On the relation between innovation and performance

Part A: literature overview.

By

Dr Emiel F.M. Wubben
Bedrijfskunde, Wageningen-UR

For:

Dr R.Kemp en dr A.Muizer
EIM, Zoetermeer

Version: 02
Wageningen, 13 May, 2002

1. Introduction

Understanding the relation between innovation and performance in both large and small firms is relevant for researchers, policy-makers and managers of large and small companies alike. Policy-makers have shown an increasing interest in (the understanding of) innovations 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, 23-24 november 2000, p.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 and small?

The objective of this research is to depict the current state of knowledge regarding the relation between innovation and performance in general, and for SME versus large firms in particular. In the EU there are some 19 million small firms (<10 employees) and 40.000 large firms (>250 employees), each employing onethird of the total of 122 million private sector jobs. This research will therefor, first, emphasize the company size related factors in innovation trajectories and growth. Second, it will oversee relevant developments in models and techniques (Muizer & Kemp, May 2001).

The structure of the paper is as follows. In section 2 you will find short description of the various scientific traditions in innovation research. This is followed by an overview of recent major changes in the innovation research apporach, in section 3. Section 4 is dedicated to new innovation indicators, in particular at micro level. Section 5 evaluates several of the old and new innovation indicators. Section 6 and 7 discuss recent empirically oriented publication, emphasizing respectively the innovation process, and the relation between innovation and performance. Section 8 closes that overview section of the paper by adding some further research on innovation indicators. In section 9 takes another perspective on innovation research by providing a brief overview of new methods. Section 10 provides a framework of dependent variables for new research. This is complemented by section 11, which details the relationships between the dependent variables and details the explanatory variables in the framework. The closing section 12 brings together some conclusions and loose ends. Now, first the the context of the research.

2. Context

The literature covered by this paper fits the first of the two complementary traditions in innovation research (Brown & Eisenhardt, 1995, 343-378). That 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 & 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" examines how specific new products are developed, and indicates "the organizational structures, roles and processes that are related to enhanced product development" (Brown & Eisenhardt, 1995, 375; Ancona & Caldwell, 1992). The entrepreneurs and the innovations are placed in the center of the analysis. This second tradition splits up into three streams; the three streams take product development as (1) a rational plan, (2) a communication web and (3) problem solving, taking as objects of research, respectively, successful and failed products, project groups, and development projects. They emphasize as performance parameters, respectively, financial success, perceptual success and operational success. Well known rational plan-researches are the Sappho-studies and the NewProd studies. Much of communication web-research starts from the work by Allen at MIT, and involves, e.g., Katz & Tushman (1981). Case-based research on the Japanese miracle by Imai, et al. (1985), and Takeuchi & Nonaka (1986), evolved into major MIT and Harvard research by, amongst others, Womack, et.al (1990) taking the line that an innovation is about problem solving, as in the activities step model (inn, 2000,7). The 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? The three streams of the second tradition are well established and, taken together, rich sources for further research. However, together they do not clarify the variety in innovation output and innovation performance. For that job the first economics-based research tradition is better suited.

In Europe, in the economics-oriented research tradition, one witnesses an evolution towards evolutionary and learning perspectives (Arnold & Thuriaux, Overview technopolis 2000, p.9). 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 primarely in line with the economics-oriented first research tradition, because it's objective is to depict the current state of knowledge regarding the relation between innovation and performance in general. We will have to see to what extend the evolution in research improves our understanding on the relation between innovation and performance.

3. The relation between innovation and growth: fundamental changes in research.

Since the 1980s one observes major changes in innovation research, namely the introduction of the Community Innovation Surveys (CIS), the process approach and the systems approach. Until than innovation studies followed standardized practices.

Already in the '50s innovation was discussed in technological and economic terms: On the one hand, there is an innovation when a product is successfully developed; on the other, a company, industry or country was considered to be innovative when there are substantial R&D-funds. For long the sole indicators for innovativeness were the expenditures on R&D and the number of employees dedicated to R&D. As a result, based on the *Frascati*-manual of the OECD an impressive longitudinal dataset with various R&D statistics was built up, the socalled Basic Science and Technology Statistics. Thereby innovation research became path-dependent, emphasizing 'hard'-ware and organisational entities. However, given the changing structure of the economy, towards a service-economy, we learn more and more about a shrinking section of the economy (Arnold & Thuriaux, Technopolis, p.12). 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). It was presumed to be efficient. As a result, there were hardly any investigations into the quality of existing indicators and the potential of alternative indicators.

Starting in the 1980s, however, new indicators were developed by various researchers, but also by large institutes such as the OECD and, in particular, the Commission of the EU. In 1992 a pilot study started the Community Innovation Surveys (CIS), which is based on the concept of national innovation systems (NIS). The CIS contains quantitative, dichotomous and polychotomous variables. The first EU harmonized survey, entitled CIS-1, was launched in 1993. CIS-2 was executed in 1996. In the autumn of 2001 CIS-3 started. The introduction and elaboration of CIS actually indicates a fundamental transformation of innovation research: a process approach became prevalent; a systems approach is introduced in (econometric) modelling; and, new innovation indicators have been formulated and tested. We will detail them in similar order.

A major advantage of CIS is that the data is available at firm level. Data from national statistics are typically at industry or national level. The CIS adopts the subject approach, i.e. the firm is the unit of observation. The alternative is an object approach, as used by patent counts and bibliometric counts of innovations. Such an object approach has the advantage that the firm is not bothered by the research, thereby lowering the response burden. On the other hand, it has the disadvantage that the data reveals no direct but derived information. The CIS data are direct data.

For the CIS the EU took a process approach. The CIS brings a three stage, firm oriented data-set (Klomp, 2001).As mentioned earlier standard R&D research was typically confined to the input-factors of an innovation trajectory: the resources (financial, human) allocated to an innovation process. It was common to presume that R&D expenditures would lead to a additional knowledge, and the dissemination of that knowledge base would result in innovations, especially products and processes. However, for several reasons additional insight into the innovation process became necessary. One of the reasons is to find out how to raise the effectiveness of innovation practices, be it via subsidies, enforcing collaborations, sector policies, or otherwise. Another reason is that R&D investments were questioned as the sole driver for innovations, strengthening the competitive position of businesses. The CIS presents a better balance of innovations by representing indicators from all the three stages of the innovation process; That is, it distinguishes between the input stage to the innovation process (e.g. R&D expenditures), the throughput stage (e.g. partner co-operation) and the output stage of the process (e.g. new products). First, there is the input to the innovation process of an industry or firm (e.g. R&D expenses); second we have to distinguish the output of the industry or firm resulting (partly) from the innovation inputs (e.g. productivity); third, when it comes to facilitating the operations of the firm, industry or economy, we call it the throughput character of innovations (e.g. innovation subsidies). It turned out, for example, that the innovation output of Sweden and Finland was relatively low. That assessment was totally at odds with results from traditional research concentrating on R&D-statistics, i.e. at the input stage (Klomp, april 2001, measuring output from R&D activities in innovation surveys). Not all firms are equally efficient in turning reseach 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 & Dagenais (2002), p.4-5).

Another section of the new methodology of CIS is complex systems modelling. The systems approach acknowledges the complexity of the external and mutual influences on the innovation process. The systems approach is often understood as a traditional lineair model, collapsing the three stages into one stage, eg. test the determinants of innovation output. This reduced-form approach holds the risk of a simultaneity bias: e.g. the total sales may consist of new or improved products realised in an unbalanced way over the years (Klomp & Van Leeuwen, 1999, 5). Furthermore, input and output may be influenced by one and the same variable, e.g. technological opportunities. 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 & Van Leeuwen (1999a), 8). We will come back to this model later on. 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.

4.New innovation indicators: macro, meso and micro-level.

Nowadays one witnesses a proliferation of research on new definitions of innovation together with new innovation indicators. Innovation indicators may be split up between macro, meso and micro level indicators on the one hand and between input, throughput and output indicators on the other hand, together providing nine cells of indicators. The SIID-project of the Dutch Ministry of economic affairs constructs a data base of innovation indicators for the service sectors subdivided in macro, meso and micro indicators, based on the level of aggregation at which the data are collected (Broersma, 2001, 2).

At the macro level, the last ten years of innovation research brought us the competitiveness diamond and the innovative capacity of nations. More in general scientists publications on international comparisons of the innovativeness of firms by placing them in a structure of a particular chain, complex or cluster of firms in the same industry (Marceau, 1994, 3-12). The concept National innovation systems is in development but there seems to be no consensus on its structure let alone the causal relations. In contrast, well known is the diamond-concept, pospaited by M.Porter (1990). By means of the diamond-concept Porter tried to answer why some firms in just some countries reap most of the benefits of innovations. To explain this phenomenon firms are considered to function in a reinforcing system comprising of challenging (1) factor conditions, and (2) demand conditions; (3)

the presence of supporting industries; and (4) a specific firm structure, strategy and rivalry. Inventions are included in this model by a chance category. Governments are expected to influence all of forementioned four determinants. The diamant-concept is internationally widely applied, especially for understanding and stimulating specific innovation clusters. As a normative policy-instrument the concept turns out to be better applicable in larger countries than in smaller countries. In smaller countries typicallly one or more of the four determinants are outside the realm of the government for located abroad.

In 2000 in an extensive cross-section time series regression model Porter tested another concept, i.e. the innovative capacity index of countries. First, he took regular indicators, such as the percentage of employees working in R&D in a country, for the common innovation infrastructure. Next, he took the percentage of total R&D in a country funded by industry as a proxy for the clustering factors in a country. Finally, he took the percentage of R&D performed by the University as indicator of the quality of connections between the two. The innovation output was measured by the number of international patents per capita. The variation of the latter across countries could be described by 99%. In the related publication the number of significant factors was high but remained inspecific. The university system does matter (Porter, M.E, (2000), p.12). The per capita international patenting was labelled the National Innovation Index (Buderi, R. (1999).

The meso level analysis seems to be emphasized by the Autralian Bureau of Statistics when it includes in their survey the concept of social capital. Social capital is defined as networks together with shared norms, values and uderstandings that facilitate co-operation within or among groups (Australian Bureau of Statistics, 2001, p.4). No further test-information is available.

At the micro-level several new definitions and innovation indicators have been proposed. First, the 1992 Oslo-manual of the OECD posits an new definition of expenditures related to (technological) effort. It added to R&D expenditures six other cost categories, namely product/industrial design, trials, market analysis/introduction, training, patents and licensing, and innovation related fixed asset investments (Felder et al, 1996, 129; Klomp, 2001, p.3). Total R&D expenditures, also called R&D investments, comprises of internal R&D, external R&D and R&D in collaboration with universities and research institutes (Klomp & Van Leeuwen, 1999, 12). These three subsets together and respectively list the ‘make, buy, or co-operate’ alternatives to management decisions on investments. It turns out that in a sample of 3000 German industrial enterprises intramural R&D covers slightly above 40 percent of total innovation expenditures (Felder, et al, 1996, 130). This is supported by the CIS research, from where it is concluded that in house R&D amounts for less than 50 percent of the total innovation expenditures (Klomp, 2001,3). When services are included a percentage even as low as 25 percent was arrived at (Kleinknecht, 2000, 3). This new indicator has as a downside that including non R&D-items in the questionnaire lowers the response rates and lowers also the precision of answers. The reason is that many firms do not keep related records (Kleinknecht, 2000, 3).

Next, since 1982 elaborate research is executed on the innovation-indicator called new product/service announcements. Those announcements are typically based on trade and technical journals. This indicator has the advantage that it opens up the potential for original research on the basis of relatively cheap, regional specific, public firm data, with a broad coverage.For example, Brouwer, et al. (1999), used the new product announcement indicator to test the urban hierarchy/breeding-place hypothesis. This hypothesis predicts that (large) urban agglomerations will result in a more efficient use of R&D inputs to realise innovative output. The authors derived and confirmed that peripheral regions tend to have a bias towards process innovation (Brouwer, et al., 1999, 542). The related socalled Manshanden’s agglomeration index was indeed significant at 99% level in explaining the announcement of new products or services in trade journals. Alternatively, research on new product/service announcements resulted in a series of studies on the relationship of firm size, market structure and innovation (for an overview, see Acs & Audretsch, 1993).

The EIM published explorative research on the innovative ability and innovative intensity (0010/A; 9912/A). The innovative ability is the micro level ability of the employees of a firm to generate ideas and to work with these ideas to develop new or improved products, services technologies, work processes or markets (0010/A, 13) The company that can realise a flow of new products and services performs better. Innovative ability is considered to be a prerequisite condition to be able to implement ideas in an actual innovation. For finding the antecedents of innovative ability 38 determinants were tested from the categories people, strategy, culture, structure, availability of means, network activities, enterprise, and the market. From the tests the following four most important determinants emerged: the willingness to take risk (people), result orientation (culture), high intensity of non-price competition (market) and high uncertainty of demand (market). Together they explain 77% of the variance in the innovative ability of service businesses. Using the process approach the EIM tried to bring innovative intensity to test. Innovative intensity is typically defined as the number of new products introduced to the market, the number of requested patents, etc. By using what is called the direct method of testing innovative intensity the quality of a number of innovative dimensions is measured. No final conclusions are drawn.

Furthermore, Mairesse & Mohnen (2001) propose two new indicators based on an innovation accounting framework: expected innovation and innovativeness. The latter is defined as the difference between the actual and the expected share of innovative sales. It is the unexpected,unexplained, or residual part of the actual observation which remains unaccounted for by the prevalent models. It corresponds to omitted factors like organisational and cultural factors. The parallel can be drawn with total factor productivity in the growth accounting framework. The expected innovation is defined as the expected share of firm innovative sales. It is derived from the recent share-in-sales indicator of innovation. The share-in-sales indicator is an output indicator of recent date. The main advantage of this indicator is the direct link between the innovation effort and the commercial success. It explicitly focusses on the added value of innovation for a common objective of firms, that is growth. The share in turnover of products new to the firm or new to the industry is already part of the CIS. As a consequence the share-in-sales indicator is widely used in research.

Finally, Mohnen & Dagenais (2002) propose yet innovation indicator, which is both constructed on the basis of and exploits the CIS-1 dataset. The authors propose as new indicator the conditional expected share in sales of innovative products. “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 & Dagenais, 2002, 26) This composite indicator combines the estimated probability to innovate and the estimated percentage of sales resulting from new products. The indicator links up to the Mairesse and Mohnen (2001) paper already discussed. However, as yet no more than a single test exists of this complex innovation indicator (Mohnen & Dagenais, 2002). Therefor, we will not go into details any further.

5. Evaluating innovation indicators.

We will discuss in extenso Kleinknecht’s overview article addressing the strenghts and weaknesses of several traditional and newly developed innovation indicators (Kleinknecht, 2000). The indicators discussed are R&D and patents, respectively total innovation expenditures, new product announcements and shares in sales of new products.

Traditionally and still the most popular are the indicators expenditures on R&D (in currency or some percentage) and the number of employees dedicated to R&D. They are still developed as indicators. Several weaknesses can be mentioned, First, R&D in merely an input to the innovation process, but it states nothing on the results, or the efficiency. Second, R&D related inputs make for a minority of innovation expenditures, varying from 25-50 percent. Third, R&D data tend to underestimate innovations in services. Fourth, official R&D surveys underestimate innovation (costs) in services. Fifth, R&D questionairres underestimate the small scale and often informal R&D activities in smaller companies. Complex questioning may result in such underestimation. It is noteworthy to mention that the number of firms that receive R&D subsidies by over 200% exceed the numbers of R&D

performing firms according to an official R&D survey (respectively 10.000 and 2,900 in 1997). Six, the promotion of subsidy schemes for SME may, by itself, have resulted in higher reported figures on R&D by SME. Seven, multi-plant companies may cause the “Singapore-effect”: R&D may be reported or even done from another location than the affiliate introducing an innovation.

Patents are often used as an (intermediate) output indicator of innovation. The advantages are first the abundancy of publicly available information, with, second, the minor disturbances in these series. First, the relative importance of patents can be assesses by using citation analysis. Problematic with this indicator is, first, the strategic use of patenting, that is to misguide a competitor. Second, many (esp. service-related) innovations cannot be patented or are just not patented. Third, patenting or not will depend also on how high imitation costs are relative to innovation. Fourth, several findings suggest that ‘time lead’, ‘secrecy’ etc. are more important to appropriate innovation benefits than patent protection. Fifth, high-tech sectors tend to have a higher prospensity to patent. Sixt, 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 info that transaction costs are high for small firms who are first to patent. However, it turns out that once these small firms patent they apply for relatively higher numbers of patents.

The share in turnover of certain products, new to the firm (imitations) or new to the industry (true innovations) , was mentioned already as new output indicator being part of the CIS. The main advantage of these indicator(s) is the direct link made between the innovation and the commercial success, re-establishing the link with Schumpeter again. Second, the efficiency of the research, both at input and as throughput, can now be estimated. Third, such indicator can more easily be adapted to services sectors and regional disaggregation. This indicator suffers from two disadvantages: First, the survey method needed suffers form a low (and possibly selective) response. Second, the comparison of this indicator over sectors is problematic because of the divers product life cycles between branches. In multivariate estimates the product life cycles by sector should be an important control variable.

As stated screening the indicator called new product/service announcements from trade and technical journals is practice since 1982 already. Interestingly, the hierarchy/breeding-place hypothesis would have been rejected when using merely R&D input data instead of data on new product/service announcements (Brouwer, et al. 1999, 547). Thus, from empirical tests it may be concluded that the innovation output variable new product/service announcements adds insights to innovation research. There are major advantages to this indicator (Kleinknecht, 2000, 7): First, it is also a direct measure of the innovation output. Second, it is cheap to collect, bypassing any non-response problem and any privacy problems. Third, it is possible to split these data by type of innovation (differentiation, imitation, etc.), degree of complexity, etc. Fourth, data from small firms can also be covered easily. Fifth, a broad coverage of sectors (including services) and intersectoral flows can easily be realised. The first disadvantage with this indicator is the troublesome inter-country comparison. The number of (adequate) journals covered determine the number of counted innovations. The comparison via ratio’s 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. According to Kleinknecht (2000, 8) this is not such an issue.

The Kleinknecht (2000) multivariate analysis is positive on the new indicators: The conceptually different and qua measurement independent indicators new product/service announcements and the share-in-sale indicators are robust: The former, in publications, is on market introductions, while the latter, in monetary terms, is on successful innovations. The signs of the coefficient of explanatory variables turn out to be robust to such differences!

6. Applications of new approaches and new innovation indicators: the innovation process.

Recent applications of new indicators and methodologies provide us with interesting new insights into the innovation process. For example, many publications of recent date applied both the systems theory, the process approach, and related new indicators. For example, the research of the CBS, Netherlands Statistics, on ‘knowledge and economy’ takes institutions and knowledge flows as part of the national innovation framework.

The Eurostat-backed CIS detailed the following innovation indicators: at the input stage, a.o. intramural or in house R&D, and innovation expenditures; at the throughput stage, extramural R&D, sources of information, and innovation cooperation; and, at the output stage, realised innovations and the turnover of new products (Klomp & van Leeuwen, 1999, 7). Derived indicators are R&D intensity and innovation intensity. R&D intensity is defined as R&D expenditures divided by value added. Innovation intensity is usually defined as the total of innovation expenditures divided by the total turnover of companies in a country.

The CBS linked the concept of innovation systems, based on CIS-2 data, to the so-called Production Surveys (Klomp & van Leeuwen, 1999) The input indicators discussed are (intramural) R&D and total innovation expenditures. In 1996, R&D realised 35 percent of total innovation expenditures, with innovation related machinery and equipment at 39 percent. Compared to their added value manufacturing contributes for 57% of total innovation expenses (75% of intramural R&D), while the added value of the Netherlands is dominated by services.

Throughput indicators used are extramural R&D, co-operation and sources of information. When it comes to sources of innovation 96 percent refers to various sources within the industrial column, but it is dominated by sources within the firm. External advisors are referred to only by 52 percent. Innovation centers are as popular by small companies (10<49 workers) as with larger firms. Publicly available sources are indicated by 79 percent, especially referring to conferences/journals and fairs and exhibitions. 24 percent of all innovating firms participate in joint co-operations. The small industrial companies, arriving at 18 percent, are the least interested. 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. Output indicators referred to are new products and new processes and resulting turnover. Remarkable especially for manufacturing is the high number of firms who introduce new products, i.e 90 percent, also introducing new processes, i.e. 74 percent. For services the innovation of a service cannot be disentangled from the innovation of the service process. In the Netherlands, in manufacturing, on average 25 percent of turnover (1996) was the result of new or improved products. But small firms (20<49 workers) questioned on this item report on average no more than 15 percent. The CBS posits that the negative result on size is zero once we restrict ourselves to the subset of innovators (Klomp & Van leeuwen, 1999, 31).

Following Kline & Rosenberg (1986), in their model Klomp & Van Leeuwen (1999) structure the innovation process with, in order, the sector-specific market potential, the technological environment, the innovation inputs, the innovation throughput, and the sales/performance. Several feedback loops are detailed. The use of technological opportunities in the environment may both affect the level of inputs and throughput directly. Innovation output, via overall performance, is stated to affect the innovation expenditures. Overall sales growth may also affect the level of innovation output directly. Its overall economic performance may affect all three stages of the innovation process of a firm. The growth of total sales is clearly higher for innovating firms than non-innovating firms. In modelling the following sets of exogenous variables were uses: financial, organisational, industry-specific (cf.Pavitt), size, and innovation objectives. The following four equations were estimated simultaneously:
innovation intensity;
log-odds ratio innovative sales to total sales (i.e., the innovation-output indicator);
average growth of total sales; and,
average growth of total employment.
Innovation intensity was made dependent on the second and third equation; The innovation-output indicator is made dependent on the first and third equation; The average sales growth is made dependent on the second equation; the average employment growth is made dependent on the

second and third equation. From the simultaneous model the following conclusions were drawn: financial variables (cash flow, subsidies) contribute significantly to the level of innovation intensity. The technological opportunity science added to the level of innovation intensity, Permanent R&D and innovation in partnership raise significantly the level of innovation output. Innovation output in turn raises significantly sales growth, but not employment growth. In contrast to the single equations estimates the Schmookler's demand-pull hypothesis is confirmed via firm sales on the level of innovation intensity.

In a recent paper the CBS together with TNO detailed the input, throughput, and output order of the innovation process for the Knowledge Based Economy (Klomp, et al, 2002). The <u>input stage</u> consists of human capital (students, secondary vocational training, graduates finding a job, company financed courses, and, finally, human resources in science and technology), next to the technological knowledge base of Dutch institutes (research institutes, universities, and private firms). The <u>throughput stage</u> is on 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. The <u>output stage</u> consist of innovations and economic performance, next to the value added of partnerships (Klomp, 2002). The paper is descriptive in principle. The elaborate and multi-faceted concept seems promising but a shortage of data will make it hard to test it.

The CPB reports several problems interpreting the new CIS-2 data on innovation intensity(CPB, 2002). Innovation intensity comprises of innovative expenditures divided by total industry turnover. The definition of innovative expenditures may count double, as the purchase of equipment results in innovative payments for the buyer, while it is already listed as R&D expenditures for the selling company. Furthermore, the denominator turnover is wrong for extra turnover is added to each and every (extra) purchaser further in the chain. The latter problem could be solved by substituting added value for turnover. Another problems is the contradictory information about intramural R&D. Such data is gathered by CIS-2 and the OECD independently and compared by the CPB. Six out of 14 countries reveil results diverging up till 50% in both directions(CPB, 2002, 6-7). CIS-2 results are questioned. The causes behind the data-problems may be international differences in sector classifications, (partial) non-response, and misinterpretation of questions. An alternative indicator is presented: innovation intensity is defined by the intramural R&D expenses, corrected (divided) for the proportion of these expenses in total innovation expenses, and divide the total by the sum of the added value of an industry. We would like to conclude that changing the denominator is to be applauded but sticking to R&D data would blind us out of free will from what is going on in services and in smaller firms.
The OECD and CIS data were also compared by Lööf, et.al. (2001). Using a Cobb-Douglas production function they try to explain variation in productivity growth between the Nordic countries, using standard inputs and the innovation investment variable, which substitutes the R&D variable. Using a Crépon, Duguet and Mairessemodel (CDM) they estimate the following four equations:
(1) firms' prospensity to innovate;
(2) innovation inputs (innovation investment per worker);
(3) innovation output (log of innovation sales per worker); and
(4) productivity (sales per employee).
Throughput is not formally included in this set of equations. A two-step investment model is applied: First, the decision to engage in research must be taken (eq.1); Next, conditional on engaging in research, the amount of investment must be decided upon (eq.2). Innovation output (eq.3) is dependent on innovation inputs (eq.2), reflecting the productivity of the innovation process; Productivity in general (eq.4) is dependent on equation 3. Equations 3 and 4 are estimated together in a 3SLS simultaneous equation system, incorporating feedback effects from productivity (predictions) to innovation output, to account for the simultaneity bias. Equation 1 and 2 are Probit and Tobit models respectively (see *. In general the model is of traditional style emphasising patents, and regular additive regressions. However, the conclusions were highly confusing at cross-country level. The model specification, and the representativeness of the respondents may explain the problems.

Felder, et al (1996), already mentioned, used the Mannhein Innovation Panel to test the relation between R&D and other innovation expenditures. The data set contains a small firm subset containing firms with 5 up till 49 workers. Some innovation parameters are: total innovation expenditures divided by sales; current innovation expenditures divided by sales. The first measure includes both current and capital expenditures on innovations. The latter does not suffer from rough estimates for the capital costs for innovations. It is concluded that the analysis arrives at similar conclusions for R&D expenditures and innovation expenditures. The participation decision to innovate raises strongly with size. However, once innovating, the amounts invested as percentage of total sales is larger with small firms than with large firms. This is confirmed by Vossen & Nooteboom (1996). This effect is most pronounced for the total innovation expenditures. The relationship between firm size and R&D seems U-shaped. Vossen & Nooteboom conclude that small firms participate less in R&D, but at a greater intensity and with a greater productivity once they participate (Vossen & Nooteboom, 1996, 167)

7. Applications of new approaches and new innovation indicators: on innovation and performance.

In a set of three papers on innovation and firm performance, presented at a 2000-conference on statistics, the indicators on innovation performance were innovation intensity based on total innovation costs; R&D intensity; new product sales; and, measures based on investment expenditures. The economic performance measures were: sales per worker; exports per worker; growth rates of sales, assets and employment; operating profit ration; and, return on investment. Three micro-level studies, combining national and CIS-data, on the Netherlands, Norway and Sweden confirm that innovation has a positive effect on company performance, especially sales. The effects on employment and profitability are conflicting. They may be in need of sectoral contextualisation & Arnold Thuriaux, 2000, 10-11). The combination of different data sets is appreciated but further research is considered necessary.

A recent publication edited by Kleinknecht and Mohnen, and entitled *Innovation and firm performance. Econometric explorations of survey data* (2002), further adds drastically to the empirical knowledge on the innovation-performance relationship. It presents a series of 13 revised workshop-papers, all using innovation survey data to explore “a wide range of topics on innovation, from measurement issues, to sources and effects of innovation.”(KM 02, xix). Most data are cross-sectional data from a single survey. Actually the number papers on performance is restricted to five papers of which two papers on export performance. We will here detail the most relevant results (KM 02 xix-xxi).

With regard to determinants of innovations four papers examine the influence of the following list of variables: firm size; market concentration, diversification, competition amongst innovators, vertical integration, firm age or experience, group or consortium membership, foreign ownership, capital intensity, export orientation, sources of knowledge, appropriability conditions, R&D intensity, research organisation, and other firm strategies (KM 02, xxii-xxv).

Four papers discuss R&D collaboration and knowledge spillovers. Amongst them Favre, et al. concentrate on the influence of French and EU subsidies on R&D and international R&D spillovers. They conclude that subsidies from the French government or the EU have a positive effect on R&D dedicated to international co-operation (KM 02, xxvii).

According to KM (2002), what are the relevant innovation determining factors? (1) The probability of being innovative increases with firm size, although some papers argue that it may be in a non-linear manner. (2) The share in sales of innovative products in total sales 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. (3) Demand enhances innovation (Schmookler-effect) and innovation enhances demand, but the evidence is still inconclusive on the relative strength on causation in either direction. (4) There is neither strong not conclusive evidence on the conductiveness of market power to innovation. Various papers conclude either that competition, intermediate levels of competition or monopoly stimulate innovation. (5) Innovative firms seem to be active at one and the same time in various complementary directions such as internal R&D, external R&D, and R&D collaborations, or in integration, organisational changes and marketing. Innovation is stimulated stronger when customers and universities are important sources of information than when competitors and suppliers take that position. (6)

KM distinguishes also between determinants of product and process innovation. Product innovation is stimulated by the following factors: (1) technological competition (percentage of innovators in one sector); (2) downward and horizontal knowledge sourcing, and the inverse of industry R&D spillovers; (3) diversification, laboratory research, innovation experience, and high capital intensity. In a similar vein process innovation is favoured by (1) firm size; (2) economic competition (various measures), foreign ownership and a recession; (3) upstream sources of knowledge and consortium research. On the other hand, also the complementarity between product and process innovations is concluded by some. Cost-reduction strategies seem to stimulate joint process and product innovation over product innovation alone.

The two final papers in the volume examine the (causal) relationship between innovation and export performance. Levebvre and Levebvre try to find out how technological (R&D, level of automation, knowledge intensity, quality norms, unique know-how) and commercial capabilities (trademarks, networking, distribution access, manufacturing agents, and import activities) stimulate export. Kleinknecht and Oostendorp 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 higher share of higher educated personnel enhances both R&D and export performance.

8. Additional research on innovation-indicators

Three papers were found comparing innovation in large and (very) small companies. Both Meinen (2001a) and Klomp & Meinen (2001a) explicitly detailed a segment comprising of companies with 1 to 10 workers. From the interpretation of descriptive data over 1996-‘98, on manufacturing and selected services, the following was concluded regarding the smallest firms (1<10 workers) (average for all firms between brackets):

Of these companies 30 percent realised innovative activities (innovativeness), vs 40 percent for all other firms.
The sum of their innovative expenditures add up to 1.4 billion guilders (1998), 9 percent of the total. The smallest firms paid out on average 85.000 guilders on innovation expenditures.
In industry, 30 (22) and 51 (44) percent of respectively product- and processinnovations is realised by a third party (extramural R&D).
In industry, by 1998 32 percent of turnover was new to the firm, developed in this period. Of that total group of innovators 31 percent (39) developed products also new to the sector, realising 24 percent (18) of total turnover in 1998.
The smallest firms who realised both technical and non-technical innovations it turned out that 72 percent of them assessed the latter as the more influential one!
32 percent of the smallest innovating firms claim that their competitive position versus the market leader has improved especially due to non-technological innovations, against 25 percent of the other innovators.
In industry, less than 40 percent experience serious bottlenecks. Of these firms, relatively speaking many small firms, ie. 54 percent (49), an innovation trajectory was cancelled very early in the process. Once started a relatively small section of these small firms stopped during the process, i.e. 25 percent (33) or was severely delayed, i.e. 44 percent (56 percent).
The Process or non-technological innovations may relate to strategy, marketing, organisational form, and reorganisation (Klomp & Meinen, 2001, 18-19).

In a more advanced multivariate analysis Kleinknecht (2000) discussed the differences in innovation between large and small companies It answered the following two questions: first, what factors influence the probability that a firm will innovate at all; second, given that a firm innovates, which factors influence the innovation intensity (number of new products; share in sales by innovative/imitative products). From the estimates (from 10 persons upward) the following conclusions regarding SME are drawn (Kleinknecht, 2000):
A high ‘small business presence’ seems to have a positive impact on the diffusion of imitative innovations.
The probability that firms are innovator increases less than proportionately with firm size. Among the innovators, smaller firms tend to have higher shares in sales of innovative products.
In the, SME-dominated, services, the (absolute) number of new product/service announcements did not increase with firm size.
Furthermore, Schmookler’s demand pull effect on innovative output was confirmed. Kleinknecht concludes that R&D efforts in smaller firms tend to be undercounted in R&D surveys, that subsidies may bias R&D-reporting upward, and that patent figures undercount the number of small innovators, overestimating the intensity of small firms that patent (Kleinknecht, 2000).

But what is the impact of innovation on performance? Publications are positive about its effect on profits and turnover. Diederen, et al. (2002) conclude that innovative farmers show significantly higher profits and growth figures than firms that are not innovative (Diederen, et al, 2002, 81-83). Also Favre, et al (2002) conclude there is a positive impact of innovations on profits. They take R&D intensity, market share, and concentration as the relevant causal factors. Also national R&D spillovers, and, moreover, international R&D spillovers are positive for profits (Favre, et al, 2002, 218-9). 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, 246). The deliberate pursuit of certain objectives (e.g. creating a new market) and higher appropriability conditions raise the return to patents. In another publication and on the basis of 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, realise extra turnover of one procentpoint over 11996-’98. Permanent R&D raises the turnover by 8.5 percent, due to the new products. Co-operation would add an extra 2 percentpoint. The use of information sources adds another 6 percentpoint. The process approach and the systems approach turned out to be useful tools to investigate such questions.

9. New methods

From the articles analysed a clear evolution. As the reduced form equations are no longer acceptable and feedback relations are to be expected, then tobit, generalized tobit, probit, and the Hackman-model are becoming more and more standard practice. In the tests by Klomp & Van Leeuwen (1999) the log-odds of the ratio (P) of innovative sales to total sales is used. The log-odds is Ln(P/1-P). The advantage is that it makes it possible to infer from the estimates directly the impact on total sales and employment. Important here is, however, that this formula is in troubles with a 0 or 100 percent turnover share of innovative sales. That is with new companies or non innovative companies. There Tobit etc comes in. Klomp and Van Leeuwen (1999) assume that the innovation input, the probability of innovation success and firm performance are jointly estimated (Klomp & Van Leeuwen, 1999, 55). As a result they estimate a simultaneous equation model with the method of Full Information Maximum Likelihood in TSP 4.3. For example, the single equations approach and the simultaneous-equation model show substantial differences. For example, the feedback loop starting from firm performance changes from the output stage to the input stage (Klomp & Van Leeuwen, 1999, 56-7).

Tobit is typically introduced to adapt for the conditionality of an equation on a certain decision, e.g. to innovate or not. One needs a Tobit analysis plus the imputation of values marginally different from the limits 0 and 1, to enable a re-estimation of the simultaneous model. 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 Hackman-modelling for the simultaneous-equation modelling. Hackman (1979) allows to identify the parameters of the participation model and the intensity model separately (Felder, et al, 1996, 139). I conclude with the obeservation that the data gathering for and the data analysis of the CIS itself is continuously improved. This is illustrated, e.g., by the changes in the questions of CIS-1 to CIS-3, But also by the proposals to change definitions or indicators.

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.

To make things even more inconclusive take head of the following exerpt from KM (2002). "Innovation survey data have peculiar characteristics, which require some special econometric techniques and invite us to be modest regarding the results obtained."(KM 02, 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) the 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, eg. 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."(KM 02, xxviii)

10. Modelling the added value of innovations. The endogenous variables.

It is remarkable to find that the literature hardly takes a serious managerial approach towards distinguishing amongst companies on the basis of different patterns of adaptive behaviour. It is probably due to the macro-economic tradition where this research tradition derives from. As a consequence, international comparisons are rather standard practice (eg. Lööf, et al., 2001; KM 2002). In such publications the amorphous population distinguishes between those who innovate and those who do not innovate. Another distinction made is a sectoral analysis, following Pavitt (1984). However, there is seldom a subdivision according to strategic orientations. E.g. the well known Miles and Snow segmentation between between prospector, analyser, defender and reactor (Miles, et al. (1978) has the advantage that it is consistent with more management oriented models and ideas formulated by Chandler, Child, Cyert & March, Drucker, and Weick. The defender deliberately enacts and maintains an environment for which a stable form of organization is appropriate. Searching for market niches, his prime capability is from efficiently serving a stable domain. The prospector typically enacts in an environment that is relatively dynamic. His prime capability is that of finding and exploiting new product and market opportunities. The analyser attempts to minimize risks while maximizing the opportunity for profit. He must be able to follow suit via imitation when an innovation has proven its viability. The three types define differently but consistently the entrepreneurial problem, the engineering problem and the administrative problem. The, negatively defined, reactor type is inconsistent in dealing with such problems.

The disadvantage of Miles & Snow (1978) for innovation research is that it emphasises the external above the internal factors. The new innovation-research combines both internal and external factors. This downside of the Miles & Snow models may be compensated by emphasising more the systems theoretical element. We may arrive at the following segmentation of companies: output-oriented, allrounders, proces-oriented, and leggards. The first and third group of companies stress the output respectively throughput of the innovation process. The second and fourth group of companies cover all respectively none of the three segments in the innovation process, that is input, throughput and output phase. The advantage of the latter segmentation of companies is that it links easily with recent innovation research. Such typologies may be useful when researchers want to stay close to actual business practices, namely when using the subject-approach. We will call these alternative orientations the strategic orientation of a firm.

Furthermore, innovations may be new to a specific disaggregate domain (e.g. new to the firm) but not to the more aggregate domains (e.g. or new to the industry, country or economic region). New to the firm but not new to the industry implies that the innovation was “imitative” at the level of the industry (Klomp, 2001). However, the same can be said for the other levels of aggregation: e.g. a product new to the sector may be assessed “imitative” at the level of a country. By distinguishing between the different levels of aggregation useful insights may be derived regarding the degree and kind of innovativeness of companies. On the other hand, the difference will get blurred between fundamental vs. incremental innovations. The added value of the former countervails the loss of clarity at a theoretical level.

The overview of research should lead us to suggestions as to detail new econometric innovation research? As stated in the introduction the objective of this research is to depict the current state of knowledge regarding the relation between innovation and performance in general, and for SME versus large firms in particular. We have found that the process approach and the systems approach bring forward serious advantages above older single regression modelling. Furthermore, the subject approach seems useful as it sets center stage direct micro-data from the companies themselves (e.g. innovation related turnover) instead of derived information, as with the object approach (e.g. new product announcements).

Based on the literature we suggest the following list of endogenous variables in line with the system theoretical approach of innovation. This approach is based on the Crepon, Duguet and Mairesse-model which consists of an related set of 4 equations, covering roughly the input, throughput output, and performance-sedction of the systems-approach to innovations. Related to that structure, the first two variables of our list are directed at the input phase of the innovation process, concentrating on respectively on the innovation decision and the innovation intensity. Next we have dependent variables directed at respectively the throughtput and the output phase of the innovation process. Finally, the performance of the integral innovation system is depicted by variables oriented at the objectives of the management of the firm or at policy objectives.

<u>1. Prospensity to innovate</u> (see Lööf, et al, 2001) Prime in any innovation research should be to answer the question what factors influence the companies’ intention and/or decision to innovate. Our research focusses on the SME. Especially the set of smaller companies splits up between those that are inclined to innovate and others that do not. This decision is modelled as a Probit [0,1]-model. Alternatively, one may consider similar variables such as innovative ability. Innovative ability emphasizes the ability of the employees of a firm to generate ideas and to work with these ideas to develop new or improved products, services technologies, work processes or markets. However, that latent variable is actually a measure of effectiveness: Are employees able to deliver new or improved products or services, open new markets, etc? It has the major disadvantage that it does not concentrate on the factual problem that many companies do innovate while seemingly comparable other firms do not innovate. Therefor, the prospensity to innovate as dichotomous <u>yes/no-answer to the question do you innovate</u> is a variable better attuned to this problem. The phenomenon of (non-) participation in an innovation trajectory is still hardly understood. Also for policy reasons,e.g. to further the European competitiveness agenda, additional knowledge on this item is valuable. We therefor take innovation prospensity as an dependent variable.

2. <u>Innovation intensity</u>. Conditional on engaging in innovations, the innovation intensity must be assessed. It concentrates on understanding the determinants of the level of resources dedicated to the innovation proces. Innovation intensity is usually defined as the total of innovation expenditures divided by the total turnover of companies in a country. This dependent variable is modelled as a a tobit model, conditional on having decided to invest in innovations (Lööf, et al, 2001, p11). The literature provides us with several indicators of the innovation intensity. First, Mairesse and Mohnen

(2001) take the share of new products in total sales as indicator for innovation intensity [cf. EIM]. It has the advantage that the final objectives of innovation trajectories is taken into account, i.e. extra turnover and/or profit. Second and alternatively, total innovation expenditures as percentage of total turnover may be used as indicator for innovation intensity (Klomp & van Leeuwen, 1999). As presented in par. 4 total innovation expenditures is an indicator of recent date, i.e. since the start of the Community Innovation Studies. Vossen & Nooteboom (1996) claim that the relationship between firm size and the amounts of money allocated to innovations is most pronounced for total innovation expenditures. This innovation intensity variable was preceded by R&D intensity, denoting the R&D-expenditures, internal and external, scaled by total sales. R&D and innovatio expenditures are highly correlated (Mohnen & Dagenais, 2002, 13) The use of total sales as denominator is general practice, for it is more does not require the imputation of depreciation costs (Klomp & Van Leeuwen, 1999, 44n16). As indicated in par.5 the use of this scaling factor is not without disadvantages. We will take the total innovation expenditures per unit of turnover, as indicator of innovation intensity. Alternatively, R&D-expenditures per unit of turnover may be tested against. The share-in-sale variable is better used for output measurement.

Deleted: second variable

3. Throughput evaluation. The evaluation of throughput may be evaluated along two lines of arguments: One line of argument is to concentrate on how expensive the innovation creation proces is. Another line of argument is to emphasize how much is going on in this innovation creation proces, the innovation efforts. Along the first line, throughput analysis functions as a measurement of efficiency of innovation processes: the ratio of innovation output and innovation input. The Innovation intensity variable may be used for this throughput evaluation (cf. Klomp & van Leeuwen, 1999). The disadvantage of this measure is that throughput remains no more than a closed black box. That is in contrast to the now prevalent views on the innovation, which emphasises the enhancement of understanding of the integral innovation trajectories. Therefor, along the second line of argument, throughput is understood to detail the innovation creation proces. As a consequence, one may focus on the internal and external orientations and relationships of the company. For example, is the company part of a larger network? Was innovation part of the company strategy? An indicator of this positive approach is the number of innovation trajectories (‘vernieuwingsinspanningen’). Subsidies as well as total innovation expenditures may be taken as innovation input factor in line with the first dependent variable. Subsidies may also indicate as innovation thoughput factor. In the latter case, innovation policies, and subsequent subsidies, are aimed at removing impediments in the functioning of the innovation system (Klomp, et all, 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 organisation via national or european institutes. Finally, a means of removing impediments is by offering support to firms, eg. via management support, the provision of specific information, etc. In the Netherlands, Synthens brings to the organisation capabilities potentially useful in the process of innovation. When the number of innovation trajectories turns out to be an inadequate throughput evaluator one may use the alternative, that is, the innovation intensity variable.

4. Output evaluation. A prevalent measure of innovation output seems to be the share-in-sales of new products or services (‘aandeel nieuwe producten of diensten in totale omzet’). It is present in Mairesse & Mohnen (2001), Klomp & Van Leeuwen (1999), and in Lööf ,et al.(2001). Kleinknecht (2000) uses the share-in-sales indicator for his innovation intensity variable. Innovation output may be restricted to the first phase of the innovation trajectory, that is, the formalisation of an model or idea still to be tested. The number of patents may be an apt indicator. Such a restriction is useful for the distinction between output evaluation and performance evaluation. An innovation may also be pre-tested but not yet introduced at large scale in the market. An indicator of this situation may be new product-announcements. In contrast, the share-in-sales indicator includes the total innovation trajectory, including the market introduction trajectory. Here also the externally oriented use of market intelligence and the systematic analysis of client satisfaction may be of additional explanatory relevancy. Kleinknecht (2000) concludes that the share-in-sales indicator is robust as innovation indicator, when compared to new product announcements. Klomp & van Leeuwen (1999), as discussed earlier, take the the log-odds ratio of innovative sales to total sales.

5. Performance evaluation. The innovation-performance may be measured by measuring additional turnover, i.e. average growth (Klomp & Van Leeuwen, 1999) or additional net profit. Note that one should distinguish the absolute added turnover or profit from a relative share in turnover or profit. Finally, for the sake of the EU-ambition of creating the most innovative economy in the world one may derive additional variables, i.e. average growth of) productivity (Lööf, et al, 2001) and (average growth of) employment (Klomp & van Leeuwen, 1999). For governmens it is relevant to know the changes in productivity per employee which may be denoted as the changes in sales per employee. Changes in employment is easily listed and explained. With regard to the relation innovation-performance one may conclude that there is confirmed direct relationship established between innovation and turnover growth, but the direct relation between innovation and employment seems harder to prove. We will use additional turnover and productivity as endogenous variables.

11. Modelling the added value of innovations: Explanatory variables.

When we model the respective equations both the relations between the endogenous variables themselves and the exogenous and control variables must be made explicit. We will used the following list of endogenous variables and abbreviations:
1.Prospensity to innovate: Pti
2.Input: Innovation intensity: Innint
3.Throughtput: Innovation efforts: Inneff
4.Output: Log odds share-in-sales: LoP
5.Performance:
5A: Productivity: Prod
5B: Average sales growth: DlogS

What are the variables that explain these endogenous variables? First, some remarks of general relevancy. We will use thew term innovation to denote various forms of renewal. As a consequence the term product innovation should be understood to refer also to innovations in services and innovation-oriented changes in processes. Especially in services the distinction cannot be made. All endogenous variables will have a constant term and an disturbance term as exogenous variable in the estimations. Industry dummies see Pavitt 1984) will be used to capture the industry specific opportunity conditions (product life cycles), and the sector specific innovation policies. Size is a standard factor to be taken into account. Firms size may be used to reflect the access to finance and economies of scale.However, it may turn out that the relation is of a non-linear form. There is still no final resolution, although data seems to confirms the U-shaped size/innovation relationship (Rothwell & Dodgson, 1994, 323). Given our concentration on smaller firms, we suggest to introduce firm size as logarithmic variable.

The prospensity to innovate Pti (Equation 1) may or may not have been an observed variable in empirical research. If the question regarding do or don't you innovate is absent in the empirical research, than the share of time dedicated to renewal/innovation can function as indicator. The Pti is dependent on DLogS, and potentially on many exogenous variables such as firm size, industry, share of exports in sales, patents, the presence of any innovation dedicated employees, the strategic orientation of the firm, monitoring of client-satisfaction, innovation cooperations, individual market share, Hirfingdahl-Hirschman index, having executed market research, the share of innovation dedicated employees, the share of employees with higher aducation, the share of employees with company paid eduction/training, development in profit/loss, the ownership of relatively advanced resources, age of the company, and organisational change.The probability of being innovative increases with firm size (KM 2002, xxiii). The idividual market share and the Hirfingdahl-Hirschman index may both model the influence of a certain market structure on the innovativeness of a firm. Several causal relations, e.g. linear, non-linear or curve-linear, may be tested. They may interfer with the industry variable, although an industry may comprise of several diverse markets. The variables dedicated employees and share of employees involved in innovation; stand for the potential to work on innovations at all. However, typically in small firms employees are not dedicated to renewal/innovations. Therefor the two variables may complement each other. The organisational change variable may function as indicator of mergers, acquisitions and major divestitures or restructuring. It incorporates structural changes within the company. Ex ante it is unclear whether or not growth in sales will be of influence directly or via the industry-dummy.

The propensity to innovate Pti (eq.1) will influence both the nominator of the Inint (2) and the throughput variable Inneff (3). This relationship is comparable to the direct influence that technological opportunities has on the level of inputs and throughput. A firm more eager than others to innovate will allocate to innovation trajectories more resources than average. Here one tests the absorptive capacitity hypothesis, which states that firms relatively open to others will need to allocate more skills and thus money to innovation itself. Furthermore such a firm will more easily than average start another innovation trajectory (Cf. Klomp & van Leeuwen 1999, see par.6).

The innovation intensity Innint (2) is dependent on Pti and DlogS, plus the exogenous variables turnover, size, industry, export share, patents, log sales, log age, use of european subsidies, use of Dutch innovation subsidies, STW-participation, turnover, innovation cooperations, the ownership of relatively advanced resources, the strategic orientation of the firm, the share of innovation dedicated employees, the share of employees with higher aducation, the share of employees with company paid eduction/training,and monitoring of client-satisfaction. The Schmookler's demand-pull hypothesis is (indirectly) tested via the growth of log firm sales on innovation intensity.

The throughput measure innovation efforts Inneff (3) is a function of Pti and Innint, plus the exogenous variables size, industry, strategic orientation of the firm, Iso-certification, other certificates, recent organisational changes, continuous improvement as business strategy, market share, written down innovations, number of automated processes, monitoring of client-satisfaction, having executed market research, development in profits, STW-participation, and innovation cooperations.

The output measure log odds of innovative share-in-sales LoP (4) is a function of Innint, Inneff, and DLogS, plus the exogenous variables industry, strategic orientation of a firm, patents ('octrooi'), Synthens-related increase in turnover, Synthens-related increase in exports, market share, HHI, products new to the industry, products new to Netherlands, products new to Europe. The Innint and Ineff may have individual or combined effects on the innovatives share in sales. Empirical tests should do the job. Maybe the Pti should also be included to see whether the strategic orientation is of direct and/or indirect relevance.

The performance measure, productivity Prod (5A) is a function of LoP and Inneff, plus the exogenous variables Synthens-related costcutting, Synthens-related turnover growth, sharew of hours dedicated to innovation, Synthens-related export growth, share higher educated employees, firm age, size, industry, number of employees, recent organisational changes (indicating the absence of organisational rigidities), and innovation cooperations.

The performance measure, average growth in sales DLogS (5B) is a function of the LoP, plus the exogenous variables Synthens related increase in turnover, size, industry, and past growth in sales. Past growth may predict future growth, as demand pull effect, or as signal of easy access to finance. (Mohnen & Dagenais (2002), 17)

The following list summarizes the projected relations between the endogenous variables:
1.Pti = f (DlogS)
2.Innint = f (Pti, DlogS)
3.Inneff = f (Pti, Innint)
4.LoP = f (Innint, Inneff, DlogS)
5A.Prod = f (LoP, Inneff)
5B.DlogS = f (LoP)

12.Conclusions

The research on innovations is in the rapids. 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.

Although the new research trajectories may seem to be challenging one must be aware that the opening of the black box may not improve the explanatory power of the data. Many for small firms relevant observations have been made in the text. Additional details may bring more questions than answers for there is no foreseeable all encompassing innovation process standard and there is no end to further detailing. Is the price for extra insight in the innovation process a loss of generality? An new indicator already passed by is the one splitting up turnover data according to their vintage of innovation. It was introduced in the nineties as the shares in a firm's total sales which relate to products in different stages of the life cycle. (Kleinknecht, 1996, 3). It is no longer in use.

The model proposed in this article encompasses the interrelated set of subsystems in the innovation process. However, mayby one or two equations cannot be estimated. That would not need fundamentally break down the relevancy of the results. Especially the set of equations 1 and 2, 2 and 3, and 5A and 5B, in section 11, may each loose one of the equations without distroying the whole of the exercise. Nevertheless, as emphasized earlier, and by others, the sensitivity of the equations to centain specifications and certain tests should make one cautions not to delete variables easily.

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, Technopolis, 9) It is recommended to work on both Hackman, tobit and probit methods. Also the FIML may be useful. They seem to be here to stay. An econometrician is to be called in for the proper application of the modelling tools. 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).

We have come to the closing section of this research. It aimed at depicting the current state of knowledge regarding the relation between innovation and performance in general, and for SME versus large firms in particular. In this publications we have listed de prime developments in innovation research; we have listed the major publications that tested such new approaches, new methods and new innovation indicators, and we have come to proposals with regard to what may be intersting for further research. However, we feel inclined to conclude with a statement by Francoz & Pattison,(2000): "Innovation surveys are in their infancy and do not appear to be producing comprehensive and reliable indicators."

Literature:

Australian Bureau of Statistics (ABS) (2001), *Measuring the Knowledge Based Economy and Society*, in Klomp, L. (2001).

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

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

Arnold & Thuriaux, 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 manafacturing, in: Kleinknecht & Mohnen (2002)(eds.), pp.225-252.

Broersma, L. (2001) *The innovative process in commercial services and its proper climate*, mimeograph, University of Groningen, pp.30.

Brouwer, E., H.Budil-Nadvornikova, & A.Kleinknecht (1999), Are Urban agglometations a better breeding place for product innovation? An analysis of new product announcements, *Regional Studies*, 33, 6, 541-549.

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

Buderi, R. (1999), In search of innovation, *Technology review*, November-december, pp.44-51.

Centraal Planbureau (2002), *Over de interpretatie en de internationale vergelijkbaarheid van CIS-indicatoren*. CPB memorandum nr.26, pp.10.

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

Dodgson, R. & R.Rothwell (1994), *The handbook of Industrial Innovation*, Cheltenham, UK: Edward Elgar.

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 & Mohnen (2002)(eds.), pp.201-224.

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

Francoz, & Pattison, in ..2000

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

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

Jong, J.P.J.de & E.Brouwer, (1999) *Determinants of the innovative ability of SME's*, Zoetermeer, Netherlands: EIM.

EIM published explorative research on the innovative ability and innovative intensity (0010/A; 9912/A).

Katz, R. & 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), N*ew indicators and determinants of innovation: an introduction,* in Kleinknecht, A. (1996)(ed.), pp.1-12.

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

Kleinknecht, A. (2000), Indicators of manaufacturing and service innovation: their strenghts and weaknesses, in Metcalf, J.S. & I.Miles (2000)(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.
Kline, S.J. & N.Rosenberg (1986) An overvie of innovation, in: R.Lindau & N.Rosenberg (eds.) *The positive sum strategy: harnassing 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, pp.6.
Klomp, L, and G.W. Meinen (2001) *Innovatie bij de kleinste bedrijven*, Statistics Netherlands, pp.20.
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, & M.Roessingh (2002), *Knowledge-based economy 2001: R&D and innovation in the Netherlands*, Statistics Netherlands, www.cbc.nl
Klomp, L. en G. van Leeuwen (1999), *The importance of innovation for firm performance*, Statistics Netherlands, pp.64.
Klomp, L. en G. van Leeuwen (1999a), Het belang van onderzoek en innovatie voor bedrijfsresultaten, *Industriemonitor*, 1999, oktober, pp.5-10.
Klomp, L. en G. van Leeuwen (2001), Linking innovation and firm performance: a new approach, proceedings of the conference *Innovation and enterprise creation: statistics and indicators*, session C: Innovation and Firm Performance, www.technopolis-group.com/innoconf, pp.86-94, also in: *International Journal of the Economics of Business*, vol.8, no.3, pp.343-364.
Lööf, H., A. Heshmati, R.Asplund & 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. & P.Mohnen (2001) *To be or not to be innovative: An exercise in measurement*, Cambridge, MA: NBER, Working paper 8644, pp.35.
Marceau, J. (1994), Clusters, chains, and complexes: three approaches to innovation with a public policy perspective, in: Dodgson & Rothwell (1994), pp.3-12.
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. & C.Snow (1978), *Organizational strategy, structure and process*, New York: McGraw-Hill, also in *Academy of Management Review*,…
Mohnen, P. & M.Dagenais (2002) Towards an innovation intensity index: the case of CIS1 in Danmark and Ireland, in Kleinknecht & Mohnen (2002)(eds.), pp.3-30.
Mohnen & Mairesse (2001), ("to be or not to be innovative: an exercise in measurement. NBER working paper no.8644.
Pavitt, K. (1984) Sectoral patterns of technological change: toward a taxonomy and a theory, *Research Policy*, vol. 13, 6, 343-373.
Porter, M. (1990), *The competitive advantage of nations*, New York: Free Press.
Porter 2000, Creating innovative capacity, The 1999 Gilbert memorial lecture, january 2000, *Management Services*, pp.8-12.
Rothwell, R. & M.Dodgson, Innovation and firm size, in: Dodgson & Rothwell (1994), pp.310-324.
Schumpeter, J.A. (1934), *The theory of economic development*, Oxford: Oxford UP (1911, 1980).
Takeuchi, H. & I.Nonaka (1986), The new new product development game, *Harvard Business Review*, vol.64, no.1, pp.137-146.
Vossen, R.W. & B.Nooteboom (1996), Firm size and participation in R&D, in: Kleinknecht (1996)(eds.), pp.155-167.
Voss, C.A. (1994), Implementation of manafacturing innovations, in: Dodgson & Rothwell (1994), pp. 405-417.