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How do firms innovate?

A Classification of Dutch SMEs

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Aanleiding en doelstelling

Innovatie is anno 2004 van belang, niet alleen voor ondernemers, maar ook voor beleidsmakers. Het is een belangrijk aangrijpingspunt voor de realisatie van een duurzame economische groei. Een punt van aandacht in dit verband is of het zinvol is om specifieke beleidsmaatregelen te ontwikkelen gericht op een beperkt aantal sectoren, of dat een generiek innovatiebeleid kan volstaan. Zo concentreert een actuele discussie onder beleidsmakers zich op de vraag, of voor de dienstverlenende sector een apart beleid moet worden ontwikkeld om innovatie te stimuleren.
In deze studie wordt een typologie ontwikkeld van innovatieve Nederlandse MKB-bedrijven, waarbij rekening wordt gehouden met verschillen tussen MKB-bedrijven in de manier waarop zij innoveren. Deze typologie biedt een raamwerk voor de ontwikkeling van beleid, en is tevens bruikbaar voor verdere theorieontwikkeling.

Theoretisch kader

De eerste en nog altijd bekendste typologie van innovatieve gedragspatronen is ontwikkeld door Pavitt (1984). Deze typologie heeft betrekking op industriële bedrijven. Op basis van structurele kenmerken van bedrijven en de manier waarop zij innovatieprocessen organiseren, onderscheidt Pavitt vier typen: leveranciersgedreven, schaalintensief, gespecialiseerde toeleveranciers, en kennisgedreven ('science-based') innovatoren.
Sinds Pavitt zijn er vele pogingen gedaan om de typologie uit te breiden. Ook zijn alternatieve indelingen voorgesteld. Kenmerkend voor eerder onderzoek naar innovatieve gedragspatronen zijn 1. het gebruik van nieuwe dimensies van innovatie en bijbehorende variabelen, 2. toepassing en uitbreiding van typologieën naar nieuwe sectoren (bijvoorbeeld de dienstverlening) en 3. het gebruik van data op bedrijfs- of sectorniveau, hetgeen consequenties heeft voor de aard van de typologie die resulteert.
Onderhavig onderzoek voegt op vier plaatsen iets toe aan de bestaande literatuur:

- De typologie wordt gebaseerd op enkele nieuwe indicatoren die belangrijk zijn voor innovatie in het MKB
- Industriële en dienstverlenende bedrijven worden tegelijk meegenomen, hetgeen een vergelijking mogelijk maakt tussen beide sectoren (verschillen patronen van innovatief gedrag tussen industrie en diensten?)
- De typologie omvat een indeling van *bedrijven*, niet van sectoren. Hierdoor kan worden bekeken in hoeverre bedrijven bínnen een sector homogeen zijn in hun innovatieve gedrag
- De typologie omvat ook bedrijven met minder dan tien medewerkers.

Data

In het onderzoek is gebruik gemaakt van gegevens van 1.234 MKB-bedrijven, die werden verzameld middels een telefonische enquête. Deze bedrijven hadden alle in de afgelopen drie jaar ten minste één innovatie doorgevoerd. De steekproef omvatte alle sectoren van het Nederlandse MKB (exclusief landbouw) en twee grootteklassen (1-9 en 10-99 werknemers).
De typologie is deels gebaseerd op klassieke innovatiekenmerken, namelijk de innovatieve output van het bedrijf (product- en procesinnovatie), de innovatieve input (reservering van tijd en geld, aanwezigheid van gespecialiseerde innovatiemedewerkers) en de inspiratiebronnen om te innoveren (leveranciers, klanten, wetenschappelijke ontwikkelingen). Ook werden enkele specifieke innovatiekenmerken meegenomen die belangrijk zijn voor MKB-bedrijven, maar die niet eerder zijn meegenomen in onderzoek naar in-

novatieve gedragspatronen: de houding van de manager/ondernemer ten aanzien van innovatie, planning van innovatie (aanwezigheid van een schriftelijk vernieuwingsplan) en externe oriëntatie (gebruik van externe kennisbronnen en samenwerking met andere partijen).

Vier groepen van innovatieve MKB-bedrijven

Er kunnen in het Nederlandse MKB vier groepen van innovatieve bedrijven worden onderscheiden: leveranciersgedreven (26% van de populatie MKB-bedrijven), klantgedreven (22%), kennisgedreven (21%), en inputintensieve bedrijven (31%). De voornaamste kenmerken van de vier typen zijn in onderstaande tabel samengevat.

	Groep			
Kenmerk	*Leveranciersgedreven (26%)*	*Klantgedreven (22%)*	*Kennisgedreven (21%)*	*Inputintensief (31%)*
Innovatieve output	Veel procesaanpassing; weinig productinnovatie	Veel productinnovatie	Veel product- én procesinnovatie	Gemiddeld op product- en procesinnovatie
Innovatieve input	Weinig reservering van tijd en geld; geen innovatiespecialisten	Weinig reservering van tijd en geld voor innovatie	Veel reservering van tijd en geld; het vaakst gespecialiseerde innovatiemedewerkers	Reserveren het vaakst tijd en geld voor innovatie
Voornaamste inspiratiebronnen	Leveranciers	Klanten	Wetenschappelijke ontwikkelingen; klanten	Kunnen zowel leveranciers als klanten zijn
Houding manager/ ondernemer	Minder positief	Gemiddeld	Positief	Gemiddeld
Planning van innovatie	Sterk ondergemiddeld	Gemiddeld	Bovengemiddeld	Gemiddeld
Externe oriëntatie	Weinig samenwerking	Laag gebruik van externe kennisbronnen	Hoog gebruik van externe kennisbronnen; veel samenwerking	Gebruik kennisbronnen en samenwerking onder gemiddeld

Ook op variabelen die niet zijn gebruikt om de typologie te ontwikkelen, blijken de vier groepen onderling te verschillen. Kennis- en klantgedreven bedrijven beschouwen zichzelf ten opzichte van hun branchegenoten vaker als innovatieve koploper. Kennisgedreven bedrijven hebben bovendien meer dan gemiddeld een expliciet beleid om nieuwe kennis te verzamelen, en maken intensiever gebruik van innovatiesubsidies. Leveranciersgedreven bedrijven vinden zichzelf daarentegen minder vaak een innovatieve koploper. Ook het subsidiegebruik is bij deze groep lager.

Conclusies

De ontwikkelde typologie voegde op vier plaatsen iets toe aan eerdere studies naar innovatieve gedragspatronen:

- Hoewel de typologie mede is gebaseerd op enkele nieuwe innovatiekenmerken die specifiek relevant zijn voor het MKB (houding ondernemer, planning van innovatie, en externe oriëntatie), lijken de vier groepen sterk op eerdere typologieën, zoals Pavitt (1984) die voor de industrie heeft ontwikkeld.
- Verschillen tussen de industrie en de dienstverlening zijn niet groot. De dienstverlening telt weliswaar iets meer inputintensieve bedrijven, maar algemeen kan worden gesteld dat de verschillen in innovatieve gedragspatronen tussen de industrie en de dienstverlening beperkt zijn.

– Het innovatief gedrag van bedrijven is bínnen sectoren zeer heterogeen. Binnen elke sector werden de vier gedragspatronen teruggevonden met een frequentie van minimaal 7% van de bedrijven. Overal vindt men een niet te verwaarlozen aantal bedrijven met een positieve houding ten aanzien van innovatie en een grote bereidheid om te investeren. Uiteraard treden wel nuanceverschillen op: zo telt de ingenieursbranche meer kennisgedreven bedrijven, terwijl in de bouwnijverheid het leveranciersgedreven type de overhand heeft.
– Bedrijfsomvang is meer bepalend voor het innovatief gedrag van bedrijven dan sector. Onder middelgrote MKB-bedrijven (10-99 werknemers) is het aandeel kennisgedreven innovatoren duidelijk hoger dan in het kleinbedrijf.

1 Introduction

1.1 Motivation

Firms need to innovate, at least on occasion, to maintain a competitive advantage and ensure long-term continuity. Schumpeter viewed innovation as the main source of competition among firms since, he pointed out, innovation "strikes at … their foundations and their very lives" (Schumpeter, 1942). Baumol more recently remarked that innovation has substituted competition in price as the rule of the game and innovation has become a "life-and-death matter for a firm" (Baumol, 2002). In a similar vein, Freeman & Soete (1997) stated that for a firm "not to innovate is to die". Accordingly, empirical studies have linked the rate at which firms are able to develop new products and processes to performance and long-term survival, both in large firms (Soni *et al.*, 1993; Banbury & Mitchell, 1995) and in small- and medium-sized enterprises (SMEs) (De Jong, Vermeulen & O'Shaughnessy, 2004).

Neither is innovation any longer the exclusive domain of managers and entrepreneurs. Policy makers attach great importance to innovation, especially since it is recognized as a key driver to long-term productivity growth. Stimulating innovation in SMEs is among the cornerstones of the 'Lisbon strategy' launched by the European Council in March 2000 and reconfirmed by the Barcelona Council in 2002 (CEC, 2002). There is a debate among policy makers concerning whether sector-specific measures are needed to stimulate innovation in firms. For example, it could be argued that service firms are dissimilar from manufacturing firms in how they deal with innovation, implying a need for separate policy interventions to stimulate innovation in services (Flikkema & Jansen, 2004).

For larger firms, sectoral patterns relating to innovation are well established. Previous research has shown that sectors vary in terms of the sources, rates and directions of technological change. Evidence has been provided for both manufacturing and service sectors (Pavitt, 1984; Evangelista, 2000), but never for both sectors at once. Besides, in previous taxonomies so-called micro-firms (< 10 employees) are overlooked. A lack of feasible data has prevented the exploration of how these firms behave when they innovate.

1.2 Objectives

This paper aims to classify groups of Dutch innovative SMEs with similar innovation patterns. Our objective is to provide policy makers with a classification that

- can serve as a basis for future policy interventions.
- makes possible a comparison between manufacturing and service firms (to what extent do they differ in their innovative behaviour?)
- enables the comparison of the innovative behaviour of small (< 10 employees) and medium-sized (10-100 employees) enterprises.

The classification is compiled using some new indicators that are particularly relevant to innovation in SMEs. In addition we used the firm as unit of classification although most previous taxonomies were formulated at sector level. Doing so enabled us to assess the heterogeneity of firms within a particular sector.

Outline

This report is organised as follows. In chapter 2 we present an overview of the relevant literature and discuss some methodological issues when building a taxonomy. Chapter 3 provides the details of our database and describes the data collection process. Chapter 4 describes the method used to construct the taxonomy and the results of our analyses. We derived a typology of four groups of firms: supplier-dominated, client-driven, science-based and input-intensive firms. Chapter 5 ends with our conclusions, implications for entrepreneurs and policy makers, and suggestions for future research.

2 Theory

This chapter starts with an overview of previous work on patterns of innovation (section 2.1). From the overview three lines of research can be derived that were used by previous researchers to try to extend the initial Pavitt (1984) typology: analysing new dimensions and variables (section 2.2), new sectors and industries (2.3) and using firm level data (2.4). In section 2.5 we discuss how the current research departs from previous work.

2.1 Previous studies on patterns of innovation

A taxonomy is a system of classification that organises and labels many different items in groups that share similar characteristics. A useful taxonomy is one that reduces the complexity of empirical phenomena to a few, easy to remember categories. Taxonomies provide scholars with a framework that helps to build theories. Practitioners and policy makers can also use taxonomies to shape firm strategies and policy decisions.

In his pioneering article, Pavitt (1984) proposed a taxonomy that distinguished various categories of innovative firms based on their structural characteristics and their organisation of innovative activities. The aim of the taxonomy was to provide an empirically based framework as a basis for developing a theory of innovation as well as guiding S&T policies. Based on the data from the SPRU innovation survey and a review of case studies, Pavitt identified four groups of firms: science-based, specialised suppliers, supplier dominated and scale intensive. Pavitt's taxonomy has become a popularly used framework for innovation researchers to explore deviations across industries. in fact the 1984 article is the most commonly quoted of Keith Pavitt's articles (Meyer *et al.,* 2004). In the past twenty years, a number of empirical taxonomies of innovation patterns have been elaborated in line with Pavitt's work . Table one provides an overview of these classifications.

table 1 Overview of empirical studies on patterns of innovation in the past twenty years

Author	*Relevant dimensions and variables*	*Data source and sample*	*Industry classification*	*Method*
Pavitt(1984), extended in Tidd *et al.* (2001)	– Sources of technology: R&D, design, suppliers, users, social science – Type of user: price or quality sensitive – Means of appropriation: patents, IPR, confidentiality, etc. – Objective: cost-cutting or product design – Nature of innovation: ratio of product on process innovation – Firm size – Rate and direction of technological diversification	– SPRU Innovation survey – 2,000 significant innovations in Great Britain (1945-1983) – Dominance of large firms (53% with more than 10,000 employees, 25% with less than 1,000)	Manufacturing and services: (1) science-based, (2) scale intensive, (3) specialised suppliers, (4) supplier dominated. Extended in Tidd et al. (2001) to include a fifth category: (5) information intensive	– Sector-level – Quantitative and qualitative analysis
Archibugi *et al.* (1991)	– Innovation intensity: share of innovators; share innovation sales; ratio of internal to external sources of knowledge – Nature of innovation: ratio product on process innovation – Knowledge sources: design; R&D; patents; capital involved. – Firm size: average size and concentration index of innovators	– CNR-ISTAT innovation survey 1987 – 16,700 Italian firms, with more than 20 employees	Manufacturing: (1) traditional consumer goods; (2) traditional intermediate goods; (3) specialised intermediate goods; (4) assembled mass-production; (5) R&D based	– Sector-level – Cut-off points in ratios of industry level indicators to the mean across industries
De Marchi *et al.* (1996)	– Innovation intensity: R&D, design, patents – Nature of innovation: ratio of product on process innovation	– CNR-ISTAT innovation survey 1987 – 16,700 Italian firms, with more than 20 employees	Manufacturing: Pavitt's (1984) taxonomy	– Sector-level – Test of Pavitt's taxonomy based on predicted rankings across pre-assigned groups and ANOVA
Malerba & Orsenigo (1996)	– Firm size of patenting firms – Concentration – Persistence of innovation – Technological entry and exit (firms patenting for the first or last time)	– Patent activities in 7 industrialised countries – Institutions and firms excluding individual inventors	Manufacturing: 'Schumpeter Mark I' (entrepreneurial) and 'Schumpeter Mark II' (routinised)	– Technology-level – Factor analysis and cut-off points of factor scores

Author	*Relevant dimensions and variables*	*Data source and sample*	*Industry classification*	*Method*
Hatzichronoglou (1997)	– Technology intensity: intensity of direct and indirect (embodied) R&D	– ANBERD STAN dataset – Samples of small firms, varying across countries	Manufacturing: (1) high tech, (2) medium-high tech, (3) medium-low tech, (4) low tech	– Sector-level – Cut-off points of technology indicators
Arvanitis & Hollenstein (1998)	– Innovation intensity: inputs (R&D, design) and outputs (innovations' value and shares of innovative sales) – Knowledge sources: other firms, institutions, universally accessible information and other inputs (machinery, licences, personnel)	– Swiss innovation survey 1996 – 516 firms with more than 5 employees	Manufacturing: 5 clusters	– Firm level – Factor analysis and clustering
Evangelista (2000)	– Innovation intensity: innovation costs per employees, % innovators – Nature of innovation: ratio of product on process innovation – Type of innovation inputs: R&D, design, software, training, machinery, marketing – Information sources: internal (R&D lab) and external (other firms, institutions, etc) – Innovation strategies: objectives of innovation (market driven, efficiency, etc)	– ISTAT-CNR innovation survey 1997 – 19,000 firms with more than 20 employees	Services: (1) technology users, (2) S&T based, (3) interactive and IT based; (4) technical consultancy.	– Sector-level – Factor analysis and clustering
Marsili (2001)	– Technological intensity – Technological entry barriers (share of innovative activity in large firms) – Persistence of innovation – Inter-firm diversity – Technological diversification – Knowledge sources	SPRU databases on innovative activities of large firms	Manufacturing: (1) science based, (2) fundamental processes, (3) complex systems, (4) product engineering, (5) continuous processes	– Sector-level – Qualitative and quantitative analysis

Author	Relevant dimensions and variables	Data source and sample	Industry classification	Method
OECD (2001)	– Knowledge intensity: direct and indirect R&D expenditure; skill levels.	– ANBERD STAN dataset – Samples of small firms, varying across countries	Manufacturing and services: (1) high-tech manufacturing, (2) low-tech manufacturing, (3) knowledge intensive services, (4) traditional services	– Sector-level – Cut-off points of indicators
Peneder (2002)	– Input intensity: labour; capital; advertising sales ratio; R&D sales ratio.	– Expenditure by investment category in US firms	Manufacturing: (1) technology-driven, (2) capital intensive, (3) market driven, (4) labour intensive, (5) mainstream manufacturing.	– Sector-level (3 digit) – Factor analysis and clustering
Raymond *et al*. (2004)	– Model of innovative behaviour: Estimated effects of firm-level and industry-level characteristics on the decision to innovate and the returns on innovation.	– Manufacturing firms with more than 10 employees in the Netherlands – CIS-2, CIS-2.5 and CIS-3	Manufacturing: (1) high-tech, (2) low-tech, (3) wood industry.	– Econometric model at firm level with industry-specific coefficients

A few of the studies reported in table 1 validate Pavitt's taxonomy using only a broad range of technological dimensions (De Marchi *et al.*, 1996). Recent work has resulted in extensions along the following lines: (1) use of new dimensions and variables, (2) introduction of new sectors/ industries, (3) use of firm-level data and (4) application of new methods of analysis. These extensions will be discussed in the next sections.

2.2 New dimensions and variables

As pointed out by Peneder (2003) in his review of industry classifications, two 'styles' of taxonomies have emerged in literature. One is centred on the contrast between high technology sectors and low technology sectors, the other type finds its premise in the concept of technological regimes.

Classifications based on technology sectors

Classifications based on technology sectors were developed under the auspices of the OECD. This type of classification is based on the intensity of technology production, as measured by the intensity of R&D expenditure in a sector. The classification was then revised to account also for the intensity of technology use, reflecting the process of diffusion across sectors (Hatzichronoglou, 1997). The revised version identifies four groups in manufacturing: high technology, medium-high technology, medium-low technology and low technology.

While the OECD classification is technology-based, recent attempts have been made to include non-technological dimensions among the factors of production. Peneder (2002) stressed the need to account for intangible investments and human capital. For the manufacturing sector, Peneder (2002) classifies US industries at the three digit level of SIC code by combining data on intensity of labour, capital, advertising and R&D expenditures. He identifies five broad clusters: mainstream manufacturing, labour intensive industries, capital intensive industries, marketing driven industries, and technology driven industries.

Technological regimes

Another type of classification finds its premise in the concept of technological regimes (or technological paradigms). This concept was introduced by Nelson & Winter (1977) and elaborated by Dosi (1982). It provides a theoretical framework that helps to understand the variety of innovation processes across technologies and industrial sectors. A technological regime defines the principles of technological and scientific knowledge that are necessary for the innovation process (Dosi, 1982) as well as the boundaries that can be achieved in the process of innovation (Nelson & Winter 1977). In addition, a technological regime shapes the directions, or technological trajectories, along which incremental innovations take place (Nelson & Winter 1977, Dosi, 1982). As Nelson & Winter (1977) exemplify for the first commercial aircraft, the DC3 aircraft defined a set of technical specifications (type of engine, wings design, type of materials, etc) that engineers had in mind in designing new aircraft ; this knowledge shaped their vision of how to improve on the existing technology, and their awareness of where the frontier of potential improvements might lie in front of them.

Given this conceptual definition, a number of dimensions, that are potentially measurable, have been suggested that characterise a technological regime. Dosi (1988) and Malerba & Orsenigo (1993) consider (a) the level and sources of technological opportunity (how easy is it to innovate in a certain technology – or in other words the productivity of a certain investment in research – and the knowledge sources that are important for innovation), (b) the appropriation conditions (how easy is to appropriate the economic return from innovation and prevent imitation), (c) the accumulation of knowledge (to what extent does innovation today depend on past innovations) and (d) the nature of knowledge bases (whether knowledge is tacit or codified, simple or complex, generic or universal, etc).

Pavitt's taxonomy of sectoral patterns of innovation is related to the concept of technological regimes. Innovative activities in Pavitt's categories are characterised by distinct combinations of level of technological opportunity, threat of technology-based entry (reflecting the sources – internal or external – of opportunities), and appropriability conditions (Pavitt, Robson & Townsend, 1989). Along this line, Marsili (2001) refined Pavitt's taxonomy to account for the nature of knowledge bases and skills in diverse technical fields. Manufacturing industries were classified into five categories: science-based, fundamental processes, complex knowledge systems, product-engineering and continuous processes.

In today's practice of innovation research, the concepts of patterns of innovation and technological regimes are used somewhat interchangeably. A technological regime is measured with variables often similar to those used by Pavitt. It is thus not surprising that technological regimes are closely linked to the organisation of the innovation process in particular industries (Malerba & Orsenigo, 1996). Winter (1984) proposed a theoretical framework with two technological regimes that shape prevailing patterns of innovative behaviour. The 'entrepreneurial regime' (or Schumpeter Mark I) is one in which the nature of technology favours innovation by new and small firms. Sources of knowledge are external to the firm and to the industry, innovation by the incumbent firm is non-cumulative and knowledge is generic and science based. On the contrary, the 'routinised regime' (or Schumpeter Mark II) is one in which the nature of technology is such that established firms are the major innovators. Sources of knowledge are internal to the firm, innovation is highly cumulative, and knowledge is targeted to specific industrial applications. Breschi, Malerba & Orsenigo (2000) explicitly link Schumpeterian patterns of innovation and technological regimes. They show that the emergence of one or the other of the two Schumpeterian patterns of innovation (Mark I or Mark II) depends on the combination of appropriability conditions, cumulativeness of innovation, and sources of technological opportunities.

The concept of technological regime is also seen as a framework to interpret differences in the strategic behaviour of firms (Malerba & Orsenigo, 1993; Kaniovski & Peneder, 2002). For example, in an empirical study of Greek manufacturing firms, Souitaris (2002) showed that firms classified according to Pavitt's taxonomy also revealed distinctive patterns with respect to a number of strategy related variables (*e.g.,* innovation budget, technology plan, management attitude etc).

2.3 New sectors and industries

Various attempts have been made to introduce refinements in the sectoral composition of the Pavitt taxonomy. For example, some studies have attempted to make an extension towards the services sector. The services sector has increasingly become the focus of policy debate and academic research (Miles, 1993). The 1984 version of the Pavitt taxonomy classified services within the category of supplier dominated. To account for changes in this sector due to the ICT revolution, Pavitt himself revised his taxonomy by adding a fifth category of information intensive firms (Tidd *et al.*, 2001). Sectors represented in this class are finance, retailing, publishing, and travel services, however, no empirical support is presented.

Studies of innovation in services have highlighted that there is more diversity of configurations within the sector than assumed in Pavitt's only category of information-intensive firms. More robust measures of innovation in services are now available from the Community Innovation Survey (Kleinknecht, 2000). Using these new data, classificatory exercises for the service sector elaborate on Pavitt's identification of a fifth broad category. For example, Evangelista (2000) used a broad set of dimensions measured at the sector level. These are the type of innovation (product/process), the intensity of innovative performance, the sources of information, collaboration with different partners, and the objectives (or strategies) of innovation. He identified four groups of industries within the service sector: 'technology users' resembles the supplier dominated firms in Pavitt's taxonomy and includes security, legal services, travel and retail services; 'S&T based' sectors share common traits with the science-based firms in Pavitt's taxonomy and consist of R&D, engineering and computing services; 'interactive and IT based' sectors are distinguished by their close interactions with customers and large investments in software (*e.g.* advertising, banks, insurance and hotels). Finally, the category of 'technical consultancy' reveals mixed patterns, with some elements of both the previous two classes (Evangelista, 2000).

Other taxonomies of the services sector include those of Miozzo & Soete (2001) and OECD (2001). Miozzo & Soete (2001) stress the links of the services sector with other parts of the industrial system, in terms of both services provided and of acquisition of intermediate and capital goods. They identify within the services sector a class of supplier dominated sectors (personal services), scale-intensive physical networks (transport and wholesales), information networks (finance, insurance and communications), and a specialised suppliers/science based sector (software, specialised business services). This taxonomy actually resembles with Pavitt's taxonomy in its original form however, no empirical data to support the classification are presented. Likewise, the OECD has extended their early classification (see Hatzichronoglou, 1997) to services industries, to take into account the increasingly intense use of technology and highly-skilled labour in this sector (OECD, 2001). This typology distinguishes four industrial classes: low-tech manufacturing, high-tech manufacturing, traditional services and knowledge-intensive services.

2.4 Use of firm-level data

A recent methodological concern includes the level of observation of the typology, in other words, the firm level or the industry level (Archibugi, 2001). Pavitt's (1984) taxonomy, as well as most of its successors, is based on industry-level indicators of innovative activities (Archibugi *et al*., 1991; Hatzichronoglou, 1997; Evangelista, 2000). The assumption underlying the construction of an industry-based taxonomy is rooted in the early work of Nelson & Winter (1977) on technological regimes, which are believed to constrain the innovative behaviour of firms that are active in similar production activities. Firm innovative behaviour could however be heterogeneous within a certain sector, because of differences in performance, techniques and strategies (Dosi, 1988). Archibugi (2001) argues that to account for this heterogeneity, technology-based taxonomies need to be developed directly at firm level, before aggregating the firms into the standard system of industrial classification.

A lack of micro data from public sources has, as consequence, that at firm level, patterns of innovation are seldom explored. Some recent work suggests that considerable heterogeneity can be observed across firms. In an empirical study of manufacturing firms in the Netherlands, based on Community Innovation Survey data, Marsili & Salter (2004) show that the degree of heterogeneity in the innovative performance of firms is substantial and varies across sectors. Indeed, empirical studies that attempted to classify firms directly (Cesaratto & Mangano, 1993; Arvanitis & Hollenstein, 1998) found that firms within the same industry are often dispersed across several different groups of the constructed taxonomy. Despite this variability, the authors argue that the results to a large extent strengthen Pavitt's taxonomy.

2.5 Extension of previous work

Following the lines of research discussed above, the current paper extends previous empirical work in four respects:

- We use some new variables to build a taxonomy with relevance to small- and medium-sized enterprises (SMEs). These variables are related particularly to the strategy of the firms.
- We deal with manufacturing and service firms at the same time, thus enabling a comparison to be made in prevailing patterns of innovative behaviour. Table 1 showed that more taxonomic exercises have been carried out for manufacturing than for services, also because of lack of statistical data on innovation in the latter. Most often taxonomies are developed separately for manufacturing and services industries or whenever done jointly , services fall within one or two broad classes. However, the similarities observed between Pavitt's categories and more detailed classifications of the service sector (Evangelista, 2000) suggest that it is possible to build taxonomies that encompass both manufacturing and services.
- Our focus is on the firm level. While most taxonomies are based on sector-level data we use firm-level data to classify firms directly according to their innovative

behaviour. This allows testing the assumption that firms within an industry share common innovative patterns.

- We also include micro enterprises (with less than 10 employees). Previous work overlooked the innovative behaviour of these firms (table 1). Samples are usually limited to firms with a number of employees above the thresholds of twenty (Archibugi et al., 1991), ten (Raymond et al., 2004) or five (Arvantitis & Hollenstein, 1998). Still , firm size has been found to be of importance for the implementation and nature of innovative practices (e.g., Welsh & White, 1981; Vossen, 1998; Bodewes & De Jong, 2003). Thus, we could expect that prevailing patterns of innovative behaviour differ across size classes.

3 Data

This chapter provides details of the data we used to develop the typology of Dutch innovative SMEs. It starts with the data collection process (3.1) and sampling procedure (3.2). This is followed by a detailed discussion of the variables we used to construct the typology and to validate it (3.3).

3.1 Data collection

The data were collected as part of a survey performed by EIM Small business research. This survey aimed to collect data on the innovative practices and outcomes of Dutch small- and medium-sized enterprises.
A stratified sample was drawn across 18 industries and two size classes. It covered all parts of the Dutch commercial business society with the exclusion of agriculture (see below). The sample was randomly drawn from the population of all small and medium-sized firms in the Netherlands. Following the Dutch definition of SMEs, firms with no more than 100 employees were included in the population of SMEs (Bangma & Peeters, 2003). The population was derived from a Chamber of Commerce data base containing data on all Dutch firms. The initial sample consisted of 2,880 firms.

The data were collected by means of computer assisted telephone interviews (CATI). All respondents were managers responsible for day-to-day business processes – usually the owner/entrepreneur, and otherwise a general manager. Six attempts were made to contact the reference person before considering the company as a non-respondent.

3.2 Sample

After three weeks of telephone interviewing, it appeared that 1,234 complete surveys had been completed. The remaining firms could not be contacted successfully, had refused to co-operate, or did not meet the requirement of an implemented innovation in the past three years. In table 2 we show how the respondents are distributed across various industries and size classes. Of the 1,234 firms, 776 (63%) firms are micro-firms, with fewer than 10 employees.

table 2 Distribution of respondents across industries and size classes

Industry	*Size class* *1-9 employees*	*10-99 employees*	*Total*
Manufacturing:			
– Food, beverages and tobacco	51	29	80
– Textiles, leather and paper	39	25	64
– Wood, construction materials and furniture	45	29	74
– Metals	48	23	71
– Chemicals, rubber and plastic products	49	31	80
– Machinery, motor vehicles and transport equipment	40	24	64
– Office, electrical, communication and medical instruments	42	29	71
Services:			
– Retail and repairs	35	25	60
– Hotels and restaurants	41	18	59
– Personal services	35	26	61
– Transport	35	23	58
– Financial services	48	26	74
– Business services (cleaning, surveillance, etc)	42	23	65
– Wholesale	48	25	73
– Computer and related services	51	29	80
– Economic services (accountancy, consultancy, etc)	45	26	71
– Engineering and architecture	48	28	76
Other:			
– Construction	34	19	53
Total:	776	458	1,234

The sample was stratified in such a way that particular types of firms were under- and over-represented with respect to the entire population. For instance, micro firms (1 to 9 employees) were under-represented, as over 90% of the Dutch business population belongs to this group (Bangma & Peeters, 2003). Some service sectors (retail and repairs, economic services, computer and related services) were also under-represented. To generalise the results of the survey to the population of Dutch SMEs, a weighing factor was calculated using EIM's database of active firms. This database provides statistics on the number of firms for various industries in 2003 and previous years (see http://www.eim.net/AO_VES_In/).

3.3 Variables

Cluster variables should be representative for the typology one wants to present (Everitt, 1993). The current research employs a combination of "core variables" that have been applied several times before and of new variables, because of their relevance to innovation in SMEs. The dimensions and variables that formed the basis of our taxonomy are listed in table 3. Two of these variables ('managerial attitude' and 'product innovation') are constructed by summing the responses to different statements.

table 3 Variables used to develop taxonomy of firms

Dimension		*Variable*	*Description*
(1)	Innovative output	Product innovation	Summated scale of two items (firm introduced any product 1. new to the firm; 2. new to the industry in the past three years) with response codes 'yes' (=1) and 'no' (=0); coded as the mean score of the items; Cronbach's alpha = 0.74
		Process innovation	Firm implemented at least one new work process in the past three years; response codes 'yes' (=1) and 'no' (=0)
(2)	Innovative input	Presence of budgets	Firm reserved an annual budget (money) to implement new products or processes; measured with response codes 'yes' (=1) and 'no' (=0)
		Presence of capacity	Firm reserved capacity (time) to implement new products or processes; response codes 'yes' (=1) and 'no' (=0)
		Innovation specialists	Firm employed people who were occupied with innovation in their daily work (*e.g.,* specialised staff members, new product developers, etc.); response codes 'yes' (=1) and 'no' (=0)
(3)	Sources of inspiration	Suppliers	Firm innovates when suppliers propose new applications; response codes 'totally agree' (=5), 'agree' (=4), 'neither agree nor disagree' (=3), 'disagree' (=2), 'totally disagree' (=1)
		Customers	Firm innovates when customers express new desires/needs; response codes 'totally agree' (=5), 'agree' (=4), 'neither agree nor disagree' (=3), 'disagree' (=2), 'totally disagree' (=1)
		Scientific development	Firm innovates to commercialise universities/knowledge institutes' new technologies or findings; response codes 'totally agree' (=5), 'agree' (=4), 'neither agree nor disagree' (=3), 'disagree' (=2), 'totally disagree' (=1)
(4)	Managerial attitude	Managerial attitude	Summated scale of three statements (1. It is worth while to spend my time on innovation; 2. Innovation enables my firm to serve its customers better, 3. Innovation is necessary to keep up with our competitors); response codes 'totally agree' (=5), 'agree' (=4), 'neither agree nor disagree' (=3), 'disagree' (=2), 'totally disagree' (=1); coded as the mean score of the statements; Cronbach's alpha = 0.67
(5)	Innovation planning	Documented plans	Firm had a documented plan describing renewal ambitions, targets and milestones; response codes 'yes' (=1) and 'no' (=0)
(6)	External orientation	Consultation of external sources	Number of sources consulted for information or advice on any business problem in the past three years (*e.g.,* suppliers, colleague firms, commercial consultants, sector organisations) based on respondents' descriptions of consulted parties; response coded as the number of valid parties
		External cooperation	Firm formally co-operated with other firms or institutes to initiate or develop renewal activities (evidenced by a formal agreement); response codes 'yes' (=1) and 'no' (=0)

Some dimensions are 'usual subjects': they have been frequently used as a basis for classification in taxonomic exercises (innovative output, input and sources of inspiration). Departing from previous work, we also included variables that are typical for innovative SMEs (managerial attitude, innovation planning and external orientation).

Innovative output

Innovative output is a dimension that has frequently been used in building taxonomies of innovation, also in relation to the different nature of product and process innovation (Pavitt, 1984; Archibugi *et al.*, 1991; De Marchi *et al.*, 1996; Evangelista; 2000). Our dataset contained measures of product and process innovation, which are similar to the measures and definitions employed in the Community Innovation Survey (CIS) (see OECD, 1997). Product innovation was measured with a two-item scale covering the presence and degree of novelty of product innovations. Its first item was broadly defined, including minor product improvements or mere competitor imitation. The second item, referring to product introductions 'new to the industry', is more stringent and covers those product innovations with a higher degree of novelty. The other output variable is process innovation, which is important not only in large firms but also in SMEs (Acs & Audretsch, 1990).

Innovative input

Innovative input is another dimension that is often used in taxonomic exercises. Examples of indicators include labour and capital investments in innovation (*e.g.,* Peneder, 2002; Arvantitis & Hollenstein, 1998). Our dataset included three relevant variables: the reservation of an annual budget (money) and of capacity (time) to implement new products or processes, and the presence of innovation specialists. Within SMEs the lack of financial resources especially can prove to be a bottleneck when realising something new (Hyvärinen, 1990; Acs & Audretsch, 1990). The investment of time is also regarded as a success factor (Brouwer & Kleinknecht, 1996; Roper, 1997). This is not limited to the time that one needs for developing innovations: time also enables employees to succeed in their supposed role of embodying a new product, service or process, for instance by supporting it and in helping clients to make the switching decision (Hyvärinen, 1990). The third variable, presence of innovation specialists, is defined by the employees occupied with innovation as part of their daily work. In SMEs, this measure has been identified as one that predicts innovation success (Hoffman *et al*., 1998). These measures have the advantage of not relying exclusively on indicators based on R&D expenditure or R&D-personnel (Brouwer & Kleinknecht, 1996; Roper, 1997; Rogers, 2004), which do not adequately capture the innovative efforts of small firms. Most SMEs are not involved in R&D themselves and, not being the best bookkeepers, R&D-expenses tend to remain unrecorded in their accounting systems. Sundbo (1996) argues that as an alternative to R&D, many small firms empower their workforce to contribute to the innovation process. For these reasons we selected alternative input indicators (reservation of time, money, and the presence of innovation specialists with a broader scope than just R&D).

Sources of inspiration

Sources of inspiration are also known as 'sources of innovation' or 'sources of technology'. They refer to parties that inspire SMEs to initiate innovations. This dimension may directly influence how various patterns in taxonomies are named. For example, some classes identified in previous taxonomies are science-based (Pavitt, 1984; Marsili, 2001; Evangelista, 2000) and supplier-dominated (Pavitt, 1984; Miozzo & Soete, 2001). For SMEs, current literature mentions clients, suppliers and knowledge/education institutes as three significant sources (Hyvärinen, 1990; Brouwer & Kleinknecht, 1996; Roper, 1997; Oerlemans *et al*., 1998; Appiah-Adu & Singh, 1998). For example, Appiah-Adu & Singh (1998), in a study of 500 small firms, showed a strong positive link between innovation and customer orientation, implying that small firms should use customer-based knowledge to develop innovative products and services through a customer-pull approach.

Managerial attitude

Managerial attitude strongly affects the decision to innovate and the way innovation is carried out in small firms (Hoffman *et al*., 1998; Hadjimanolis, 2000; Kim *et al*., 1993). In SMEs the owner/entrepreneur has a greater direct influence on employees compared to managers of large organizations (Bodewes & De Jong, 2003). Davenport & Bibby (1999) speak of the 'entrepreneurial dynamism', which leaders in small firms can instil in the behaviour of others in the organisation. A positive attitude towards innovation correlates with continuous awareness of innovative opportunities and provides employees with support for innovative behaviour. Managerial attitude was measured on a three-item scale (Cronbach's alpha = 0.67).

Innovation planning

Innovation planning is another recognized driver of innovation success in SMEs. In our dataset, this variable is measured by the presence of a documented innovation plan, implying that explicit ambitions, targets and milestones were defined and written down. This is one of the factors that distinguishes innovate firms from their less innovative counterparts (Hadjimanolis, 2000).

External orientation

Finally, external orientation is frequently mentioned as being significant for SMEs (Freel, 2003; Romijn & Albadejo, 2002). For this dimension, we used two variables. One expressed the consultation of external parties, which usually extends a firm's knowledge base. Empirical evidence supports the fact that SMEs that are aware of and use external information perform significantly better in terms of innovation success (Hoffman *et al*., 1998). The second variable referred to the participation in external cooperation. Particularly in SMEs, this is believed to ease innovation for a variety of reasons, including the ability to overcome a lack of resources, to spread risks, and to acquire complementary assets (Brouwer & Kleinknecht, 1996; Hadjimanolis, 2000; Hanna & Walsh, 2002).

Variables used for validation

A good practice in any taxonomic exercise includes the assessment of validity by analysing variables not used to form the taxonomy but known or expected to vary across its clusters (Milligan & Cooper, 1987; Hair *et al*., 1998). In table 4 we present the variables that we used for this purpose.

table 4 Variables used to validate the taxonomy of firms

Variable	*Description*
First-mover	Firm is among the first to introduce new products, services or techniques (self-rated); response codes 'yes' (=1) and 'no' (=0).
Policy to collect new knowledge	Firm has explicit policy to collect new knowledge; response codes 'yes' (=1) and 'no' (=0).
Use of innovation subsidies	Firm used innovation subsidies in the past three years; response codes 'yes' (=1) and 'no' (=0).
Type of industry	Type of industry; coded 'Food' (=1), 'Textiles' (=2), 'Wood' (=3), 'Metals' (=4), 'Chemicals' (=5), 'Machinery' (=6), 'Instruments' (=7), 'Retail and repairs' (=8), 'Hotels and restaurants' (=9), 'Personal services' (=10), 'Transport' (=11), 'Financial services' (=12), 'Business services' (=13), 'Wholesale' (=14), 'Computer and related services' (=15), 'Economic services' (=16), 'Engineering and architecture' (=17), 'Construction' (=18).
Size class	Size class; coded '1-9 employees' (=1) and '10-99 employees' (=2).

The variables in table 4 can be assumed to vary across (groups of) innovative firms. Should any cluster be highly innovative, we would expect that its firms increasingly regard themselves as first-movers in innovation and use innovation subsidies more frequently. We also investigated differences across type of industry and size class to establish whether some industries are better represented in some clusters of firms than others and to assess whether different patterns emerge across size classes.

Limitations

Some frequently used indicators were no part of the current study. For example, one could regard the application of patents as an indicator for innovative output (Archibugi *et al.*, 1991; De Marchi *et al.*, 1996), but we argue that this one is less suitable in the context of SMEs. In the Netherlands, using patents is something typical of large enterprises. The share of SMEs possessing a patent does not exceed five percent (De Jong, 2002).

Another limitation is that most of the indicators we used are based on dichotomous questions, which simplify the view on the innovative practices and innovative output in the various firms. One could argue that this methodological disadvantage is shared with basically all previous taxonomies (usually based on public data sources like the CIS) and that simple questions are not disadvantageous. In this respect, when respondents are asked for simple actual facts, a better reliability and decreased risk of common-method variance can be expected (Churchill, 1999).

4 Analysis and results

This chapter starts with descriptive statistics for the variables in our data (4.1). Next we discuss how the typology of innovative SMEs is developed and what it looks like (4.2). Section 4.3 focuses on the validation of the typology.

4.1 Descriptive statistics

Means and frequencies for all variables are given in table 5. This shows that almost all firms in the sample had implemented process innovations recently (91%). The presence of innovation specialists (13%) and the use of subsidies (11%) were relatively scarce. Customers were considered to be a source of inspiration more frequently than suppliers and scientific developments. As for the consultation of external parties, respondents managed to mention rather more than three parties on average. Finally, most respondents claim to have a positive attitude towards innovation. The positive mean score of 4.07 is not surprising if one keeps in mind that the sample consists of innovative firms only. Still , we are able to recognize some variance in the extent to which respondents agree on this scale.

table 5 Descriptive statistics

Dimension	*Variable*	*Mean*	*Frequencies*
Innovative output	Product innovation	0.39	'mean score of 1.0' 27%, 'mean score of 0.5' 25%, 'mean score of 0.0' 48%
	Process innovation	0.91	'yes' 91%, 'no' 9%
Innovative input	Presence of budgets	0.48	'yes' 48%, 'no' 52%
	Presence of capacity	0.67	'yes' 67%, 'no' 33%
	Innovation specialists	0.13	'yes' 13%, 'no' 87%
Sources of inspiration	Suppliers	2.76	'totally agree' 6%, 'agree' 28%, 'neither agree nor disagree' 11%, 'disagree' 43%, 'totally disagree' 11%
	Customers	3.12	'totally agree' 11%, 'agree' 36%, 'neither agree nor disagree' 13%, 'disagree' 34%, 'totally disagree' 6%
	Scientific development	1.91	'totally agree' 5%, 'agree' 12%, 'neither agree nor disagree' 6%, 'disagree' 23%, 'totally disagree' 54%
Managerial attitude	Managerial attitude	4.07	'mean score within range <4.0;5.0]' 34%, '<3.0;4.0]' 61%, '<2.0;3.0]' 5%, '[1.0;2.0]' 0%
Innovation planning	Documented plans	0.35	'yes' 35%, 'no' 65%
External orientation	Consultation of external sources (no. of sources)	3.11	'6 or more sources' 5%, 'five' 12%, 'four' 24%, 'three' 27%, 'two' 18%, 'one' 12%, 'none' 3%
	External cooperation	0.51	'yes' 51%, 'no' 49%
Validation and profiling	First-mover in innovation	0.21	'yes' 21%, 'no' 79%
	Policy to collect new knowledge	0.56	'yes' 56%, 'no' 44%
	Use of innovation subsidies	0.11	'yes' 11%, 'no' 89%

4.2 Taxonomy of innovative SMEs

To develop a taxonomy of innovative SMEs we started with a principal component analysis to reduce the number of dimensions in our dataset. Next, we applied cluster analysis techniques to build a taxonomy of innovative firms. For the interested reader frame 1 provides technical information on how the analysis was done. It can be skipped without loss of continuity.

frame 1 Technical details of the analysis

Component analysis

- Component analysis is an established practice in taxonomic exercises of innovative behaviour. It summarizes data to form a limited number of uncorrelated factors, reducing the risk that single indicators dominate a cluster solution. This helps to prevent non-discriminative variables being included (Everitt, 1993; Hair *et al.*, 1998).
- We checked if our data were suitable for component analysis. MSA-values that are calculated to judge the suitability of data suggested that our indicator for process innovation could better be left out of the analysis. In the sample 91% of the firms had recent process innovations, leaving a small group of only 9% of the cases that would dominate any solution.
- We next ran the components analysis using the PCA extraction technique with varimax rotation. Application of the latent root criterion (eigenvalues > 1) suggested a three-dimensional solution explaining 46% of the variance. Since we aimed to reduce the original number of variables, regardless of the how meaningful the components were, the output of the component analysis is not presented here.

Cluster analysis

- We proceeded with a hierarchical cluster analysis to group the sample into homogeneous clusters. We used Ward's method based on squared Euclidian distances to obtain a first hierarchy of clusters. Ward's method generally provides excellent results (Milligan & Cooper, 1987).
- Because cluster analysis is known to be sensitive to outliers, the scores on the three components were first examined for outlying observations. Using Hair *et al.*'s (1998) detection procedures, two extreme cases were found (their scores on the first component deviated more than three standard deviations from the mean). Both cases were omitted from further analyses.
- Visual inspection of the dendogram suggested a taxonomy with four clusters. To enable a better assessment of the robustness of this taxonomy, we required SPSS to save a range of initial solutions with two up to and including six clusters. To improve the various initial solutions and assess robustness, we performed various k-means cluster analyses. This is a 'non-hierarchical' clustering method in which the innovative firms are iteratively divided into clusters based on their distance from some initial starting points. Some k-means methods use randomly selected starting positions, but we employed the centroids of our initial hierarchical solutions for this purpose. Generally, this two-step procedure results in more stable and better taxonomies (Milligan & Sokol 1980; Punj & Stewart 1983).
- To assess robustness we followed Singh (1990) by computing Kappa, the chance corrected coefficient of agreement, between each initial and final solution. It appeared that the four-cluster solution had the best value of Kappa (k = 0.75, while k < 0.72 for the other solutions).

Four groups of innovative SMEs

The procedure of classification led to the identification of an empirical taxonomy composed of four clusters. Descriptive statistics for each of the clusters and the results of oneway analysis of variance tests for significant differences are revealed in table 6. Based on their scores for the cluster variables, the four clusters were labelled as supplier-dominated (26% of the population of Dutch SMEs), customer-driven (22%), science-based (21%) and input-intensive firms (31%).

table 6 Descriptive statistics for the clusters and tests of significant differences

		Cluster					
Dimension	*Variable*	*Supplier-dominated (26%)*	*Customer-driven (22%)*	*Science-based (21%)*	*Input-intensive (31%)*	*Total*	*Significance*
Innovative output	Product innovation[1]	0.16	0.54	0.57	0.37	0.39	**
	Process innovation[2]	89%	87%	95%	94%	91%	*
Innovative input	Presence of budgets	10%	13%	67%	93%	48%	**
	Presence of capacity	25%	58%	89%	95%	67%	**
	Innovation specialists	1%	18%	25%	11%	13%	**
Sources of inspiration	Suppliers[1]	3.50	1.90	2.52	2.89	2.76	**
	Customers[1]	2.60	3.43	3.64	2.98	3.12	**
	Scientific development[1]	1.53	1.09	4.44	1.15	1.91	**
Managerial attitude	Managerial attitude[1]	3.76	4.11	4.27	4.16	4.07	**
Innovation planning	Documented plans	12%	37%	62%	36%	35%	**
External orientation	Consultation of external sources (no. of sources)	3.06	2.37	4.71	2.62	3.11	**
	External cooperation	33%	56%	88%	39%	51%	**

*** p < 0.001, * p < 0.01, ^ p < 0.05, [1] scale scores, [2] variable was not used to develop the typology.*

Supplier-dominated firms are most often inspired and supported by suppliers to initiate and implement innovations. Their innovative output is usually limited to new processes: new products are barely introduced. Their reservation of money and time is scarce. All other groups outperform the firms within this cluster on all input indicators (table 6). Only one percent of the firms employ innovation specialists (people occupied with innovation as part of their daily work). Supplier-dominated firms are clearly most passive in their innovative behaviour and tend to innovate when new applications come along. This is confirmed by a low share of firms with documented innovation plans (12% versus 35% for all innovative SMEs), a lower than average managerial attitude towards innovation, and a low share of firms with formal cooperation agreements.

Customer-driven firms rely on new desires/needs of their customers as a source of innovation. New applications from suppliers and scientific developments are seldom a trigger to innovate. To satisfy customers' needs, firms within this cluster frequently introduce new products, resulting in a higher than average score on product innovation. In comparison process innovations are realised less often (table 6). As for the other innovative practices, customer-driven firms score below or just on average. For instance, the reservation of budgets and capacity falls short of the mean scores for all innovative SMEs. The same applies to the consultation of external sources. On the other hand, external cooperation, innovation planning and managerial attitude are comparable to other firms.

Science-based firms distinguished themselves by using knowledge from universities and research institutes as a source of innovation. They also draw heavily on new needs of customers to initiate innovations, a feature that is shared with customer-driven firms. New applications of suppliers are regarded to be less important. Furthermore, their innovative output is relatively good. For new product introductions and the implementation of new work processes, science-based firms scored highest (table 6). Another feature is that science-based firms use innovative practices more than average, no matter what indicator one looks at. For example, science-based firms on average consult the largest number of external sources (4.71 vs 3.11 in general), most frequently have documented innovation plans (62% vs. 35%) and have managers with a positive attitude towards innovation. In addition, science-based firms most often employ innovation specialists (25% vs. 13%).

For *input-intensive firms* one cannot identify one single party as the main driver of innovative effort. Scientific development is rarely a source of inspiration but *both customers and suppliers* can act as a trigger to innovate. Their most distinguishing feature includes a high share of firms with reserved budgets and capacity for innovative activities (93% and 95% respectively). The external orientation of input-intensive firms is slightly below average. These findings suggest that input-intensive firms are somewhat similar to customer-driven firms in their limited use of networks. For the other indicators input-intensive firms are never far from average.

As a minimum requirement for validity, one must find significant differences in the variables that have been used to develop a taxonomy (Milligan & Cooper, 1987). Analyses of variance for each individual variable confirmed this finding (see table 6). Also, a significant difference between the groups was also found for the indicator on process innovation that had not been used for cluster development. This may be considered as a first indication of validity. The issue of validity is further investigated later in this paper .

4.3 Validation

Differences across external variables

A check on the validity of clusters exploits variables not used to form the clusters, but known or expected to vary across them (Milligan & Cooper, 1987; Hair *et al*., 1998: 501). Using three external variables, namely if firms regard themselves as first-movers in innovation, the presence of a formal policy to collect new knowledge and the use of innovation subsidies, analyses of variance were performed to assess significant differences. Based on table 6, one would expect science-based firms to rank first on all the external variables. Similarly, we would be surprised if the cluster of supplier-dominated firms, being merely passive receivers of innovations developed elsewhere, would contain a substantial number of firms rating themselves as first-movers. Results of the analyses across the three variables are in table 7**.**

table 7 **Descriptive statistics across three external variables and tests of significant differences**

	Cluster					
Variable	*Supplier-dominated (26%)*	*Customer-driven (22%)*	*Science-based (21%)*	*Input-intensive (31%)*	*Total*	*Significance*
First-mover in innovation (self-rated)	8%	30%	33%	16%	20%	**
Policy to collect new knowledge	49%	47%	73%	57%	56%	**
Use of innovation subsidies	4%	8%	26%	10%	11%	**

*** $p < 0.001$, * $p < 0.01$, ^ $p < 0.05$.*

Table 7 shows significant differences across the four groups for all external variables. The nature of differences advocates our taxonomy as valid. Science-based firms did indeed do well on all external variables. Being most active in their innovative practices science-based firms take the lead in the use of innovation subsidies and the presence of explicit knowledge policies. They also rate themselves more frequently as first-movers in the introduction of new products, services or techniques. Customer-driven firms also classified themselves as first-movers frequently (30% vs. 20% for all innovative SMEs). This is probably due to the fact that innovative, tailor-made products are developed to satisfy the needs of individual clients. Supplier-dominated firms also confirmed our expectations with low scores for all external variables. Finally, input-intensive firms again scored slightly below or never far from the average of all innovative SMEs.

Differences across industry and size

Some more evidence that the clusters are valid is found when a comparison is made across the type of industry and size class. In table 8 it is shown how the clusters are distributed within each of the industries and size classes of our data.

table 8 **Distribution across clusters within industries and size classes**

	Cluster			
Variable	*Supplier-dominated*	*Customer-driven*	*Science-based*	*Input-intensive*
Type of industry:				
Manufacturing:				
– Food, beverages and tobacco	26%	26%	26%	21%
– Textiles, leather and paper	33%	20%	17%	30%
– Wood, construction materials and furniture	26%	33%	15%	26%
– Metals	38%	25%	21%	17%
– Chemicals, rubber and plastic products	14%	29%	43%	14%
– Machinery, motor vehicles and transport equipment	23%	27%	36%	14%
– Office, electrical, communication and medical instruments	18%	27%	36%	18%
Services:				
– Retail and repairs	29%	19%	18%	33%
– Hotels and restaurants	29%	20%	10%	41%
– Personal services	33%	9%	9%	49%
– Transport	41%	18%	15%	26%
– Financial services	21%	26%	23%	31%
– Business services (cleaning, surveillance, etc)	15%	26%	29%	29%
– Wholesale	17%	34%	20%	29%
– Computer and related services	7%	37%	23%	33%
– Economic services (accountancy, consultancy, etc)	18%	25%	39%	17%
– Engineering and architecture	13%	19%	35%	32%
Other:				
– Construction	38%	12%	16%	34%
Totals:				

Variable	Cluster			
	Supplier-dominated	*Customer-driven*	*Science-based*	*Input-intensive*
– ***Manufacturing***	***28%***	***26%***	***24%***	***22%***
– ***Services***	***25%***	***21%***	***21%***	***32%***
– General (manufacturing, services and other)	26%	22%	21%	31%
Size class:				
– 1-9 employees	26%	23%	18%	33%
– 10-99 employees	26%	19%	31%	24%
Total:	26%	22%	21%	31%

In some industries particular patterns prevail, providing additional support for the validity of our taxonomy. For example, science-based firms are well represented among manufacturers of chemicals, machinery and equipment but also among economic service providers (*e.g.,* consultants) engineers and architects. In the Netherlands, these industries are characterised by a well-educated workforce and the frequent application of new technologies. Supplier-dominated firms were the prevailing type in the metal industry, transport and construction, three industries which in the Netherlands are known for their passive attitude towards innovation.

To establish whether prevailing patterns of innovation differ between manufacturing and service industries, we performed an additional analysis of the total figures (printed in italics, see table 8). Within both sectors the shares of the four clusters were calculated (leaving out construction firms). A chi-square test showed no significant difference at the 5% level (χ^2=5.0, df=3, $p > 0.05$). This result suggest that as far as innovative behaviour is concerned, manufacturing and service firms are rather similar.

A visual inspection of the percentages for the 18 industries shows that the four patterns of innovative behaviour are, of course, found in each individual industry (*e.g.,* in each industry at least 7 percent of the firms can be classified as supplier-dominated). The assumption that all firms within an industry at least share some common innovative patterns has to be put into perspective.

Another contradictory result included the impact of size classes. Here, significant differences could be established. A chi-square test indicated that the patterns of innovative behaviour were dissimilar across both classes (χ^2=22.9, df=3, $p < 0.001$). Science-based firms were much better represented among firms with more than ten employees.

5 Discussion

Innovation is a complex and multidimensional phenomenon, and taxonomic exercises of innovative behaviour provide useful frameworks to 'organize' such complexity into relatively general patterns. In contrast with previous taxonomic exercises, this paper contributed by employing new indicators, by enclosing both manufacturing and service firms, by focusing on the firm level and also by including micro-enterprises (< 10 employees). This section contains our conclusions (section 5.1), implications for entrepreneurs and policy makers (5.2), and suggestions for future research (5.3).

5.1 Conclusions

Four groups of innovative SMEs

Drawing upon a sample of 1,234 SMEs, a taxonomy of four types of innovative firms was derived, each type having its own distinctive features. The classification shared common traits with Pavitt's taxonomy. We found a group of supplier-dominated firms, that rely heavily on their suppliers for innovation and make limited use of innovative practices, both in terms of employing funds and personnel in innovation, and of having a certain strategic and managerial attitude towards innovation. A second group, which we called customer-driven, can be compared to Pavitt's category of specialised suppliers. In this category, firms rely mostly on new desires/needs of customers as a source of innovation. They frequently introduce new products to satisfy customers' needs, although there is no distinctive and proactive use of innovative practices. Science-based firms show a clear external and strategic orientation towards innovation; these firms are heavy users of external sources, distinguishing themselves by very intensive contacts with universities and research institutes and above average scores on all innovative practices. Finally, for the fourth group no a single main source of innovative ideas can be identified. Most remarkable is that firms in this category most frequently reserve budgets and capacity for innovative activities, but they do not depart from the average for the other indicators. This group is actually somewhat dissimilar to the Pavitt taxonomy.

With this paper we aimed to extend the current literature on patterns of innovation in four respects: i. to account for innovation characteristics of SMEs, ii. to examine manufacturing and service firms at the same time, iii. to use firm-level data, and iv to include micro-enterprises. A number of qualifications can be made.

Common patterns underlie firms' innovative behaviour

Our results were based on a combination of traditional indicators of innovative output and of less frequently used non-technological indicators, related to firm strategy (Souitaris, 2002). These indicators, including managerial attitude, documented innovation plans, consultation of external parties, and external cooperation, are especially important for SMEs. Despite the different nature of the indicators, our classification is consistent with previous taxonomies. This suggests that common patterns underlie firms' use of technological and non-technological innovative practices. Despite the use of different indicators, similar groups of innovative firms are found.

No major differences between manufacturing and services
Second, by using a sample of both manufacturing and service firms, we found that firms in both industries share a fairly common classification of innovative behaviour. Although in the services sector input-intensive firms are relatively more frequent, firms from both services and manufacturing could well be found in all clusters. This finding is in line with Archibugi (2001) who proposes that the two sectors share some fundamentals in the process of innovation, such as the interaction with suppliers and the innovation intensity. This is also consistent with the observation that the boundaries between manufacturing and services have blurred as services and manufacturing activities are often closely bundled within organizations (Miles, 1993; Schmoch, 2003).

Innovative behaviour of firms is heterogeneous within industries
Third, using firm-level data and classifying firms directly according to their innovative behaviour provided a test of the assumption that firms within an industry are bound by common innovative patterns. Our results showed that the innovative behaviour of SMEs is heterogeneous within any industry. This variety probably originates from multiple causes: randomness of innovation results, diversity of the motivation to innovate, differentiation of product segments within an industry, and diverse strategic choices by the firms. Despite this heterogeneity, prevailing patterns of innovative behaviour could be recognised within most industries, and most of them are in line with the conclusions of sector-level studies. For example, science-based firms can most often be found in chemicals, machinery (including transportation), electrical/electronics, and consultancy and engineering services. However, it would be overdone to classify complete industries in a single cluster.

Size matters for the use of innovative practices
Finally, it appeared that size matters: science-based firms were much more present among larger SMEs (10-99 employees). This makes sense because larger firms are believed to enjoy resource advantages compared to small firms and have better opportunities to spread risks (Welsh & White, 1981; Vossen, 1998; Bodewes & De Jong, 2003). One could assume that larger firms more often use innovative practices (such as the reservation of time and money, documentation of innovation plans and the use of external sources of knowledge) to their advantage , resulting in a larger share of science-based firms. Our results confirmed that size helps to shape innovative practices, although one must remain aware of the fact that just like the sectoral differences, the four patterns of innovative behaviour are well represented in both size classes.

5.2 Implications

Our results have implications for both entrepreneurial decision-makers and policy makers who aim to stimulate innovation.

Implications for entrepreneurs
Entrepreneurial decision-makers can use taxonomies of innovative behaviour as well as firm strategies to shape their innovative decisions. We revealed that (within any industry and/or size class) firms are diverse in their use of innovative practices (including external orientation, innovation planning, managerial attitude, reservation of resources, etc) and realised outputs. This implies that those who are not satisfied with their current innovative performance could scan their direct (competitive) environment for examples of ‘how things can be done differently’. To be able to take a closer at what competitors do, co-operation and intense external orientation are options, but decision-makers may

also profit from a wide range of commercial and non-profit initiatives, including fairs, conferences, consultants, associations of interest, chambers of commerce, etc. The taxonomy also suggests a number of sources of inspiration, some of which decision-makers will not be aware of but that may be highly relevant (*e.g.,* scientific developments).

Implications for policy makers

Our results suggest that interventions directed towards a limited number of industries may be less effective. Since we found out that firms are quite heterogeneous within industries and the four patterns of innovative behaviour are present across all industries, such an approach is expected to be less effective. Following industry-specific measures one might exclude too many firms with positive attitudes towards innovation and motivated to make investments.

As mentioned in chapter 1, a current debate among policy makers is concerned with the question whether any specific measures should be taken to stimulate the innovative behaviour of service firms. Our results contribute to this debate: although the services sector was characterised by a slightly larger share of input-intensive firms, no significant difference was found between manufacturing and service firms.

In all, a purely industrial focus does not seem to be the best way to distinguish potentially innovative firms from their less innovative counterparts. Instead it would be better to take the (homogeneous) clusters of innovative firms as a basis for new policy design, and check if there is sufficient support for each type. In this context, it is striking that based on the systems approach (Lundvall, 1992; Smith, 1997) most Dutch policy interventions aim to enhance knowledge diffusion. Besides, a large share of the expenditure on innovation policy is obtained from innovation subsidies (Ministry of Economic Affairs, 2003). Our results suggest that a single cluster, namely science-based firms, will benefit most from these policies (since they rely heavily on knowledge acquisition and subsidies in their innovation processes). Policy makers should realise that the other types of innovative firms could be easily overlooked under the current intervention policies.

5.3 Suggestions for future research

Our results indicate various areas for future research. A wide range of research questions related to various patterns of innovative behaviour can be identified, including what drives firms to innovate in a particular way. The taxonomy provides a basis for making comparisons across homogeneous groups of SMEs in any innovation study. Similarly, Pavitt's taxonomy is often used for this purpose in manufacturing studies (see for example Oerlemans *et al*., 1998).

As a consequence of the sector-level approach in building taxonomies, policy makers might be tempted to use industrial classifications to select innovative firms. Since our analysis showed that such selection mechanisms are far from optimal, the question is how one can easily identify firms with particular types of behaviour. Future research should provide rules-of-thumb to identify patterns of innovation. Alternatively, one may try to balance between firm- and sector-level analyses, combining the advantages of the two. The approach would be to identify categories of firms that are more likely to follow divergent patterns of behaviour within an industry. For example, technological conditions may have a distinct effect on the innovative behaviour of new and small firms, as opposed to the routine activities of large and established firms (Winter, 1984; Marsili, 2002). By using different but detailed categories of firms, based for example on combinations of age classes, type of industry and size classes, taxonomies that descend the firm level might become more beneficial. This ‘go-between’ approach would make it possible to account for some distinctive structural traits and, at the same time, to generalise t of the heterogeneity at firm level.

Another important issue is whether it is correct to classify a particular firm always within a particular cluster. One could reason that firms implement various types of innovations. Some of them could be supplier-dominated, while others may be initiated by customers or by scientific development. Investigating these mixtures of patterns would require a different kind of data, namely at the level of individual innovations and the accompanying behaviour of firms.

A final issue is whether taxonomies are invariant across institutional contexts (for example across countries) and over time. Studies that have systematically compared taxonomies across countries are limited. Arvanitis & Hollenstein (1998) qualitatively compared the results of their clustering exercise of Swiss manufacturing firms to a similar exercise carried out for Italian manufacturing firms (Cesaratto & Mangano, 1993). Indeed, they concluded that the composition of comparable groups, in terms of percentage of firms and employment, differed substantially (however, the typology of the different clusters is fairly consistent in both studies, again suggesting that common factors shape the innovative behaviour of firms). As for the dimension time, it should be investigated if and how prevailing patterns can change. For instance, new technologies may emerge leading to the creation of new industries, but also because existing industries may change in their profile.

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