SCALES-paper N200213

Innovation and firm performance

differences between small and medium-sized firms

R.G.M. Kemp
M. Folkeringa
J.P.J. de Jong
E.F.M. Wubben

Zoetermeer, May, 2003

EIM Business & Policy Research

SCALES
SCientific AnaLysis of Entrepreneurship and SMEs

The SCALES-paper series is an electronic working paper series of EIM Business and Policy Research. The SCALES-initiative (Scientific Analysis of Entrepreneurship and SMEs) is part of the 'SMEs and Entrepreneurship' programme, financed by the Netherlands' Ministry of Economic Affairs. Complete information on this programme can be found at www.eim.nl/smes-and-entrepreneurship

The papers in the SCALES-series report on ongoing research at EIM. The information in the papers may be (1) background material to regular EIM Research Reports, (2) papers presented at international academic conferences, (3) submissions under review at academic journals. The papers are directed at a research-oriented audience and intended to share knowledge and promote discussion on topics in the academic fields of small business economics and entrepreneurship research.

address:	Italiëlaan 33
mail address:	P.O. Box 7001
	2701 AA Zoetermeer
telephone:	+ 31 79 341 36 34
telefax:	+ 31 79 341 50 24
website:	www.eim.nl

Introduction

Understanding the relation between innovation and performance in both large, medium, and small firms is of crucial importance for ongoing economic growth, but still hardly understood. The topic of understanding innovations and their relationship with firm performance has become more relevant since the EU stated, in March 2000 in Lisbon, the ambition to become the world's most competitive and innovative region by 2010. The underlying rationale is that encouraging firms to innovate will lead to a better economic performance (Sirelli, 2000: 61); higher growth, more jobs and higher wages. Is this rationale empirically validated, and is there a preferential one-size-fits-all innovation trajectory for all European companies (large, medium and small)?

The objective of this paper is to depict the current state of knowledge regarding the relation between innovation and performance in general, and for SMEs in particular. This paper will therefore, first, emphasize the company size related factors in innovation trajectories and firm performance (growth). Second, it will oversee relevant developments in models and techniques. Based on the literature, several innovation models will be tested. To test a potential size effect, these models will be tested for the total sample, as well as for small and medium-sized firms separately.

The structure of the paper is as follows. In chapter two, we describe the literature on innovation and firm performance. We will discuss the relationship between innovation and performance by distinguishing the following stages: decision to innovate, innovation input, innovation process and innovation output. In chapter three, the methodology and the measurement instrument will be discussed. In chapter four, the innovation process and the relationship between innovation and firm performance will be tested. The closing chapter brings together some conclusions and discussions for further research.

Literature review

In this chapter, the literature on innovation and firm performance will be discussed. In section 1.1, two different research traditions are discussed; the economics-oriented tradition and the business-oriented tradition. In section 1.2, the changes in the economics-oriented research tradition are discussed. It evolves into research in the innovation process at firm level taking into account important explanatory variables of the business-oriented tradition. Section 1.3 and 1.4 discuss the definitions and indicators used in the new approach, respectively, the implications for empirical research (models and estimation methods). Finally, section 1.5 concludes this chapter.

Introduction

The literature covered by this paper fits the first of the two complementary traditions in innovation research (Brown and Eisenhardt, 1995: 343-378). The first and prevalent research tradition is economics-oriented. It traditionally examines both innovation patterns across countries and industries, and differences in the propensity of firms to innovate (Brown and Eisenhardt, 1995: 343; Dosi, 1988). However, in this research tradition the actual product development process remains a "black box". The second research tradition, which is business-oriented, opens up that "black box". It examines how specific new products are developed, and indicates "the organizational structures, roles and processes that are related to enhanced product development" (Brown and Eisenhardt, 1995: 375; Ancona and Caldwell, 1992). The entrepreneurs and the innovations are placed in the centre of the analysis. This second tradition, in the terminology of the economics-based research tradition, discusses in essence the efficiency of the innovation trajectory; to what degree are innovative inputs transformed into innovative outputs? It splits up into three streams. The three streams take product development as respectively (1) a rational plan (eg. NewProd, Cooper, 1992), (2) a communication web (Katz and Tushman, 1981) and (3) problem solving (Imai, et al., 1985; Takeuchi and Nonaka, 1986; Womack, et al., 1990). However, the three streams are unable to clarify the variety in innovation output and innovation performance, as the unit of analysis is primarily the project level. The unit of analysis in the economics-based research tradition is the firm. As a consequence, the economics-based research tradition is better suited for enhancing our understanding of the relation between innovation output and innovation performance.

In the economics-based research tradition R&D research was typically confined to the input-factors of an innovation trajectory. It was common to presume that R&D expenditures would lead to additional knowledge, and the dissemination of this knowledge would result in innovations, especially products and processes. For long the sole indicators for innovativeness were the expenditures on R&D and the number of employees dedicated to formal R&D. As the structure of the economy changes towards a service-economy, we learn more and more about a shrinking section of the economy (Arnold and Thuriaux, 2000: 12). Furthermore, when evaluating innovations business success was not considered to be a key issue (contrary to Schumpeter 1934; Voss 1994: 405-6), nor was the relation between the inputs (resources) and the output of the innovation process seriously questioned (Kleinknecht, 2000: 169-186). As a consequence, there were hardly any investigations into the quality of existing indicators and the potential of alternative indicators. But from a policy perspective one wanted to find out how to raise the effectiveness of public stimulation of innovation practices, be it via subsidies, enforcing collaborations, sector policies, or otherwise. Furthermore, R&D investments were questioned as the sole driver for innovations, strengthening the competitive position of businesses. Due to these two reasons additional insight into the innovation process became necessary (Arnold and Thuriaux, 2000).

In Europe, one witnesses a change towards evolutionary and learning perspectives (Arnold and Thuriaux, 2000: 9). In these perspectives, innovation becomes more interactive with more attention for incremental changes and knowledge creation. The advantage of this change is a better understanding of the selection mechanisms in innovations. The price to be paid is in the loss of generality. This paper is primarily in line with the current practices in the economics-oriented first research tradition, as it focuses on the relation between innovation and performance in general. We incorporate parts of the second tradition by focusing on the innovation process (innovation inputs, transformation process and innovation output).

Fundamental changes in research.

Since the 1980s one observes major changes in innovation research, namely the development of the process approach, the systems approach and an alternative level of analysis. Many of these innovations in innovation research were stimulated by the publication of the EU-harmonized Community Innovation Survey, in 1993 and 1994.

The Community Innovation Surveys present a three-stage process approach, distinguishing between the input stage, the throughput stage, and the output stage of the innovation process (Klomp, 2001). First, there is the input to the innovation process of an industry or firm (e.g. R&D expenditures, people involved in innovation, national subsidies); second, the innovation output of the industry or firm (e.g. productivity, new products or processes); third, when it comes to facilitating the operations of the firm, industry or economy, we call it the throughput stage of innovations (e.g. partner cooperation, innovation in the mission statement). The CIS offers an interesting balanced overview of the innovation process by presenting indicators from all the three stages of the innovation process. It turned out, for example, that the innovation output of Sweden and Finland was relatively low. That negative assessment was totally at odds with traditional research concentrating on R&D-statistics, i.e. at the input stage (Klomp, 2001). The conclusion from the process-based research may be that not all firms are equally efficient in turning research into sales or profits. Furthermore, firms may have different ways of innovating. Some firms rely on internal research while others may emphasize research networks (Mohnen and Dagenais, 2002: 4-5). The process approach promises additional insights into the integral innovation process.

The complex systems approach is another element in the new methodology of CIS. The systems approach acknowledges the complexity of the external and mutual influences on the innovation process. The traditional model assumes a causal linear model that innovation input influences the innovation process and the innovation process influences the innovation output. This related reduced-form approach holds the risk of a simultaneity bias. Absent in such an approach may be that, for example, the total sales may consist of new or improved products realised in an unbalanced way over the years (Klomp and Van Leeuwen, 1999: 5). Furthermore, input and output may be influenced by a common variable, e.g. technological opportunities or total sales. The impact of that third factor on the two interrelated factors should be estimated simultaneously. A final problematic aspect in modelling the relations in an innovation process is that the causalities are unclear, as with the chicken-and-egg problem: what was there first? The chain-link model of Kline and Rosenberg (1986) can be used to elaborate both unspecified feedback relations and unspecified causalities (Klomp and Van Leeuwen, 1999: 8). We may conclude that the elaboration and application of the process approach and the systems approach together made it possible to take a more inductive approach towards the innovation process and its relation with firm performance.

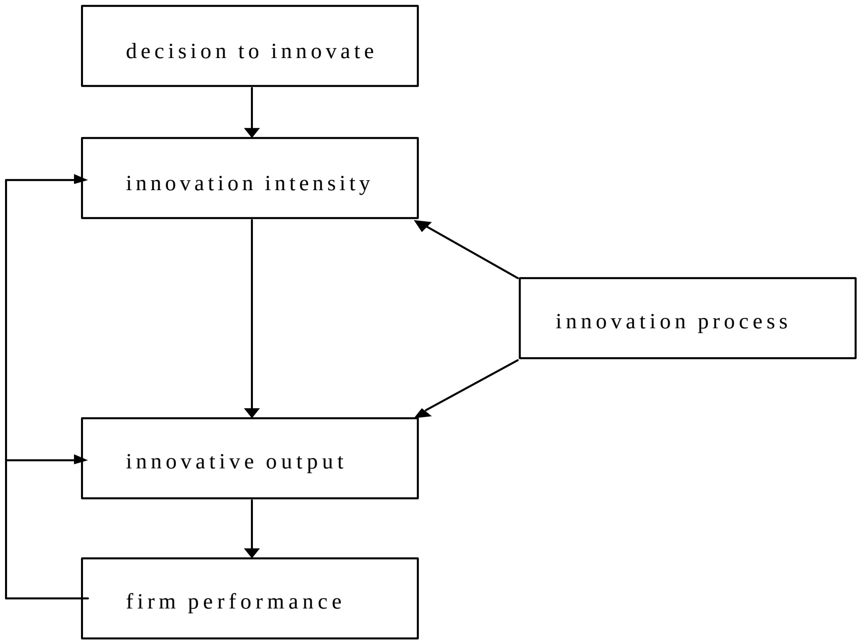
Another element in the CIS is the availability of data at firm level. Data from national statistical offices are typically at industry or national level, e.g. by patent counts and bibliometric counts of innovations, representing an object approach. An object approach has the advantage that the firm is not bothered by the research. On the other hand, it has the major disadvantage that the data reveal no direct but derived information. In contrast, the CIS adopts the subject approach, i.e. the firm is the unit of observation. The CIS data are direct data, i.e. information is gathered directly from the company. This study focuses on the firm level and distinguishes input, throughput and output indicators.

Innovation model

In this section, we will define the research model and the relationships between its elements.

Much of the literature in the systems theoretical approach uses models that incorporate at least four elements. These models are based on the Crepon, Duguet and Mairesse model (1998). First of all, there is a decision to innovate or not. Several aspects may influence this decision. Second, the company decision to innovate or not influences the innovative intensity. Third, the innovative output is studied. In most studies, the innovation output is determined by the efficiency and/or the absolute value of the innovative input, i.e., the transformation of input into output (the throughput stage). Finally, the innovative output is related to the firm performance. For example, the growth of total sales may be higher for innovating firms than for non-innovating firms. This is visualized in figure 1.

figure 1 Research model



The innovation process itself may contain several feedback loops. Innovative output, via firm performance, may affect innovation expenditures, i.e. innovative input. The overall economic performance of a firm may affect all three stages of the innovation process of a firm.

The decision to innovate

Introduction

Prime in innovation research is the question what factors influence the companies' intention and/or decision to innovate. Especially small companies fall into clear subcategories of companies that are inclined to innovate and others that do not. A company can decide to be either at the forefront of new developments, or step in once new developments prove to be interesting, or be reactive and adjust only when urgent (Miles and Snow, 1978). Indicators distinguishing innovative firms from non-innovative firms are sales of new or improved products, direct questions like "does the firm innovate yes or no?", or the total amount of time employees spend on innovation (input side) (Mairesse and Mohnen, 2001; Klomp and Van Leeuwen, 1999). Once the decision to innovate is made, the firm has to allocate resources, typically financial or human resources.

Factors influencing the decision to innovate

Several studies empirically test the propensity of firms to innovate. Felder, et al., (1996) used the Mannhein Innovation Panel, with a subset of firms with 5-49 workers, to test the relation between R&D and other innovation expenditures. Firm size turns out to be a major factor influencing the decision to innovate. Moreover, once innovating, the total amounts invested as percentage of total sales is larger with the smaller firms. The effect is most pronounced for the total innovation expenditures, as confirmed by Vossen and Nooteboom (1996). The relationship between firm size and R&D seems U-shaped. Vossen and Nooteboom conclude that small firms participate less in R&D, but at a greater intensity and with a greater productivity once they participate (Vossen and Nooteboom, 1996: 167). Also Kleinknecht (2000) and Kleinknecht and Mohnen (2002) found that the propensity to innovate is positively related with size although the relationship may not be linear, and amongst the innovators smaller firms tend to have higher shares in sales of innovative products. Lööf, et al., (2001) used OECD and CIS-data to explain variation in productivity growth between the Nordic countries. In their Crépon, Duguet and Mairesse model (1998) an innovation investment variable substitutes the R&D variable. Firm size and patent applications are clearly significant to explain the propensity to innovate, even more so than export intensity. Also technological opportunities, factor intensity (level of education) and sector characteristics influence the innovation decision (Lööf, et al., 2001). In a sector with a high-tech potential firms are more inclined to innovate. Finally, some process characteristics like the mission of the firm influences the innovation decision.

innovative intensity

Innovation intensity concentrates on understanding the determinants that influence the resources dedicated to the innovation process.

The literature provides us with several indicators of the innovation intensity. Traditionally and still the most popular input indicator is the figure on expenditures on R&D (Klomp and Van Leeuwen, 1999, Lööf, et al., 2001). The innovation expenditures are often divided by total sales to define the R&D intensity of a company. Another traditional indicator is the number of employees dedicated to R&D. It is easy to measure and is suitable for services sectors. However, it does not include the quality of the employment input nor the exact hours devoted to innovation. Mairesse and Mohnen (2001) take the share of new products in total sales as indicator for innovation intensity. It has the advantage that the final objectives of innovation trajectories are taken into account, i.e. extra turnover and/or profit. However, this share-in-sales variable is better used for output measurement.

In this study, we use the number of employees dedicated to R&D as indicator for innovative intensity. The indicator is improved by correcting for the average time these employees spent on innovation. This variable is also appropriate for small companies.

Factors influencing the innovation intensity

Several studies examined the factors that influence the innovation intensity. Next to the variables that explain the propensity to innovate, Lööf, et al., (2001) include obstacles to innovate, information for innovation, innovation strategies/innovation objectives, and cooperation (domestic and foreign). The results are somewhat confusing at cross-country level. For example, the effect of firm size on innovation investment, is negative for Finland, positive for Norway, and non-significant for Sweden. Significant and positively related with the innovation investment in all three countries are 1) the innovation objective of extending the product range, 2) information sources within the firm itself and 3) customers and 4) domestic cooperation with customers.

Klomp and Van Leeuwen (1999) used a single equation approach and the simultaneous approach for testing the relationship between innovation and firm performance. There are feedback loops from the performance via total sales. They also include sector dummies and dummies for sector-size interactions. They test the model for all innovative firms and innovative firms with innovative output. In the single equation approach the innovation intensity was significantly related to the following variables; prior total sales (as indicator of size), prior cash flows, technological

opportunities, age of the firm, subsidies, R&D on a permanent base, and cooperation. In the simultaneous equation model prior cash flow, development of sales and subsidies proved to be significant.
In a study on the causality between R&D intensity and export intensity, Kleinknecht and Oostendorp (2002) proved that an increase in the export intensity of a firm significantly and positively influences the R&D intensity.
In a recent paper, Statistics Netherlands together with TNO detailed the input, throughput, and output order of the innovation process for the Knowledge Based Economy (Klomp, et al., 2002). The innovation intensity is influenced by the firm size, export intensity, prior sales level of education of the employees, external support (subsidies) and innovation process characteristics.

innovation process

The innovation process refers to the transformation process in an innovation trajectory. Here, as in most studies, the innovation process (e.g. cooperation in innovation projects) is modelled as influencing the innovative input and output. The process or throughput indicators are used to explain the effectiveness of the transformation processes of innovative input to innovative outputs.

Throughput may be evaluated along two lines of arguments: One line of argument is to concentrate on how expensive the innovation creation process is. Along this line, throughput analysis functions as a measurement of efficiency of innovation processes: the ratio of innovation output and innovation input. The efficiency of the innovation can be enhanced by outsourcing part of the innovation activities for example to universities or technological institutes. The innovation intensity variable may be used for this throughput evaluation by means of extramural R&D expenditures (cf. Klomp and Van Leeuwen, 1999). Still throughput remains a closed black box. In contrast, the second line of argumentation emphasizes how much is going on in this innovation creation process, the efforts. Now, throughput is understood to detail the innovation creation process. As a consequence, one may focus on the internal and external orientations and relationships of the company. An indicator of this second approach is the number of innovation projects. Subsidies may be taken as innovation throughput factor. In such a case, innovation policies, and subsequent subsidies, are aimed at removing impediments in the functioning of the innovation system (Klomp, et al., 2002, point 28). One means for removing impediments is to get companies involved in more general research projects, apart from joint ventures, co-makership agreements, etc. In the Netherlands we refer to STW-projects. Another means is well known, namely to subsidize the company via national or European institutes. Finally, a means of removing impediments is by offering support to firms, e.g. via management support, the provision of specific information, etc. In the Netherlands, Syntens amongst others brings to the organisation (especially SMEs) such capabilities potentially useful in the process of innovation.

The CIS uses the following throughput indicators: extramural/external R&D, co-operation and sources of information used for innovation. When it comes to sources of innovation 96 percent of all respondents refer to various sources within the industrial column, but it is dominated by sources within the firm. Innovation centres are as popular by small companies (10<49 workers) as with larger firms. Publicly available sources are indicated by 79 percent. Of all innovating firms the least interested to participate in joint co-operations are the small industrial companies, i.e. 18 percent of them. Extramural R&D amounts to almost 7 percent of total innovation expenditures, one-third of which goes abroad and one-third to universities and research institutes (Klomp and Van Leeuwen, 1999).
Klomp, et al., (2002) see the throughput or process stage as knowledge diffusion. Prime is the stimulating effect of the government on the interactions between the universities and intermediaries, research institutes, and/or with firms. The same counts, c.p., for research institutes and intermediairies; Firms may have research-contacts with forementioned parties but also with one another. This will stimulate the innovation efficiency.

Klomp and Van Leeuwen (1999) and Lööf, et al., (2001) include process related variables in explaining the innovative intensity and the innovative output. They are subsidies, R&D on a permanent basis and innovation in partnership/cooperation. In the single equation model, these variables significantly influence the innovation intensity. Permanent R&D has a positive effect on the innovative output, the other two variables show mixed results. Lööf, et al., (2001) include five groups of process indicators: obstacles to innovate, strategy on innovation (innovation objectives), crucial sources of information for innovation, domestic and foreign cooperation in innovation. As discussed in the innovation intensity section, only the innovation objective extending the product range, information sources within the firm itself and customers, and domestic cooperation with customers are significant and positively related with the innovation investment in all three subsets (Finland, Norway and Sweden) of the data. The variable "Firm underwent a major restructuring" is important according to Kleinknecht and Oostendorp (2002). The variable is significant in the equation explaining the propensity to innovate. In the R&D intensity equation this variable is not significant. Although they did not define it as a process indicator, we take it to influence the innovation transformation process and thereby is a process indicator because restructuring opens new opportunities and approaches for the firm. This in turn will influence the efficiency of the innovation process.

Summarizing, the innovation process refers to the efficiency of the transformation process of innovative input into innovative output. This efficiency is influenced by several aspects like long-term R&D, subsidies, various info sources, cooperation with other firms, customers or universities, stated innovation ambitions, innovation centres, and organizational change.

innovative output

The innovation input and innovation processes may result in various forms of innovative output. The most visible innovative output is a new or modified product. Alternatively, process innovations may also turn out to be important. These process innovations improve the transformation process, and they make the transformation process more efficient. E.g. the Ikea and Dell business models are exemplar for these process innovations. This can have a direct effect on the profitability of a company. For services the innovation of a service cannot be disentangled from the innovation of the service process (De Jong, et al., 2002). Most output indicators in empirical research are closely related with product innovations. Process innovations outputs are still less focused upon.

In empirical research, the main indicators for innovative output are new products and new processes, innovative sales (as percentage of total sales), the conditional expected share in sales of innovative products, and the number of patents. Between product and process innovations there seems to be a relationship. Especially for manufacturing there is a strong relation between the number of firms who introduce new products and firms how also introducing new processes (Klomp and Van Leeuwen, 1999). The share-in-sales indicator is an output indicator of recent date, but already widely used in research (Mairesse and Mohnen, 2001; Klomp and Van Leeuwen, 1999). For example, the share in turnover of products new to the firm or new to the industry is part of the CIS. The advantage of this share-in-sales indicator explicitly is that it focuses on the added value of innovation for a common objective of firms, that is growth. Next, now efficiency of the research can be estimated (Kleinknecht, 2000). Another advantage is that it can easily be adapted to service sectors. A final advantage of this indicator is the direct link between the innovation effort and the commercial success. There are two main disadvantages; first of all that a survey method is needed which may result in low (and possibly selective) response. Second, it makes a comparison over sectors more problematic because of the divers product life cycles between branches. In the Netherlands, in manufacturing, size influences this indicator: on average, 25 percent of turnover was the result of new or improved products for manufacturing, in 1996, but only 15 percent for the smaller firms (20 to 49 workers). Statistics Netherlands posits that the result on size turns into zero once we restrict ourselves to the subset of innovators (Klomp and Van Leeuwen, 1999: 31).

On the basis of and exploiting the CIS-1 dataset, Mohnen and Dagenais (2002) propose the conditional expected share in sales of innovative products as an alternative innovation indicator: “Innovation is measured as the expected mean share of sales resulting from new or improved products conditional on the innovation input, the way innovation is organized, and some characteristics of the firm and its environment” (Mohnen and Dagenais, 2002: 26). This composite indicator combines the estimated probability to innovate and the estimated percentage of sales resulting from new products. From an estimation and exploratory application the authors conclude that size influences the ability to innovate but not the share in sales of innovative output. In contrast, research on a continuous basis does increase the share-in-sales (Mohnen and Dagenais, 2002: 21).

Next, patents are used as an (intermediate) output indicator of innovation (Kleinknecht, 1996, 2000). The advantages of using this indicator are, first, the abundancy of publicly available information, with, second, the minor disturbances in these series. However, there is a series of problems with this indicator. First, many (service-related) innovations cannot be patented or are just not patented. Second, how to deal with the strategic use of patenting, which is meant to misguide a competitor. Third, patenting will depend also on how high imitation costs are relative to innovation costs. Fourth, several findings suggest that ‘time lead’ and ‘secrecy’ are more important to appropriate innovation benefits than patent protection. Fifth, high-tech sectors tend to have a higher prospensity to patent. Sixth, several findings demonstrate that patent data underestimate, in terms of probabilities, the rate of small innovators (<10 workers), while overestimating the innovation intensity of those that innovate. We derive from this and related information that transaction costs are high for small firms who are first to patent, but once these small firms patent they apply for relatively higher numbers of patents.

Important innovation output indicators are the share-in-sales of new products or services and patents. The share-in-sales indicator is present in recent empirical research of Mairesse and Mohnen (2001), Klomp and Van Leeuwen (1999), and in Lööf, et al., (2001). Kleinknecht (2000) concludes that this indicator is robust. The share-in-sales indicator encompasses the total innovation trajectory, including the market introduction trajectory. Patents provide an often-used, but criticised source of information. Patents are an apt indicator for the specific first phase of the innovation trajectory. In our study, we use the indicator percentage of new products/services in turnover (last three years) as output indicator.

Factors influencing innovative output

Conform figure 1 innovative output is directly influenced by the innovative input and the innovation process. Several studies investigate this relationship. Lööf, et al., (2001) found only a significant relationship between innovative input and innovative output in their Sweden sub-sample. None of their variables proved to be significant for all three countries. The authors argue that the model specification and the representativeness of the respondents may explain the mixed results.

Klomp and Van Leeuwen (1999) find that with regard to innovation process variables, R&D on a permanent basis and cooperation are significant. They include subsidies in the innovation intensity equation. Surprisingly, even in their advanced simultaneous equation model, the innovation intensity is significant but only at the 10% level. Furthermore, they conclude that the use of the opportunities offered by science has a smaller effect on the level of innovative output than the use of technological opportunities offered by customers, suppliers and competitors (Klomp and Van Leeuwen, 1999: 61).

In their introduction to a volume dedicated to innovation and firm performance, Kleinknecht and Mohnen (2002) derive several conclusions from previous research. First, the share-in-sales of innovative products is not strongly related to size. Smaller firms have a lower probability to innovate, but once they innovate that share in sales is not lower than in larger firms. Second, due to the so-called Schmookler-effect, demand enhances innovation and innovation enhances demand, but evidence is inconclusive on the relative strength of causation in either direction. Third, there is a difference between determinants of product and process innovation. Nevertheless, some researchers demonstrated complementarity between product and process innovations (e.g. Cabagnols and Le Bas, 2002). Cost-reduction strategies seem to stimulate joint process and product innovation over product innovation alone.

Summarizing, innovation output refers to the results of the innovation process. Innovation output is often measured by the share-in-sales of new products, next to patents and product announcements. The innovation output is influenced by the innovative inputs, the innovation process, R&D on a permanent basis, cooperation, and technological opportunities offered by customers, suppliers and competitors

firm performance

In the end, the aim of all firms considering innovative activities is to boost the firm performance compared to non-innovating companies. In measuring firm performance, various concepts are found: sales per employee, export per employee, growth rates of sales, total assets, total employment, operation profit ratio, turnover and return on investment (Sirilli, 2001).

Innovation related factors influencing firm performance

In general, publications are positive about the effect of innovation on firm performance. The already mentioned publication edited by Kleinknecht and Mohnen (2002) present a series of econometric explorations. Diederen, et al., (2002) conclude from the Dutch FADN-database that innovative farmers show significantly higher profits and growth figures than firms that are not innovative. Favre, et al., (2002) conclude, from a sample of 2879 French firms from fourteen industries, there is a positive impact of innovations on profits. R&D intensity and co-operation, capital intensity, sales, innovative exports, market share, and industry concentration, and national and international R&D spill-overs exert a significant influence on a firm's profits (Favre, et al., 2002). Avanitis and Hollenstein (2002) conclude that the use of external knowledge, technological opportunity and the degree of innovativeness significantly increase the productivity of knowledge capital (Avanitis and Hollerstein, 2002).

Two papers in Kleinknecht and Mohnen (2002) examine the (causal) relationship between innovation and export performance. Levebvre and Levebvre (2002), on the basis of a SME-database on 3187 firms over a three-year period, conclude that, in decreasing order, size, import activities, R&D, knowledge intensity, and distribution access, determine significantly the export performance. Kleinknecht and Oostendorp (2002) focus on the causal relationship between R&D and exports. They conclude that R&D intensity increases the probability of being an exporter, but it does not influence export intensity. On the other hand, export intensity influences R&D-intensity. Also the higher share of higher educated personnel enhances both R&D and export performance.

In a publication based on the Dutch innovation monitor, Meinen (2001) is positive on the question whether innovation is worth doing. Firms executing R&D on a permanent basis, who co-operate with others, and who use various sources of information, raise extra turnover over the period 1996-'98, by respectively 8.5 percent, 2 percent, and 6 percent.

In two publications, Lööf investigates innovative sales per employee, employment growth, the sales margin and productivity. Lööf (2000) presents a positive relationship of innovative sales per employee (elasticity) on five different performance measurements, namely employment growth, value added per employee, sales per employee, operating profit per employee, and return on assets. The sales margin is not significantly influenced by innovative output. When we distinguish between manufacturing and service firms, the relationship between innovative output and employment growth is not significant anymore for service firms. In another study, Lööf, et al., (2001) tested the effect of different concepts on the productivity for three Nordic countries. From these factors, innovation output, firm size, % non R&D engineers, % administrators are significant at the 5% level in at least two of the three Nordic countries.

Summarizing, studies show that innovative firms have a higher profits and grow faster. Performance studies are presented detailing profits, turnover growth, export performance, export intensity, innovative sales per employee, sales margin and productivity. Especially innovation on a permanent basis, cooperation with other parties and the use of several information resources will result in extra turnover.

Implications for the research model and estimation methods

implications for the research model

From the literature review, it is clear that state of the art research approach consists of the combination of the process and systems approach, feedback loops and the subject approach. This new research approach is based on the models of Kline and Rosenberg (1986) and Crépon, Duguet and Mairresse (1998). In these models, the innovation process breaks down in innovation input, innovation throughput and innovation output. Sometimes the innovation propensity and firm performance are included. These models take into account selectivity and simultaneity biases (see e.g. Lööf, et al., 2001, Klomp and Van Leeuwen, 1999).
Another central point in the new approach is the feedback loop from economic performance to innovation performance. There can be feedback loops from firm performance to innovation input and/or innovation output. By using a simultaneous equation model, these feedback mechanisms can be tested.
Furthermore, the subject approach seems useful as it uses direct micro-data from the companies themselves (e.g. innovation related turnover) instead of derived information, as with the object approach (e.g. patents). The subject approach also better serves the international comparability and new research areas like the effect of organizational innovations and aspects of the knowledge-based economy (Archibugi and Sirilli, 2001).

implications for the estimation methods

Recent studies have revealed a clear revolution as far as the estimation methods are concerned. As the reduced form equations are no longer acceptable and feedback relations are to be expected, then tobit, generalized tobit, probit, and the Heckman-models are becoming more and more standard practice

Tobit is typically introduced to adapt for the conditionality of an equation on a certain decision, e.g. to innovate or not. In the papers analysed the generalized tobit model is standard practice for establishing the prospensity and intensity of innovations. In that model the actual level of an indicator is estimated as is the probability of observing a score between 0 and 1 (probit). The distribution of the disturbances can thus be established. In a neat modelling exercise the two disturbance terms do not differ significantly. Many researchers also use Heckman-modelling for the simultaneous-equation modelling. Heckman (1979) allows to identify the parameters of the participation model and the intensity model separately (Felder, et al., 1996: 139).

Lööf, et al., (2001) apply both 2SLS and 3 SLS. The 3SLS may bring in feedback effects from e.g. productivity (predictions) to innovation output. There is no clear direction in the resulting differences in significant factors.

We conclude that a wide range of estimation methods may be applicable. “Innovation survey data have peculiar characteristics, which require some special econometric techniques and invite us to be modest regarding the results obtained” (Kleinknecht and Mohnen 2002: xxviii). First of all the use of additional data sets is recommended as the number of explanatory variables may otherwise be rather limited. Second, the problem of selection bias is evident here. The (generalized) Tobit-models may correct for that problem. Third, to correct for qualitative variables (ordinal, binary, or count data) different dependent variable techniques are required. One may use the univariate probit model, the univariate logit model, the bivariate probit model, the trivariate probit model, the univariate probit model, count data models, and the multinominal logit model. Fourth, innovation survey data share the problem of simultaneity, e.g. between innovation, exports, investments, and R&D investments. Fifth, dynamic models and panel data techniques typically cannot be applied as they require longitudinal data. "Yet, after controlling for experience effects (lagged variables) and unobserved heterogeneity, the picture regarding determinants of innovation can be quite different" (Kleinknecht and Mohnen 2002: xxviii).

Besides, we will look at the differences between small and medium-sized firms as well. Several studies indicate that this distinction is worth to investigate because of differences between both types of firms (e.g. Meinen, 2001a, Klomp and Meinen, 2001a and Kleinknecht, 2000).

Conclusions

We have come to the closing section of this chapter. It aimed at depicting the current state of knowledge regarding the relation between innovation and performance in general.
The research on innovations is rapidly developing. Due to political pressure and scientific advancement innovation research is transforming itself. The process approach, the systems approach and new indicators lead the research into new uncharted waters. But there is clearly a first mover advantage for research on R&D data, and, to a minor degree, patent data. New innovation parameters have a hard time to prove their superiority. The backing of the Community Innovation Surveys by Eurostat clearly strengthens their position. The new indicators to stay are most probably the share in turnover of products new to the firm or new to the industry. Note that such a high share in sales of innovative products may be the result of the number of new products and/or the rapid diffusion of new products. Furthermore, the innovation expenditures indicator will stay, although not all the underlying items may be included in the end. The reason is that the extra administrative burden on the firms may not countervene the added value of that extra information. Of the others, e.g., information sources, and technical innovations additional testing will have to settle matters.

In innovation studies, the 'linear model' and the neoclassical approach are left behind in favour of complex systems models and entrepreneurship and knowledge creation at the centre of research. The methodologically based picture of the atomistic profit maximising firm is replaced by the learning entity with bounded rationality, developing external networks and internal capabilities working in a geographical space (Arnold and Thuriaux, 2000: 9). It is recommended to work on both Heckman, tobit and probit methods. Also the Full Information Maximum Likelyhood may be useful. They seem to be here to stay. Nevertheless, a major problem for our innovation research, as with other economic growth literature, is that there remains a huge gap between the formal models and the complex mechanisms tested in empirical work. Also the need to work often with indicators instead of factual data enlarges the problematic interpretation of empirical tests (Lööf, et al., 2001: 4).

In this chapter we have listed the prime developments in innovation research; we have listed the major publications that tested such new approaches, new methods and new innovation indicators. In the next section, we will discuss the methodology of this research. In chapter four the model discussed in this chapter will be tested.

Research methodology and operationalisation

Research setting

To test the model previously presented, we collected data from 3042 Dutch companies. In the telephone survey, the general manager was interviewed or the person responsible for R&D and innovation. In total, 13,759 companies were contacted. Of these companies, 2,144 companies did not meet our criteria (e.g. younger than three years, companies liquidated, wrong telephone number etc.). Of the 11,615 companies that did meet our criteria, 3,042 completed the questionnaire, a response rate of 26%. With 3,081 companies, an appointment was made for an interview. These appointments were not used because the target of a total number of 3,000 interviews was reached before the appointment. The rest of the companies refused to cooperate or could not be reached (answering machine, busy etc.). We tested for non-response bias. Characteristics of respondents are compared to characteristics (sector and size) of non-respondents. It proved that there are no significant differences between the respondents and non-respondents; thus we conclude that our response is representative for the composed sampling frame.

Variables

The used data set contains a large number of different innovation indicators and firm performance variables. Table 1 presents the selected variables. For each variable a description is given, as well as the scale and, in case of categorical variables, the value assigned to each category. The innovation related variables can be grouped into three categories, innovation input variables, innovation process variables and innovation output variables.

Table 1 Variable characteristics

Variable	*Description*	*Scale*	*Scale values*
Innovation intensity			
innovation intensity	% total time employees spend on innovative activities	metric	
degree education	% employees with masters or university degree	metric	
courses	% employees with training financed by own company	metric	
Innovation process			
nat. subs	use of national innovation and technology subsidies	dichotomous	0 = no subsidy 1 = use of subsidy
Eur. subs	use of European innovation and technology subsidies	dichotomous	0 = no subsidy 1 = use of subsidy
cont. innovation	continuous innovating as part of the company strategy	dichotomous	0 = no 1 = yes
innov. written down	written down innovative activities	dichotomous	0 = no 1 = yes
certificate	in possession of certificate	ordinal	0 = no 1 = attempting to get certificate 2 = yes
change organization	change in organizational structure in last 2 years	dichotomous	0 = no 1 = yes
customer satisfaction	systematic measurement or customer satisfaction	dichotomous	0 = no 1 = yes
market research	performing market research in last 2 years	dichotomous	0 = no 1 = yes

intermediate	customer of intermediate organization	dichotomous	0 = no 1 = yes
product innovation	innovation goal is product innovation	dichotomous	0 = no 1 = yes
process innovation	innovation goal is process innovation	dichotomous	0 = no 1 = yes
co-op other firms	co-operation with other companies	dichotomous	0 = no 1 = yes
co-op research inst	co-operation with research institutes	dichotomous	0 = no 1 = yes
co-op educational inst	co-operation with educational institutes	dichotomous	0 = no 1 = yes
Innovation output			
innovation output	% new products/services in total turnover	metric	
Performance			
turnover growth	% change in total turnover between 1997 and 1999	metric	
employment growth	% change in total employment between 1997 and 1999	metric	
Control variables			
log turnover	logarithm of total turnover 1999	metric	
export growth	change in share of export in total turnover between 1997 and 1999	metric	
profit development	profit development indication in period 1997-1999	ordinal	-1 = decreased 0 = same level 1 = increased
loss99	dummy indicating loss in 1999	dichotomous	0 = no loss 1 = loss
profit99	dummy indicating profit in 1999	dichotomous	0 = no profit 1 = profit
sector dummies	Dummy indicating manufacturing, trade, construction, hotel/transport and services	dichotomous	

Empirical results

In this section, the empirical results will be discussed. Various econometric models are estimated in order to find determinants of innovation input, innovation output and firm performance. Our focus is on small and medium-sized enterprises (SMEs). Most studies focus on medium-sized and large companies and use size as a control variable. Our data set allows us to focus on small and medium-sized firms and do separate analysis for small firms and medium-sized firms.

Analyses are generally carried out in threefold. Firstly, models are estimated at the level of all available firms in the data set. Secondly and thirdly, the same model specifications are used to determine coefficients for the samples of small firms and medium firms separately. Small firms are defined as a firm with less than 10 employees. Medium firms have a number of employees that lies between 10 and 99.

Determinants of innovation input

The first part of our analysis aims at finding determinants of innovation input. The variable of interest is *innovation intensity*, the total amount of time all employees spend on innovative activities, as a

percentage of total available time[1]. The whole set of innovation process variables, firm performance variables, and control variables are used as explanatory variables in the innovation equation. A standard linear regression model seems most appropriate to model the innovation input equation, using ordinary least squares (OLS) as estimation method. The equation could have been modelled as a Tobit model, which takes account of zero shares of innovation input. However, the number of observed firms for which this is the case, is relatively small (167 firms).
Table 2 presents the estimation results of the innovation input equation. First we comment on the results of the sample of all small and medium firms, then the two separate groups are discussed.

Table 2 Estimation results innovation input model

	all SMEs		small firms		medium firms	
	coefficient	t-value	coefficient	t-value	coefficient	t-value
constant	56.46***	13.5	58.97***	8.3	13.89**	2.1
nat. subs	2.05**	2.1	5.73***	3.0	0.83	0.9
Eur. subs	1.20	0.8	1.77	0.5	2.04	1.5
cont innov.	4.07***	3.8	4.54***	2.7	2.66**	2.3
innov. written down	1.04	1.2	2.08	1.5	-0.74	-0.8
change organization	-1.07	-1.3	-.084	-0.6	0.07	0.1
customer satisfaction	0.27	0.3	-0.24	-0.2	0.71	0.9
market research	2.32***	2.7	3.02**	2.1	1.34	1.5
intermediate	1.29	1.5	3.47**	2.4	-1.34	-1.6
product innov.	1.19**	2.5	1.44*	1.8	0.90*	1.8
process innov.	-1.61	-1.6	-2.83*	-1.8	1.29	1.1
co-op. other firms	2.17***	2.7	2.19	1.6	1.13	1.4
co-op. research inst.	2.58**	2.5	4.57**	2.3	1.14	1.2
co-op. universities	-0.04	0.0	0.03	0.0	0.03	0.0
turnover (log)	-7.66***	-12.8	-8.35***	-7.6	-1.17	-1.3
turnover growth	0.00	1.1	0.01	0.8	0.01	0.8
export growth	0.13**	2.5	0.22***	2.9	-0.02	-0.3
profit development	-0.12	-0.3	-0.01	0.0	-0.14	-0.3
dummy loss 99	3.17**	2.0	3.96	1.6	2.38	1.4
dummy profit 99	-1.15	-1.1	-0.16	-0.1	-1.65	-1.4
dummy industry	0.08	0.1	0.61	0.4	-0.07	-0.1
dummy trade	1.98**	2.0	2.10	1.2	1.37	1.4
dummy hotel, transport	0.41	0.3	1.06	0.4	0.26	0.2
dummy services	2.26**	2.4	2.17	1.4	2.38**	2.4
number of firms	1,769		907		862	
R^2	0.20		0.21		0.09	
F value	F (23,1745) = 18.9***		F (23,883) = 10.16***		F (23,838) = 3.52***	

*p < .10, **p<.05, ***p<.01

In the equation with all SMEs included, 12 of the 24 variables are significant. Among these variables are the use of national subsidies, continuous innovation in the mission, market research, product innovation, export growth and cooperation with other firms. These variables all have a positive effect, as expected. The turnover has a negative effect on the innovation input. This implies that if the turnover increases, the innovation input decreases.

[1] The innovative inputs degree education and courses are not used as dependent variables. They focus on the quality of the input and not the level of input that is the relevant aspect in this research.

When splitting up the sample in small and medium sized firms, different results come to the fore. The independent variables in the regression model explain the innovation intensity fairly well for the sample of small firms. However, for medium firms, none of the coefficients are significant at the 1%-level. Only three variables have a significant effect at the 5% level.
For small firms, obtaining national subsidies has a significant positive effect on the amount of time put into innovation. European subsidies have no discernible effect on the innovation intensity.
Firms that incorporate innovating activities in their long-term strategies, spend relatively more time on innovation. This can be seen as a structural process. This holds for both small and medium-sized firms, displaying a larger effect for small firms. Writing down this innovative strategy has no significant effect on innovation input. A change in the organizational structure of the firm and the measurement of customer satisfaction also display no discernible influences. In contrast, carrying out market research leads to increased innovation intensity. Again, the effect is only significant for small firms. Small companies that have contacts with the intermediate organization have significantly higher innovation inputs than firms without the contacts. Co-operation with other firms and research institutes have a positive effect on innovation input for the sample of all firms, but when the distinction is made between small and medium firms, only the coefficient of co-operation with research institutes holds its significance for small firms.
Larger firms, in terms of the logarithm of total turnover, spend relatively less time on innovative activities. Looking at the two different size classes, this only holds for small firms. Apparently, medium firms form a more homogeneous group where firm size does not matter for the amount of time put into innovation. Turnover growth has no significant effect on innovation input. However, a larger mutation of export share (in total turnover) leads to increased innovation intensity. This effect is again only observable for the sample of small firms.
Based on the presented results one may conclude that size does influence the relationship between several explanatory variables and the innovation input. Especially for small firms, several variables have a positive impact on the innovation input. National subsidies, contacts with the intermediary organization, the cooperation with research institutes and the growth in export intensity influences the innovation input. For medium sized firms, it is not so clear what contributes to the innovation input. Variance in the individual explanatory variables does not significantly explain the variance in the innovation input (except for continuous innovation and product innovation, the latter only at the 10% level).

Determinants of innovation output

Our next focus is on innovation output. We use the share of new products or services in total turnover as innovation output indicator and dependent variable. Since a number of firms have zero innovative output, simply estimating a linear regression model by OLS leads to biased estimates. Tobit models are better suited to model such a dependent variable (Greene, 2000, Franses and Paap, 2001). We use a type-2 Tobit model (Amemiya, 1985). The type-2 Tobit model consists of two different models, a Probit model and a standard linear regression model. In the Probit part of the model, a binary dependent variable is considered, which takes a value of 1 if a firm has innovative sales (0 if firm has no innovative sales). Conditional on having innovative sales, the share of innovative sales in total turnover can be modelled using a standard linear regression model ("the OLS part"). The type-2 Tobit model reads as follows:

$$y_i = \begin{cases} a + \sum_{j=1}^{J} b_j x_{ij} + e_{2i} & if\ y_i^* = a + \sum_{j=1}^{J} b_j x_{ij} + e_{1i} > 0 \\ 0 & if\ y_i^* = a + \sum_{j=1}^{J} b_j x_{ij} + e_{1i} \leq 0 \end{cases}$$

with e_{1i} ~ N(0,1) and e_{2i} ~ N(0, s_2^2). The model can be estimated using ML. However, a simpler method can be applied, known as the Heckman two step-procedure (Heckman, 1976). In the first step the Probit model is estimated with ML. In the second step, the linear regression model is estimated (using OLS) for the firms with a positive share of innovative sales. In the OLS - part, the inverse Mills ratio (or "Heckman-term") is added to the standard regression model, correcting for the bias in the estimates. This produces less efficient estimates than ML, but in general estimation results will not differ substantially. We shall use the Heckman two-step procedure in our analysis.

The estimation results of the type-2 Tobit model are displayed in Table 3. The Probit part explains the aspects that influence the probability of having innovative sales, the OLS part the extent that the different aspects contribute to the level of innovative output. The inverse Mills ratio is insignificant for all specifications, indicating we have a two-part model, with no bias in the estimation of the OLS part of the model.
For all firms, the probability of having innovative output is positively influenced by continuous innovation, a change in the organization structure, the measurement of customer satisfaction, product innovation as innovation goal and the turnover. Contacts with the intermediate organization have a significant and negative effect on the probability of having innovative output. This is in contrast to our expectations.

Table 3 Estimation results innovation output model, type-2 Tobit model

	all firms				small firms				medium firms			
	probit part		*ols part*		*probit part*		*ols part*		*probit part*		*ols part*	
	coef	t-value	coef	t-value	coef	t-value	coef	t-value	coef	t-value	coef	t-value
constant	-0,39	-0,8	38,48**	2,1	-1,15	-1,6	64,21*	1,9	0,06	0,1	56,19***	3,1
innovation intensity	0,00	1,2	0,48***	12,0	0,00	0,5	0,44***	7,9	0,03***	2,9	0,46***	6,5
degree education	0,00	1,4	0,03	1,4	0,00	1,1	0,01	0,4	0,00	0,4	0,05	1,1
courses financed by firm	-0,00	-1,4	-0,06**	-2,2	-0,00	-0,9	-0,05	-1,3	-0,00	-1,1	-0,05	-1,3
nat subs.	0,20*	1,7	3,35**	2,1	0,02	0,1	4,97*	1,7	0,25	1,6	1,23	0,7
Eur subs.	-0,18	-1,0	-4,23	-1,6	0,13	0,4	-9,79*	-1,8	-0,41*	-1,7	-0,07	0,0
cont innovation	0,39***	3,6	5,75**	2,1	0,41***	2,8	5,17	1,2	0,42**	2,5	1,22	0,4
innovation written down	0,05	0,5	1,44	0,9	-0,06	-0,5	1,14	0,5	0,32**	2,0	1,13	0,5
certificate	-0,11	-1,4	-3,02***	-2,6	-0,13	-1,2	-1,65	-0,8	-0,05	-0,4	-3,19**	-2,5
change in organization	0,23**	2,5	2,90**	2,0	0,27**	2,0	2,56	1,0	0,28**	2,0	1,28	0,8
customer satisfaction	0,33***	3,4	0,87	0,5	0,38***	2,7	-1,39	-0,5	0,33**	2,3	0,77	0,5
market research	0,06	0,6	0,11	0,1	-0,11	-0,8	-0,51	-0,2	0,23	1,4	0,64	0,4
intermediate	-0,23**	-2,4	-0,90	-0,6	-0,31**	-2,2	0,94	0,3	-0,21	-1,4	0,03	0,0
product innovation	0,61***	11,9	2,52	0,9	0,60***	8,6	-1,94	-0,5	0,66***	8,2	0,38	0,2
process innovation	0,11	1,0	-2,72	-1,5	0,11	0,8	-4,56*	-1,7	0,05	0,3	0,11	0,0
co-op other firms	0,15	1,6	0,26	0,2	0,08	0,6	0,08	0,0	0,23	1,6	-1,09	-0,7
co-op research inst	-0,21*	-1,8	1,50	0,9	-0,09	-0,5	6,06*	1,8	-0,36**	-2,1	-0,03	0,0
co-op universities	0,03	0,2	0,84	0,6	0,22	1,4	1,80	0,6	-0,10	-0,7	-1,19	-0,7
log turnover	0,14**	2,0	-4,67***	-3,8	0,28***	2,6	-6,27**	-2,5	0,03	0,2	-4,05**	-2,2
turnover growth	0,00	1,0	0,04***	3,8	0,00	1,1	0,04***	2,6	0,00	0,5	0,05***	3,1
export growth	0,01	1,1	0,25***	3,1	0,00	0,2	0,24*	1,9	0,02	1,3	0,16	1,5
profit development	0,03	0,7	0,38	0,5	0,12*	1,7	0,41	0,3	-0,08	-1,1	0,37	0,4

dummy loss99	-0,28*	-1,7	5,96**	2,1	-0,09	-0,4	11,14***	2,6	-0,62**	-2,1	2,40	0,7
dummy profit99	0,03	0,2	-0,04	0,0	0,08	0,5	1,73	0,6	-0,09	-0,4	-2,09	-0,9
dummy industry	0,14	1,5	-0,42	-0,2	0,18	1,4	-1,26	-0,4	0,12	0,8	-0,98	-0,4
dummy trade	0,17	1,6	1,09	0,5	0,27*	1,8	-0,67	-0,2	0,09	0,6	1,05	0,4
dummy hotel,transport	0,08	0,5	6,63**	2,2	-0,15	-0,6	11,879*	1,9	0,23	1,0	3,75	1,2
dummy services	0,08	0,8	1,28	0,6	0,19	1,3	1,38	0,4	-0,06	-0,4	-0,26	-0,1
inverse mills ratio			31,66	1,0			-1,16	0,0			-20,75	-0,7
# of firms	1.418		1.099		719		538		699		561	
R^2			0,31				0,31				0,23	
McFadden R^2	0,25				0,244				0,31			

$^{*}p < .10$, $^{**}p<.05$, $^{***}p<.01$

The extent of innovative output is positively influenced by the innovative intensity, national subsidies, continuous innovation, change in the organization, the growth in turnover and the growth in export. Courses financed by the firm, certificates and the turnover have a negative effect on the level of innovative output. The effect of courses and certificates is the same as in the previous analysis. Cources and certificates seem to have a negative effect on creativity and the flexibility necessary for innovation. For turnover there is a positive effect on the probability of having innovate output (the larger the firm measured in turnover, the higher the chance of having innovative output) and a negative relationship with the level of innovative output (the larger the firm, the lower the percentage of innovative output). This confirms the findings of Van Vossen and Nooteboom (1996) that if a small firm decides to have innovative output, they are more innovative than larger firms.
Effects for small and medium-sized firms separately are very similar. The variables *continuous innovation*, *change in organization*, *customer satisfaction* and *product innovation* all have a significant positive effect on the probability on having innovative sales. For small firms, *turnover* (log) has a significant positive effect on the probability of having innovative sales. The variable *Contacts with intermediate organization* has a significant negative effect. For medium-sized firms the variables *innovation intensity*, and *innovation written down* also have a significant positive effect on the probability of having innovative sales, *cooperation with research institutes* has a negative effect.
Most of the variables that influence the probability of having innovative sales do not affect the level of innovative output significantly. The level of innovative output for both small and medium-sized is positively influence by innovation intensity and turnover growth. The level is negatively influenced by turnover (log). Certificates also have a negative effect on innovative output for medium-sized firm.
A striking result is the positive impact on innovative output of the event of a loss in 1999 for small firms. The size of the effect is very large. Small firms with losses could concern firms in the start-up phase, which invest heavily in innovative activities, resulting in modest innovative output, while turnover remains at a low level.

Determinants of firm performance

The last step in our analysis deals with the relationship between innovation and firm performance. We tested for four different performance measures: the growth in turnover, growth in employment, profit and productivity in 1999. We will only present the results of the growth in turnover (Table 4) and employment (Table 5). The regression for profit is not significant and the differences in productivity are only explained by the sector dummies. It is important to remark that the R^2s for the presented equations are relatively low for all regressions. This implies that turnover growth and employment growth are to a large extent explained by other aspects as well.
For all firms as well as for firm small and medium-sized firms separately, the innovative output has a significant and positive effect on the turnover growth. The effect for small firms is stronger than for medium-sized firms.

Table 4 Relationship innovation and turnover growth

	all firms	small firms	medium firms

	coefficient	t-value	coefficient	t-value	coefficient	t-value
constant	26.83***	3.15	35.80**	2.39	19.91**	2.55
innovative output	0.40***	6.73	0.46***	5.27	0.20***	2.88
dummy industry	0.43	0.13	4.34	0.76	-2.18	-0.71
dummy trade	0.41	0.11	2.87	0.47	-1.91	-0.56
dummy hotel, transportation	5.45	0.94	8.79	0.82	3.82	0.76
dummy services	9.13***	2.64	10.61*	1.85	5.73*	1.67
# of firms	1857		999		858	
R^2	0.05		0.04		0.03	
F value	F (5,1851) = 18.19***		F (5,993) = 8.57***		F (5,852) = 5.86***	

*p < .10, **p<.05, ***p<.01

Employment growth is explained by innovative output as well as by turnover growth. For medium-sized firms, the effects are larger. The employment growth of small firms is not explained by the innovative output.

Table 5 Relationship innovation and employment growth

	all firms		small firms		medium firms	
	coefficient	t-value	coefficient	t-value	coefficient	t-value
constant	4.47**	2.48	0.57	0.37	5.82*	1.74
innovative output	0.03**	2.20	0.00	0.69	0.09***	3.00
turnover growth	0.02***	4.87	0.02***	5.51	0.06***	4.18
dummy industry	-0.28	-0.39	0.07	0.11	-0.84	-0.64
dummy trade	-0.27	-0.36	-0.04	-0.06	-0.56	-0.38
dummy hotel, transportation	3.93***	3.21	-0.05	-0.04	5.94***	2.76
dummy services	-0.19	-0.27	0.47	0.81	-0.58	-0.40
# of firms	1847		994		853	
R^2	0.03		0.04		0.05	
F value	F (6,1840) = 8.56***		F (6,987) = 6.64***		F (6,846) = 7.90***	

*p < .10, **p<.05, ***p<.01

Conclusions

Conclusion and discussion

In this study, we investigated the relationship between innovation and firm performance with a special focus on small and medium-sized firms. Based on the literature review, the process approach to innovation was used as starting point. In this process approach, the innovation process is split in four stages. In the first stage, a firm has to decide to be active in innovation or not. Once a firm decides to be active, it must decide how much to invest in innovation, i.e. the input stage. The innovative input has to be transformed in innovative output, i.e. the transformation or process stage. The last stage is the output stage, the actual innovation/innovative sales. This innovative output has to contribute to the firm performance, e.g. in terms of turnover, employment growth or profitability.

The following conclusions can be drawn from our empirical test. The innovative input is explained for small and medium-sized firms by different factors. The size effect becomes clear for the use of subsidies. Small firms use national subsidies, medium-sized firms use European subsidies. Small firms have more innovative input if they innovate in a continuous way. Also medium-sized firms have higher innovative input if they innovate in a continuous way. For small firms also performing market research, having contacts with an intermediate organization and cooperation with other firms and research institutes have a positive effect on the innovative input.

Based on these results one may conclude that the national innovation policy has a positive effect on the level of innovative input of small firms. The use of national subsidies and contact with the (government supported) intermediate organization has a significant and positive effect on the level of innovative input.

Furthermore, we found a negative relationship between firm size (measured in turnover) and the innovative input. Export growth has a positive effect on the innovative input. If the sample is split up in small and medium-sized firms, these relationships are only significant for small firms. This finding is in line with previous empirical research (Vossen and Nooteboom, 1996, Kleinknecht, 2000, Lööf, et al., 2001). Our findings indicate that the negative relationship is especially relevant for small firms. If the firms are bigger and more homogeneous (in our research ten or more employees), the negative relationship disappears. A similar argument can be given for the positive relationship between export growth and innovative input.

The effects of different variables on the innovative output are tested with a type-2 Tobit model. The decision to have innovative output is positively influenced by the continuity of the innovation efforts, changes in the organization, the measurement of customer satisfaction and the focus on product innovations. Strikingly, contacts with the intermediate organization have a negative effect on the decision to have innovative output. The effect disappears for medium-sized firms. This might indicate that contacts with the intermediate organization have a negative effect on the transformation process from innovative input to innovative output. On the other hand, firms may get in contact with the intermediate organization once there are not successful in transforming input into innovative output. It may take time before the contact with the intermediate organization results in innovative output. For medium-sized firms, also the innovation intensity, innovation written down and the cooperation with research institutes have a positive effect on the chance of having innovative output.

The level of the innovative input has a strong positive effect on the level of innovative output. For all firms together, national subsidies, continuous innovation, changes in the organization all have a positive effect on the innovative output. Courses financed by the firm and certificates have a negative effect on the innovative output. It looks like that these aspects hamper the creativity and the flexibility of the employees resulting in a lower innovative output. For small and medium-sized firms separately, most of the effects disappear. Only the effect of the level of innovative input remains significant. Furthermore, certificates have a negative effect on the innovative output of medium-sized firms. Finally, turnover has a negative effect and turnover growth a positive effect on the innovative output.

Our results suggest that innovation contribute to the turnover and employee growth. The employment growth is also influenced by turnover growth. For small firms, the innovative output does not influence the level of the employee growth. The innovative output has no effect on the profitability and productivity of the firm.

To conclude, our research shows that the innovation process of small firms differs from medium-sized firms. Therefore, it is important to treat both groups differently. Our results furthermore suggest that the national innovation policy stimulate especially small firms to increase their innovative input. On the other hand, the innovation policy does not have a direct effect on the innovative output. This might ask for a change in policy, focusing more on the transformation process from innovative input to innovative output. Stressing the importance of continuous innovation, measuring customer satisfaction and the importance of product innovation may lead to an increase in the number of firms that have innovative output. Once they have innovative output, the level of input is important. As stated before, policy on this aspect seems to be effective, at least for small firms.

Finally, innovation seems to have a positive effect on the turnover growth and employment growth of organizations, although the size of the effect is relatively small. We could not find an effect on the profitability of the firm or the productivity.

Suggestions for further research

Based on the results of our study, we can formulate some directions for further research.

In our model, we used a single indicator for innovative input (percentage dedicated time to innovation) and innovative output (innovative sales). However, innovative input and innovative output are multi-aspect concepts. Besides the dedicated time dedicated to innovation also R&D expenditures, the education of the employees, newness of the machines, etc. influences the (quality of the) innovation input. The innovative output may also be captured by the number of patents, new and efficient processes, etc. Further research is encouraged to use these multi-aspects approach to the innovation process.

In our study, we did not find an effect of innovation on profitability and productivity. From a theoretical perspective one may expect a positive effect. For firms that do not invest in innovation one may expect that the profit will decrease over time. Therefore, new research may focus on the relationship between innovation and the development or persistency of the profitability.

In this study, we used cross-sectional data to test causal relationship. To test these relationships, longitudinal data are necessary. Further research is encouraged in this issue.

Literature

Acs, Z.J., and D.B. Audretsch (1993), Analyzing innovation output indicators: the US experience, in: A. Kleinknecht and D. Bain (eds.), *New concepts in innovative output measurement*, London: MacMillan, pp. 10-41.

Amemiya, T. (1985), *Advanced Econometrics*, Oxford, Blackwell.

Ancona, D.G., and D.F. Caldwell (1992), Bridging the boundary: external process and performance in organizational teams, *Administrative Science Quarterly*, vol. 37, pp. 634-665.

Archibugi, D., and G. Sirilli (2000), The direct measurement of technological innovation in business, proceedings of the conference *Innovation and enterprise creation: statistics and indicators*, session A: Survey methodology and measurement, www.technopolis-group.com/innoconf, pp. 3-15.

Arnold, E., and B. Thuriaux (2000), Overview, Technopolis, proceedings of the conference *Innovation and enterprise creation: statistics and indicators*, session C: Innovation and Firm Performance, www.technopolis-group.com/innoconf, pp. 9-14.

Avanitis, S., and H. Hollerstein (2002), The impact of spillovers and knowledge heterogeneity on firm performance: evidence from Swiss manufacturing, in: Kleinknecht and Mohnen (eds.), pp. 225-252.

Brouwer, E., H. Budil-Nadvornikova, and A. Kleinknecht (1999), Are Urban agglometations a better breeding place for product innovation? An analysis of new product announcements, *Regional Studies*, vol. 33, no. 6, pp. 541-549.

Brown, S.L., and K.M. Eisenhardt (1995), Product development: past research, present findings, and future directions, *Academy of Management Review*, vol. 20, no. 2, pp. 343-378.

Cabagnols, A., and Ch. Le Bas (2002), Differences in the determinants of product and process innovations: The Franch case, in: Kleinknecht, A. and P. Mohnen (2002) (eds.), *Innovation and firm performance. Econometric explorations of survey data*, Basingstoke, UK: Palgrave.

Cooper, R.G. (1992), The NewProd system: The industry experience, *Journal of Product Innovation Management*, vol. 9, pp. 113-127

Crépon, B., E. Duguet, and J. Mairesse (1998), *Research, innovation, and productivity: An econometric analysis at the firm level*, NBER Working Paper no. 6696.

Diederen, P., H. van Meijl and A. Wolters (2002), Innovation and farm performance: the case of Dutch Agriculture, in: Kleinknecht and Mohnen (eds.), pp. 73-85.

Dosi, G. (1988), Sources, procedures, and microeconomic effects of innovation, *Journal of Economic Literature*, vol. 26, pp. 1120-1171.

Favre, F., S. Negassi and E. Pfister (2002), The effects of spillovers and government subsidies on R&D, international R&D cooperation and profits, in: Kleinknecht and Mohnen (2002) (eds.), pp. 201-224.

Felder, J., Georg Licht, E. Nerlinger and H. Stahl (1996), Factors determining R&D and innovation expenditure in German manufacturing industries, in: Kleinknecht (ed.), pp. 125-154.

Franses, P.H., and R. Paap (2001), *Quantitative Model in Marketing Research*, Cambridge: Cambridge University Press.

Greene, W.H. (2000), *Econometric Analysis*, 4th ed., New Jersey: Prentice Hall.

Heckman, J.J. (1976), The Common Structure of Statistical Models of Truncation, Sample Selection and Limited Dependent Variables and a Simple Estimator for Such Models, *Annals of Economic and Social Measurement*, **5**, p. 475-492.

Heckman, J.J. (1979), Sample selection bias as a specification error, *Econometrica*, vol. 49, 153-61.

Imai, K., N. Ikujiro and H. Takeuchi (1985), Managing the new product development process: how Japanese companies learn and unlearn, in: R.H. Hayes, K. Clark and Lorenz (eds.), *The uneasy alliance: managing the productivity-technology dilemma*, Boston: Harvard Business School Press, pp. 337-375.

Jong, J.P.J. de, W. Dolfsma, A. Bruins and J. Meijaard (2002), *Innovation in service firms unraveled: What, how and why*, Zoetermeer, the Netherlands: EIM.

Katz, R., and M.L. Tushman (1981), An investigation into the managerial roles and career paths of gatekeepers and project supervisors in a major R&D facility, *R&D management*, vol. 11, pp. 103-110.

Kleinknecht, A. (1996), *New indicators and determinants of innovation: an introduction,* in Kleinknecht, A. (ed.), pp. 1-12.

Kleinknecht, A. (ed.) (1996), *Determinants of innovation, The message from new indicators*, Basingstoke, UK: Palgrave.

Kleinknecht, A. (2000), Indicators of manufacturing and service innovation: their strengths and weaknesses, in Metcalf, J.S., and I. Miles (eds), *Innovation system and the service economy*, Boston: Kluwer AP, pp. 169-186).

Kleinknecht, A., and P. Mohnen (2002) (eds.), *Innovation and firm performance. Econometric explorations of survey data*, Basingstoke, UK: Palgrave.

Kleinknecht, A., and R. Oostendorp (2002), R&D and export performance: Taking account of simultaneity, In: Kleinknecht, A., and P. Mohnen (eds.), *Innovation and firm performance. Econometric explorations of survey data*, Basingstoke, UK: Palgrave, pp. 310-320.

Kline, S.J., and N. Rosenberg (1986), An overview of innovation, in: R. Lindau and N. Rosenberg (eds.), *The positive sum strategy: harnessing technology for economic growth*, Washington, DC: National Academic Press, pp. 275-305.

Klomp, L. (2001), *Measuring output from R&D activities in innovation surveys*, Paper prepared for the ISI 53 conference, Statistics Netherlands, p. 6.

Klomp, L., en G. van Leeuwen (1999), *The importance of innovation for firm performance*, Statistics Netherlands.

Klomp, L., and G.W. Meinen (2001a), Klein en innovatief: rol kleinste bedrijven in innovatieproces niet te verwaarlozen, *Index*, Statistics Netherlands, p. 5.

Klomp, L., G.W. Meinen, A. Meurink, and M. Roessingh (2002), *Knowledge-based economy 2001: R&D and innovation in the Netherlands*, Statistics Netherlands, www.cbs.nl.

Lefebvre, E., and L-A Lefebvre (2002), Innovative capabilities as determinants of export performance and behaviour: A longitudinal study of manufacturing SMEs, in Kleinknecht, A., and P. Mohnen (eds.), *Innovation and firm performance. Econometric explorations of survey data*, Basingstoke, UK: Palgrave, pp. 281-309.

Lööf, H. (2000), Outsourcing, innovation and performance in service and manufacturing industries, *Conference innovation and enterprise creation: Statistics and indicators*, France, 23-24/11/2000.

Lööf, H., A. Heshmati, R. Asplund and S.O. Naas (2001), *Innovation and performance in manufacturing industries: a comparison of the Nordic countries*, SSE/EFI working paper series in economics and finance no. 457, pp. 38.

Mairesse, J., and P. Mohnen (2001), *To be or not to be innovative: An exercise in measurement*, Cambridge, MA: NBER, Working paper 8644, pp. 35.

Meinen, G. (2001), Industriële innovatie, deel II: loont innoveren? *Industriemonitor*, Statistics Netherlands.

Meinen, G. (2001a), Innovatie bij groot en klein, *Innovatiemonitor*, Statistics Netherlands.

Miles, R., and C. Snow (1978), *Organizational strategy, structure and process*, New York: McGraw-Hill.

Mohnen, P., and M. Dagenais (2002), Towards an innovation intensity index: the case of CIS1 in Denmark and Ireland, in Kleinknecht and Mohnen (eds.), pp. 3-30.

Schumpeter, J.A. (1934), *The theory of economic development*, Oxford: Oxford UP (1911, 1980).

Sirelli, G. (2000), Innovation and firm performance, summary of session C, *Conference innovation and enterprise creation: Statistics and indicators*, France, 23-24/11/2000.

Takeuchi, H. and I. Nonaka (1986), The new product development game, *Harvard Business Review*, vol. 64, no. 1, pp. 137-146.

Vossen, R.W., and B. Nooteboom (1996), Firm size and participation in R&D, in: Kleinknecht (1996) (ed.), pp. 155-167.

Voss, C.A. (1994), Implementation of manufacturing innovations, in: Dodgson and Rothwell (1994), pp. 405-417.