the coefficient for input is positive but not significant. This suggests that any impact input levels may have on outputs is accomplished through the throughput level. Thus, our results confirm the notion that for small firms the input-throughput-output model is appropriate.

-- INSERT TABLE 5 ABOUT HERE --

6. Discussion and implications

Our investigation into the innovative practices of SMEs in the Netherlands produces a number of interesting results. First, we find significant support for the input-throughput-output model. Thus, the conversion model - delineating the innovation process as being rather unstructured - seems to provide an adequate description of innovation activities in small firms. Our results show that SMEs, which invest more in the inputs and throughputs of innovation, are the firms that more often produce innovations. Firms that invest in more innovation inputs also invest more in innovation throughputs and firms that invest more in innovation throughputs produce more innovation outputs. This result is fairly important. SMEs need to innovate in order to survive in the long run and our results show that the amount these firms invest in their innovation cycle is related to the level of innovation output they produce. The suggestion is that to some extent SMEs control their destiny. Those that develop the organizational capabilities to innovate are the ones that produce innovations and therefore should be the ones with the best long-term prospects.

Second, we found that firm size has a contingent impact on the innovation process. We found a significant effect on innovative output for the interaction term between firm size and innovative throughputs. This implies that larger SMEs will benefit more from investing in their development processes by which innovative inputs are transformed into outputs. This is not surprising, since streamlining innovative processes is generally recognized to be more profitable in larger firms (e.g. Tidd et al., 1997; Acs & Audretsch, 1990).

A third important result is that the output to performance relationship is contingent upon size. Thus, in a cross-sectional context the relationship between output and performance is only found through the moderating variable size. Given the clear importance of innovation to the long-term prospects of firms this result is a bit surprising. We expected to find a direct relationship between innovation outputs and performance but similar to prior research we find that this relationship is elusive. This curious result can be explained in several ways. We suggest that benefiting from innovation may require a certain level of organization. It is possible that small firms may not have enough available organizational capabilities to effectively commercialize their innovations. The organizational capability to commercialize innovations can be seen as a complementary asset (Teece, 1984) to the innovation and may only be present in larger SMEs. Another explanation may be that small SMEs are less motivated to develop new products to improve firm performance. They might strive to develop new products only when they are forced to do so by market developments, or for reasons of continuity. The conversion model does not include any motivational aspects of innovation. Finally, we should notice that we might be missing a significant relationship between output and performance due to longitudinal effects. One could think of the development of new products that affect return on sales only after a couple of years. Future research should provide answers to this (see below).

Our fourth important discovery is that we do not find any substantial differences in the input-throughput-output model between manufacturing firms and services firms. This result would be remarkable when one thinks of the distinction between large, high-tech manufacturing firms and (for instance) low-tech service firms. Given their very different nature of innovation we could expect to see some differences in the model. However, in many smaller firms the innovation activities are not organized in separate R&D departments, instead, innovation is the responsibility of many employees while no innovation specialists are present (Sundbo, 1997). Therefore, we are not surprised that the conversion model is empirically supported in both sectors. The relationships in the input-throughput-output model were quite similar between these two groups of firms. This result points out that among SMEs the ability to produce innovations is related to the investments made in a way that varies little across industry contexts.

7. Limitations and future research

We acknowledge a few limitations to our research. First, the large correlation between the input measure and the throughput measure leads us to question whether or not these two are truly distinct constructs. Beyond the mere mathematical similarity one could argue that throughput and input are both investments in the innovation development process, which would be the underlying construct. Undoubtedly, combining the two into a single measure would produce the same significant relationship between the innovation investments and innovation output and would not solve the problem finding a significant relationship between outputs and performance. Thus, given the similarity on the empirical side the important question that remains is does the theoretical development require that input and throughput are distinct ideas or not? This remains work for additional study.

Second, our measures of innovation may only capture a portion of the innovative activities of SMEs. New product introductions are certainly important to SMEs but relying solely on this measure may ignore other types of innovations that help SMEs remain competitive in the marketplace (such as new markets). This topic should be investigated in future research.

Third, our measures of performance may not be truly meaningful for smaller firms. For example, survival may be a measure that captures the realized goals of many smaller firms. Research that investigates how SMEs view performance would help solve this limitation. In fact, it may the reason that we find no relationship between innovative output and performance for the smallest SMEs.

Several directions for future research should be considered at this stage. First, our finding that the input-throughput-output-performance model is remarkably similar between manufacturing and services firms deserves a deeper investigation. It should include exploring the differences between firms with separate R&D departments and firms that organize the innovation process in a structured, informal manner. If we can investigate more closely how the process of innovation differs between these two sets of firms we can perhaps better understand how context influences the innovation process.

Second, the organization piece of the innovation output and performance linkage needs further investigation. Longitudinal research is needed to explore the exact relationship between output and performance, especially for the smallest SMEs. Besides, the cross-sectional result for the contingent effect of size needs more investigation. An understanding of which attributes of organization that are missing in smaller firms allow the relatively larger SMEs (still small firms) to profit from innovative outputs should be explored. Given the symbolic role of small firms as the drivers of innovation in the economy, it would be interesting to discover specifically which organizational impediments to commercialization of innovations present the largest hurdles to smaller firms.

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FIGURE 1

The Model Utilized to Examine Innovation in Small Firms

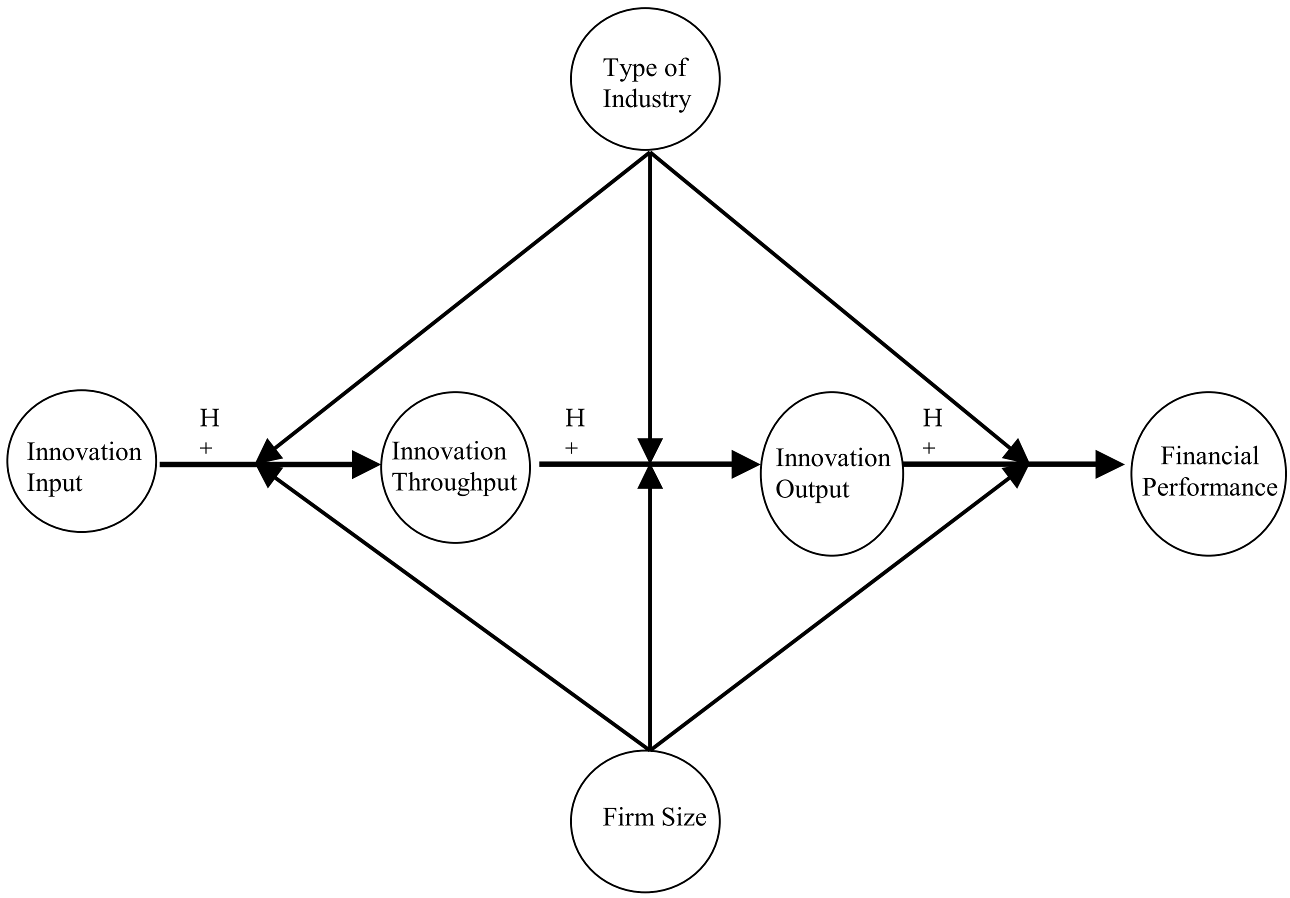

TABLE 1
Means, Standard Deviations and Correlations

	Mean	S. D.	MIN	MAX	1	2	3	4
1. Return on Sales	0.099	0.13	-0.07	0.60				
2. Input	1.36	0.74	0	2	-0.25***			
3. Throughput	3.23	1.93	0	6	-0.21***	0.61***		
4. Output	0.75	1.07	0	3	-0.06	0.29***	0.45***	
5. Size (# of Empl)	41.48	74.75	1	100	-0.21***	0.18**	0.25***	0.15***

*p < .05
**p < .01
***p < .001

TABLE 2
Results of OLS Regressions[a]

Variable	Model 1(H1): Throughput	Model 2(H2): Output	Model 3(H3): Performance
Constant	0.74(0.16)***	0.065(0.10)	0.19(0.018)***
Input	1.33(0.06)***		
Throughput		0.22(0.02)***	
Output			-0.0008(0.0044)
Size	0.01(0.001)	0.0013(0.0007)	-0.0006(0.0001)***
Industry Controls:			
manufacturing	0.68(0.17)***	0.23(0.11)*	-0.083(0.02)***
construction	-0.10(0.17)	-0.16(0.11)	-0.067(0.02)**
trade & repairs	0.47(0.17)**	-0.03(0.11)	-0.091(0.02)***
lodging & meals	0.0008(0.18)	-0.21(0.12)	-0.029(0.02)
transport	-0.013(0.17)	-0.34(0.11)**	-0.080(0.02)***
business services	0.60(0.18)***	0.21(0.12)	-0.026(0.02)
financial services	0.94(0.21)***	0.052(0.14)	-0.002(0.03)
Ownership Controls:			
Corporate	0.09(0.09)	-0.05(0.06)	-0.026(0.01)**
Entrepreneur	0.02(0.15)	-0.12(0.10)	0.12(0.02)***
N	1286	1286	619
Adj R-Square	0.441	0.228	0.191
F-stat	93.20***	35.50***	14.2***

[a] Unstandardized regression coefficients are shown, with standard errors in parentheses.
* p < .05, ** p < .01, *** p < .001

TABLE 3
Comparisons of Means

Variable	Manufacturing	Service	T-stat
Input	1.74	1.65	1.64
Throughput	3.24(1.49)	3.22(1.46)	0.236
Output	0.792(0.98)	0.707 (0.93)	1.44

TABLE 4
Results of OLS Regressions[a] comparing manufacturing and service

Variable	Model 1a(H4b): Throughput	Model 1b(H4b): Throughput	Model 2a(H4b): Output	Model 2b(H4b): Output	Model 3a(H4b): Performance	Model 3b(H4b): Performance
	Service	Manufacturing	Service	Manufacturing	Service	Manufacturing
Constant	0.85(0.13)***	0.95(0.14)***	-0.068(0.077)	0.10(0.11)	0.15(0.013)***	0.10(0.011)***
Input	1.41(0.08)***	1.38(0.09)***				
Throughput			0.24(0.02)***	0.24(0.02)***		
Output					0.005(0.0072)	-0.002(0.0049)
Size	0.01(0.0015)***	0.009(0.0018)***	0.0006(0.0009)	0.019(0.001)	-0.0007(0.0002)***	-0.0005(0.0002)**
Ownership Controls:						
Corporate	-0.03(0.132)	0.26(0.13)*	0.027(0.083)	-0.07(0.085)	-0.027(0.017)	-0.028(0.01)*
Entrepreneur	-0.07(0.20)	0.19(0.24)	-0.16(0.127)	0.007(0.15)	0.14(0.03)***	0.11(0.03)***
N	687	599	687	599	314	305
Adj R-Square	0.42	0.41	0.20	0.20	0.14	0.11
F-stat	124.7***	103.2***	45.12***	31.27***	13.74***	10.26***

[a] Unstandardized regression coefficients are shown, with standard errors in parentheses.
* p < .05, ** p < .01, *** p < .001

TABLE 5

Results of OLS Regressions[a] with size interactions

Variable	Model 1 (H5a): Throughput	Model 2(H5b): Output	Model 3(H5c): Performance
Constant	0.70(0.17)***	0.15(0.10)	0.20(0.018)***
Input	1.36(0.07)***		
Throughput		0.19(0.02)***	
Output			-0.013(0.0068)*
Input*Size	-0.001(0.001)		
Throughput*Size		0.001(0.0004)*	
Output*Size			0.00026(0.0001)*
Size	0.011(0.003)***	-0.0025(0.002)	-0.0009(0.0002)***
Industry Controls:			
manufacturing	0.68(0.17)***	0.23(0.11)*	-0.082(0.02)***
construction	-0.10(0.17)	-0.15(0.11)	-0.066(0.02)**
trade & repairs	0.47(0.17)**	-0.03(0.11)	-0.088(0.02)***
lodging & meals	0.002(0.18)	-0.22(0.12)	-0.030(0.02)
transport	-0.017(0.17)	-0.33(0.11)**	-0.080(0.02)***
business services	0.60(0.18)***	0.23(0.12)*	-0.023(0.02)
financial services	0.95(0.21)***	0.036(0.14)	-0.002(0.03)
Ownership Controls:			
Corporate	0.09(0.09)	-0.03(0.06)	-0.026(0.01)**
Entrepreneur	0.04(0.15)	-0.16(0.10)	0.12(0.02)***
N	1286	1286	619
Adj R-Square	0.441	0.231	0.197
F-stat	85.41***	33.2***	13.7***

[a] Unstandardized regression coefficients are shown, with standard errors in parentheses.
* p < .05, ** p < .01, *** p < .001

Appendix

Table A1

Response per sector and size class

Size Sector	**0-9 employees**	**10-49 employees**	**50-99 employees**	**Total**
manufacturing	47	65	58	170
construction	61	64	60	185
trade & repairs	61	59	62	182
lodging & meals	55	50	52	157
transport	58	61	60	179
business services	48	52	54	154
financial services	51	53	50	154
personal services	55	51	16	122
Total	**436**	**455**	**412**	**1303**

Appendix

Table A2

Questionnaire

Subject	Item
Input	I1. Does your company have any co-workers being involved in renewal efforts in their daily work? (yes/no)
	I2. Does your company have any co-workers who attended an education or training funded by the company in the past year? (yes/no)
Throughput	P1. Did your company introduce any new or improved work processes in the past three years? (yes/no)
	P2. Is enduring renewal part of your business strategy? (yes/no)
	P3. (If yes) Is this ambition written down in some way (f.i. in your business plan)? (yes/no)
	P4. Does your company use an external network to exchange information (f.i. with universities, suppliers, competitors, etc)? (yes/no)
	P5. Do you co-operate with other companies to develop innovative projects? (yes/no)
	P6. Did your company perform or outsource any market research activities in the past three years? (yes/no)
Output	O1. Did your company introduce any new products or services to the market in the past three years? (yes/no)
	O2. (If yes) Did your company introduce any products or services that are new for the sector in the past three years? (yes/no)
	O3. (If yes) Did your company introduce any products or services that are new for the Netherlands in the past three years? (yes/no)
Performance	What was your turnover (sales) for 2000? For 2001?
	What were your profits for 2000? For 2001?