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Lessons from innovation empirical studies in the manufacturing sector: A systematic review of the literature from 1993–2003

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Abstract

What is innovation and what determines its development in manufacturing firms? The literature on the topic has evolved exponentially during the last decades. However, the divergence of the research results makes it so that the innovation process is still poorly understood. Relying on a systematic review of empirical studies published between 1993 and 2003, this article propose and discuss a framework which brings together a set of variables related to the innovation process and the internal and contextual factors driving it. The ensuing results highlight several avenues which would help managers and policy makers to better foster innovation and researchers to better channel their efforts in studying the phenomenon.

Keywords: Technological innovations; Innovation determinants; Innovation measurement; Manufacturing sector; Systematic review

What is innovation and what determines its development within firms? This question has sparked the interest of researchers, managers and policy makers for decades. The work of Joseph Schumpeter at the beginning of the 20th century was an outstanding stage in this field's evolution. In his two famous books, *The Theory of Economic Development* and *Capitalism, Socialism, and Democracy*, this eminent Austrian economist claims that innovation represents the driving force of economic development (Schumpeter, 1934, 1942). He argues that innovations made by capitalist entrepreneurs ensure a cyclic alternation of prosperity and recession phases, which in turn ensures economic expansion. Today, the economic landscape has changed considerably in comparison to Schumpeter's time. However, his work remains topical. According to several specialists, innovation is now unavoidable for companies which want to develop and maintain a competitive advantage and/or gain entry into new markets (Brown and Eisenhardt, 1995; OEDC, 1997; Rosenthal, 1992; Stock et al., 2002). It also represents one of the main factors underlying countries' international competitiveness and their productivity, output and employment performance (Asheim and Isaksen, 1997; Michie, 1998).

The undeniable importance of innovation for contemporary companies justifies the increasing interest that researchers are taking in it. However, if the number of papers on the topic has evolved exponentially during the last decades, there is still no precise prescription for successful innovation (Rothwell, 1992). Several researchers have tested the effect of a large number of innovation-related variables. However, even though they tested similar variables, they discovered differing degrees of association with the rate of innovation (Souitaris, 1999, 2002; Wolf, 1994). The innovation process is thus still poorly understood (Coombs et al., 1996) and the current state of the literature contributes little to improving our understanding of the phenomenon.

This paper aims to go beyond the highly dispersed work on innovation by providing a systematic review of empirical articles published between 1993 and 2003 on technological innovations in the manufacturing sector. Our main purpose is to integrate the findings of these studies in order to identify where the conclusions converge and diverge. This will help to advance our knowledge of innovative performance in companies and to better channel future research.

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This article is organized as follows. First, we will explain in more details the objective and scope of our study (Section 1) and describe the method used to locate and select the relevant literature (Section 2). Next, we will present some general features of the reviewed studies (Section 3). We will then present and discuss the results of our review (Section 4), and finish with the main conclusions, implications and recommendations for managers, researchers and policy makers.

1. Objective and scope of the study

This study consists of a systematic review of empirical articles published in scholarly reviews between 1993 and 2003 on the topic of technological innovations in the manufacturing sector. There were two main objectives: (1) to study how the variable 'innovation' was approached and measured by the authors, and (2) to identify the main explanatory variables which determine the innovative behavior and capacity of the firms. Some details are needed to better understand our research problem.

First of all, the choice of 1993 as the lower limit of the temporal horizon of our study is justified by the publication in 1992 by the Organization for Economic Cooperation and Development (OECD) of the first version of the 'Oslo Manual'. This manual set down the guidelines for gathering and interpreting data on technological innovations. The Oslo Manual (OECD, 1992, 1997) has two objectives: to assist newcomers to the field of innovation and to provide a framework within which research on innovation can evolve towards comparability. To do this, the key concepts related to innovation are explicitly defined and a set of measurements and survey procedures are proposed. Several OECD countries adopted the recommendations of the Oslo Manual straight away, making their research results more comparable and attempts to synthesize them more coherent.

Following the Oslo Manual's lead, we defined innovation as 'implemented technologically new products and processes and significant technological improvements in products and processes.' (1997: 31). Three points need to be specified with regard to this definition:

1. We are interested in technological innovations related to products and processes. Thus, other types of innovation, in particular organizational/administrative innovations and the entry into new markets are not covered by our analysis;
2. An innovation implies a technologically new product/process or a product/process having undergone a significant technological improvement. Consequently, minor modifications to products and processes (e.g. improvement of the product design or package) are not considered as innovations;
3. To be considered, the innovations must have been implemented, that is introduced into the market (product innovations) or used in a production process (process innovations). Thus, aborted innovations and those in progress are not considered.

Also, it should be noticed that in this systematic review we considered only empirical articles published in scholarly journals. Indeed, we excluded non empirical studies (conceptual work, qualitative studies, etc.) as well as those disseminated using a different medium (book, internet, etc.). This allows us to have a better comparable body of research, which enhances the quality of the systematic review results. Finally, it is important to mention that our review covers only the manufacturing sector. As mentioned in the Oslo Manual and confirmed by several recent studies, innovation in the service sector has particular characteristics. Furthermore, focusing on the manufacturing sector will make more sense when summarizing and comparing research results.

2. Methods

Before specifying the methodological details of the study, it is worth while answering first the question: why to do a systematic review? In the management field, the traditional narrative literature reviews have been widely criticized for the lack of relevance due to the use of a personal, and usually subjective and biased methodology by authors (Fink, 1998; Hart, 1998). To mitigate this gap, Transfield et al. (2003) propose to apply the specific principles of the systematic review methodology usually used in the medical sciences. The main difference between a systematic review and a traditional narrative review is that, contrary to the later, the former uses a rigorous, replicable, scientific and transparent process (Cook et al., 1997). A systematic review is, however, different from a meta-analysis in the sense that it does not uses statistical and econometric procedures for synthesizing findings and analyzing data (Transfield et al., 2003). The main purpose of a systematic review is to identify key scientific contributions to a field or question and its results are often descriptively presented and discussed. Applying the principles of the systematic review will then help to limit bias (systematic errors), reduce chance effects, enhance the legitimacy and authority of the ensuing evidence and provide more reliable results upon which to draw conclusions and make decisions.

Two steps are particularly important when doing a systematic review: (1) the setting of inclusion criteria and, (2) the strategy of locating and selecting the potential studies (Alderson et al., 2004).

2.1. The inclusion criteria

Four criteria were used to select and assess the potential studies. To be included in our systematic review, a study had to:

1. Deal with technological product/process (TPP) innovations. Studies dedicated to other types of innovation (i.e. organizational innovations, insignificant or minor product/process changes, etc.) were not retained;
2. Be an article published between 1993 and 2003 inclusively in a peer review journal. Thus, other publication forms (conference proceedings, books, newspapers articles, unpublished works, etc.) were not considered;
3. Include an empirical study of a sample of companies belonging entirely or mainly to the manufacturing sector. Theoretical and conceptual studies as well as case studies were not retained. However, we did not in any way restrict the data analysis method used by the authors—both descriptive statistics and econometric methods were included;
4. Consider innovation as the dependent variable (i.e. the variable to be explained). Consequently, articles which considered innovation as an independent variable (i.e. an explanatory variable of another phenomenon like the firm's performance, export, etc.) were not included.

2.2. Data sources and studies selection

We used a three stages strategy to look for and select the articles included in our systematic review. First, we carried out a computerized search by using multiple keywords (see Appendix) in three databases, namely ABI/INFORM of Proquest, Business Source Premier (BSP) of EBSCO, and ScienceDirect of Elsevier. The two first databases provide access respectively to about 1 800 and 4 500 scientific journals in administrative and management sciences. As for ScienceDirect, the section 'Business, management and accounting' covers over a hundred periodicals specialized in the business administration field. In the second stage we searched systematically all the articles published between January 1993 and December 2003 in three renowned journals in the innovation field, namely *Research Policy*, *Technovation* and *Technological Forecasting and Social Change*. Finally, we manually searched the reference lists of the articles retrieved after the two first steps. By so doing, we identified 4 373 potential articles for our systematic review.

The identified articles were subjected to a double screening (Fig. 1). A first sorting of the articles' title and summary allowed us to exclude 3 653 papers which did not meet the inclusion criteria. This left us with 720 potential articles for thorough analysis. Each one of these 720 articles was reviewed by at least two of the three authors and assessed according to the inclusion criteria. The second screening went beyond the title and summary into the main body of the articles and led us to exclude 612 articles which did not meet the inclusion criteria (e.g. definitions covering innovations other than TPP, propositions of a mathematical model without empirical testing, samples including a high proportion of service firms, uses of multiple case studies). This left a total of 108 studies which matched all the inclusion criteria[1].

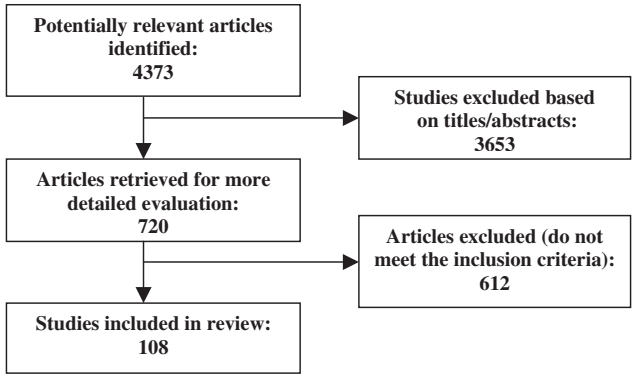

Fig. 1. Systematic review flow diagram.

All the selected articles were computer managed. For the purposes of our study, we designed a Microsoft Excel database that contained each article's reference, the type of innovation considered (i.e. product, process or both), the sample size, the nationality of the investigated firms, the sector(s) to which these firms belong, the statistical method used for data analysis as well as the conceptual and operational definitions of the dependent and explanatory variables included in the analysis.

3. Some general characteristics of the included studies

The distribution of the reviewed articles per publication year shows that 1996 was an outstanding date for research on innovation (Fig. 2). Beginning with a very limited number of articles per year for the period 1993–-1995, the rate of published articles on manufacturing sector innovation increased remarkably since 1996 to reach an average of over 12 articles per year for the period 1996–-2003. This publication trend might originate in the series of Community Innovation Surveys (CIS) conducted in Europe during the last decade. It consisted of three innovation surveys carried out simultaneously in several European countries in 1993, 1997 and 2001. The publication of the two first surveys' results in 1995 and 2000 respectively might explain the significant number of articles published in 1996 and 2001 (i.e. right after the publication of the CIS1 and CIS2 results). If this tendency holds true, one could expect a significant number of publications in 2005 and 2006, following the publication in 2004 of the CIS3 results.

The CIS's possible catalyst effect finds another explanation in the distribution of the reviewed studies by country/region. As Fig. 3 shows it, European industries are the most often studied, followed by North American

[1] The list of the 108 articles is available on the web site http://kuuc.chair.ulaval.ca (tab 'Knowledge Transfer Resources').

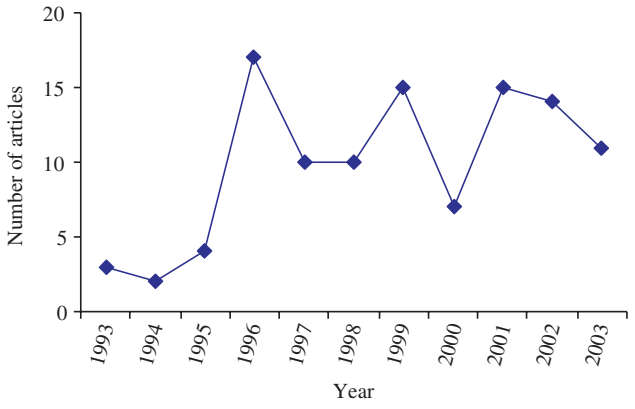

Fig. 2. Publication trend.

and, to a lesser degree, Asian companies. On a country scale, seven of the ten most investigated countries are European (Table 1). The three other countries are the USA - which was the most studied -Canada and Japan. It is worth noting that in the case of the USA and Canada, surveys using an approach similar to that of the CIS were also conducted in the decade covered by our systematic review.

In addition, the distribution of the authors of the reviewed studies shows that innovation research was split into several areas of inquiry (Fig. 4). Management and economics were the disciplines in which this phenomenon was most examined, with 44% and 34% of the authors respectively. This result confirms the assertion of several authors (e.g. Adler, 1989; Brown and Eisenhardt, 1995) concerning the pre-eminence of the economics- and managerial-oriented traditions in innovation studies.

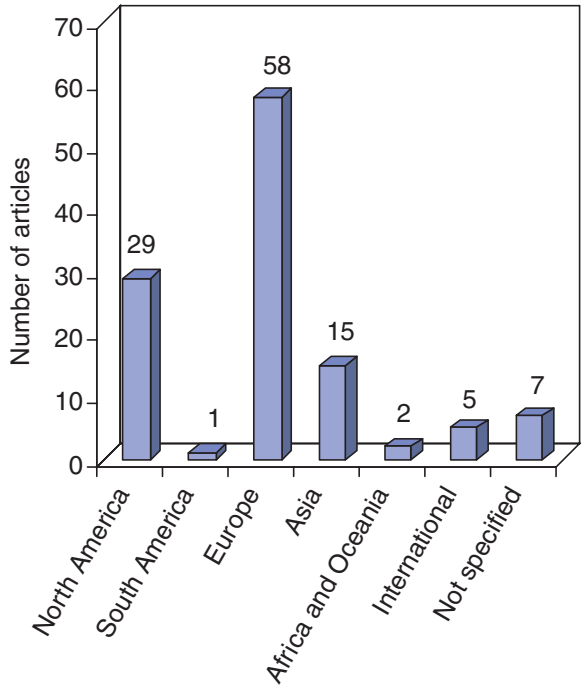

Fig. 3. Distribution of the articles by investigated regions.

Table 1
Distribution of the articles by investigated countries

Country	Number of articles	Percentage
USA	21	19
UK	20	18
Germany	10	9
France	8	7
Spain	6	6
Italy	6	6
Canada	5	5
Japan	5	5
Belgium	4	4
Greece	4	4
The netherlands	4	4
China	2	2
Denmark	2	2
Irelande	2	2
Taiwan	2	2
Others	18	17
Regional/International	11	10
Not specified	7	6
Total	137	126[a]

[a] The total is higher than 100% because some studies cover more than one country.

The economic-oriented studies particularly investigated the macroeconomic determinants of innovation, whereas the managerial studies focused on the variables related to innovative firms (Brown and Eisenhardt, 1995).

4. Findings

The examination of the 108 articles included in our systematic review brought out a wide range of issues related

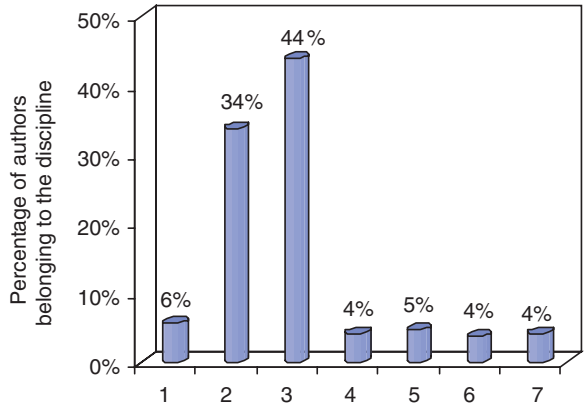

Fig. 4. Distribution of the authors by disciplines.

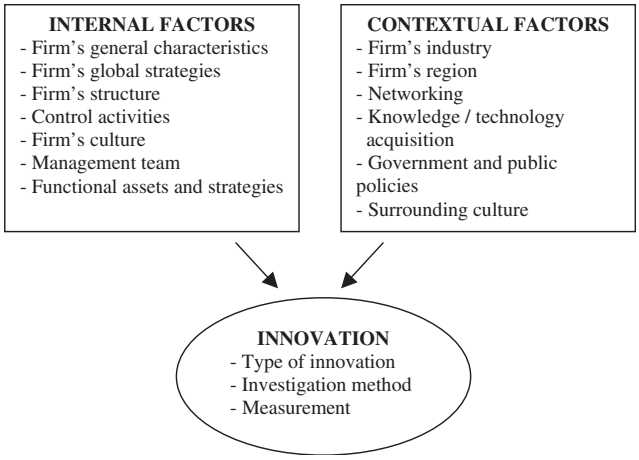

Fig. 5. A framework for integrating innovation findings.

to innovation and its explanatory factors. An integrative framework was thus needed to provide a comprehensive and coherent characterization of the state of knowledge in this field. A thorough analysis of the reviewed studies led us to propose the framework presented in Fig. 5, which brings together a set of variables related to innovation and the internal and contextual factors driving it. We will use this framework to organize the presentation and discussion of our findings.

The first block of the proposed framework considers three major issues when viewing innovation as a dependent variable: (1) the type of innovation (product versus process), (2) the statistical and/or econometric method used in the data analysis, and (3) the indicators used to measure innovation. The two others blocks refer to the explanatory variables of innovation. All in all, we distinguished approximately sixty variables which, in addition to being numerous, were quite varied. Based on the variables' characteristics, we grouped them into two families: (1) the internal variables (i.e. specific to the firm), and (2) the contextual variables (i.e. related to the firm's environment). The remainder of this section will examine respectively these various elements integrated into our framework.

4.1. The dependent variable 'innovation'

4.1.1. Type of innovation

As mentioned earlier, our systematic review concerns only technological product and process innovations. Of the two, product innovations were the most often studied by authors. Indeed, 37% of the articles included in our review focused exclusively on this type of innovation, and 43% examined both product and process innovations (Fig. 6). It is worth noting that a relatively insignificant proportion (1%) of the articles considered only process innovations. Furthermore, 13% of the articles studied innovation via patent data without specifying if these data represented product and/or process innovations. Finally, 6% of the studies did not specify the type of innovation they

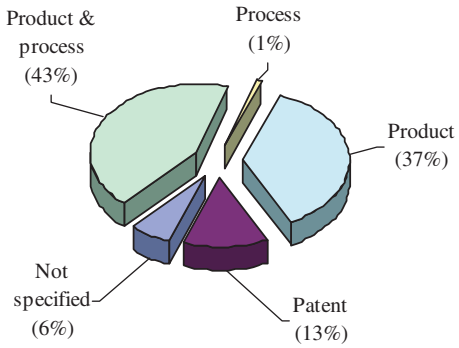

Fig. 6. Distribution of the articles by type of innovation investigated.

examined. They generally consisted in descriptive studies where the conceptual definition of innovation conformed to that of the Oslo Manual (i.e. TPP innovation) but where the operational definition was missing.

Two remarks ensue from these observations. First, in spite of the strategic importance for firms of process innovations -process innovations often lead to improved productivity (Heygate, 1996) -, they were of relatively little interest to researchers. The study of Linder et al. (2003), conducted with forty managers, revealed that these managers had the same attitude with respect to process innovations. Indeed, the majority of executives in the study indicated that they thought primarily about new products when considering innovation and much less often about processes. However, other studies (e.g. Martinez-Ros, 1999) found that product and process innovations are interdependent and closely linked. Neglecting process innovations could thus weaken a firm's capacity to develop new products and undermine the innovation process entirely.

Though it is true that a close link exists between product and process innovations, several studies (e.g. Freel, 2003; Gopalakrishnan et al., 1999; Lager and Hörte, 2002; Michie and Sheehan, 2003; Papadakis and Bourantas, 1998; Sternberg and Arndt, 2001) have shown that product and process innovations follow different processes and do not necessarily have the same determinants. Moreover, while using the same database, Michie and Sheehan (2003) found that the determinants of innovation and their effect -positive or negative -differ according to whether one considers only the product innovations, the process innovations or both. It is thus strongly recommended for future research not only to consider more process innovations, but also to consider them separately.

4.1.2. Data analysis techniques used to study innovation

Multiple regression analysis -especially OLS regression - represented the most widely used analytical approach to investigate innovation. As shown in Fig. 7, 37% of the reviewed articles used this econometric method. Other types of regression models were also used, depending on the way the dependent variable was measured. We noticed in particular that the Probit, Logit, Tobit, negative binomial

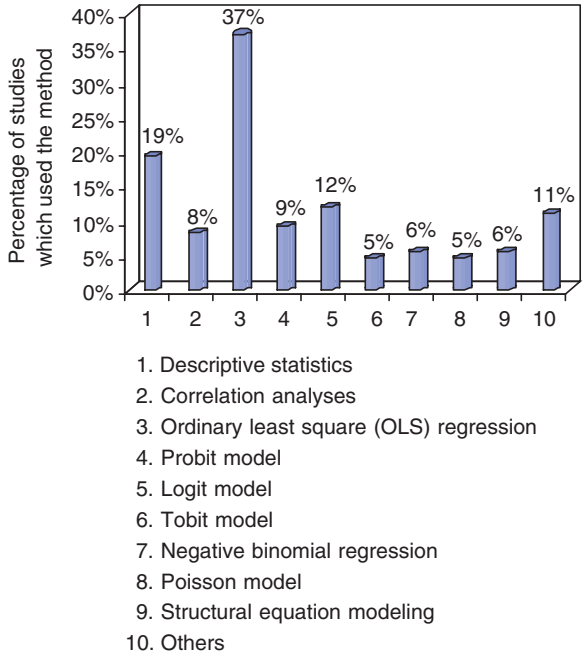

Fig. 7. Statistical and econometric techniques used to study innovation.

and Poisson regression models were used in 9, 12, 5, 6 and 5% of the cases respectively. In all these models, the dependent variable (i.e. innovation) was regressed on a set of factors integrated into the equation as explanatory variables.

We should also point out that the structural equation modeling (SEM) and the correlation analyses (e.g. Pearson's correlation, canonical correlation, Spearman rank correlation) were used in 6 and 8% of the cases respectively. In addition, 19% of the studies carried out a descriptive analysis of the collected data separately or jointly with econometric analyses. Finally, 11% of the studies used other less common statistical methods such as the Cox, Weibull, ASP (asymptotic least squares) and NLS (non-linear least squares) regressions as well as non-parametric techniques like Kendal's *W*-test and Kolmogorov–Smirnov-*Z*.

4.1.3. Innovation measurement

The examination of the articles included in our review showed that innovation was measured in various ways. It should be noticed here that innovation measurement was always a thorny task for researchers (Archibrugi and Pianta, 1996; Archibugi and Sirilli, 2001). Innovation is a complex, diversified activity with many interacting components, and sources of data need to reflect this (OECD, 1997). Traditionally, innovation has often been measured by using two indirect indicators: research and development (R&D) and patent data. However, with time, these indicators have been shown to have many shortcomings (Table 2).

R&D represents an input to the innovation process which does not necessarily lead to technologically new or improved products and/or processes (Flor and Oltra, 2004; Kleinknecht et al., 2002). Thus, R&D data would seem to be an over-estimated measure of innovation since it includes aborted R&D efforts. Moreover, all innovations are not necessarily 'simmered' in R&D laboratories (Michie, 1998). Innovations can emerge in response to a specific problem or quite simply following a clever idea that the innovator suddenly had. In this case, measuring innovation by using R&D data will underestimate the phenomenon. Finally, it is noteworthy that R&D data used as an innovation indicator tends to favor large firms compared to small and medium enterprises (SME) due to the fact that SMEs' R&D efforts are often informal (Acs and Audretsch, 1991; Kleinknecht et al., 2002) and occasional (Michie, 1998). Due to all these limits, R&D data is used less and less in research as an innovation indicator. Our review shows that this measurement was only used in 6% of the cases (Fig. 8).

As for patent data, it measures inventions rather than innovations (Coombs et al., 1996; Flor and Oltra, 2004; OECD, 1997). As innovation is the translation of an invention into a marketable new or improved product or process, measuring it by using patent data risks to overestimate the innovation output by including in the measurement those inventions that have not been transformed into marketable products or processes. Moreover, the tendency to patent varies between industries (Archibugi and Sirilli, 2001; Michie, 1998). For various reasons (e.g. high costs, cumbersome patenting procedures, relatively high imitation costs, etc.) some companies/industries would

Table 2
Main disadvantages of innovation indicators

Indicators		Disadvantages
Indirect measures	R&D	R&D activities are an input to the innovation process
		All innovations do not necessarily stem from R&D
		There is a tendency to favor large companies over SMEs
	Patents	Patents measure invention rather than innovation
		Propensity to patent differs across sectors
		Not all innovations are patented
Direct measures	Innovation count (object approach)	There is a tendency to privilege major (product) innovations as opposed to minor (process) ones
		Excludes unsuccessful innovations
		Must appeal to a panel of experts to evaluate the innovations (practical difficulty/subjectivity)
	Firm-based surveys (subject approach)	The significance and representativeness of the results depend on the response rate
		Is an unqualified dichotomous measure of innovation

References: Archibrugi and Pianta (1996), Coombs et al. (1996), Hagedoorn and Cloodt (2003), Kleinknecht et al. (2002), Michie (1998), and Patel (2000).

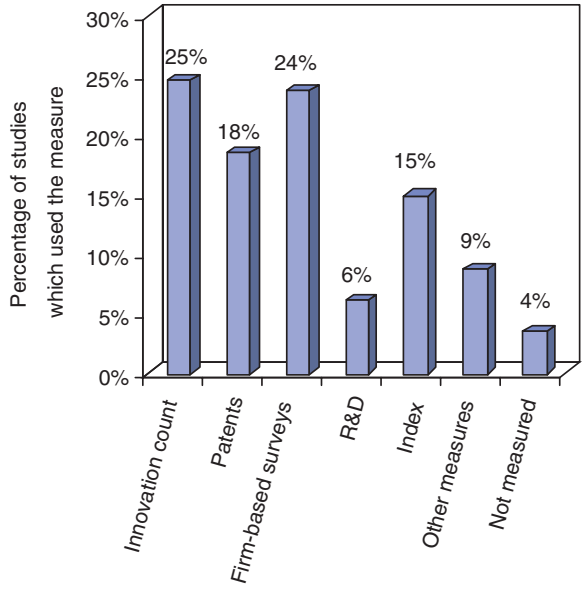

Fig. 8. Measurement of innovation.

prefer to protect their innovations by other appropriability methods such as technological complexity, industrial secrecy, and maintaining a lead time over competitors (Archibugi and Pianta, 1996; Kleinknecht et al., 2002; Mansfield, 1985). Given that all innovations are not necessarily patented, patent data is thus a distorted measurement of innovation. These limitations have not however prevented patent data from being used in various studies-18% of the cases in our review-mainly due to their availability and relatively easy access.

So as to deal with the shortcomings of measuring innovation indirectly, new, more direct indicators were developed. The main indicators are: (1) innovation count, and (2) firm-based surveys. The former consists in collecting information on innovations from various sources such as new product/process announcements, specialized journals, databases, etc. It is considered to be an object approach since it concentrates on the innovations themselves. The second measurement consists of surveys carried out with companies. This approach is qualified as a subject approach since information on the innovations comes from firms through surveys and/or interviews. The firm-based survey approach is becoming the standard method of collecting direct information on innovation (Michie, 1998), thanks in particular to endeavors by the OECD and some regional and international institutions such as Eurostat to standardize the methods used and the information collected in such surveys (Archibugi and Sirilli, 2001). In the case of the articles included in our review, these two approaches are those that were most often used to measure innovation, with 25 and 24% of the cases respectively (Fig. 8).

It is worth noting that these direct measures of innovation (i.e. innovation count and firm-based surveys) also have some disadvantages. The object approach (i.e. innovation count) tends, in practice, to favor radical innovations over incremental ones (OECD, 1997) and product over process innovations (Flor and Oltra, 2004; Kleinknecht et al., 2002; Tether, 1998). Also, this approach naturally excludes unsuccessful innovations, thereby preventing any comparative analysis of success and failure. Moreover, the researcher, not being an expert in various industries, needs a set of experts to evaluate the innovations under study, which, in addition to idiosyncratic bias (Archibugi and Pianta, 1996; Archibugi and Sirilli, 2001), makes the research difficult to carry out.

As for firm-based surveys, one of their major disadvantages is that the significance and the representativeness of the results depend widely on the answer rates (Archibugi and Sirilli, 2001). Another shortcoming is related to the fact that these surveys are based on the methodological guidelines of the Oslo Manual which measures newness by asking questions such as the following: 'During the last three years, did your business unit introduce onto the market any new or significantly improved products?' Findings from this research trend indicate that the percentage of innovative firms has increased steadily and significantly during the last decade, bordering on 80% in some countries (Amara et al., 2004). However, research findings based on this operationalization of innovation are becoming less and less productive since empirical studies are increasingly delivering additional confirmation of prior results instead of shedding new light on the nature of innovation and its determinants. On the management and public policy side, such empirical results are less and less effective because they suggest that all innovations are the same and that most firms innovate, thus providing limited pertinent knowledge for decision-making. It is therefore important to upgrade this approach by introducing indicators assessing the degree of newness or innovativeness rather than measuring, in an unqualified, dichotomous way, whether firms have innovated or not[2].

These limits have pushed some researchers to develop their own index to measure innovation—15% of the studies included in our review did this. These indexes are in many cases a combination of two or several of the above-mentioned measurements. The aim is to take advantage of their strong points while limiting their shortcomings. In the remaining cases, these indexes consist of multi-item measurements of innovation obtained through a factor analysis of the answers to a set of survey questions. It is noteworthy that 9% of the investigated studies used other measurements of innovation (e.g. sales generated by the innovations, the number of trademarks, the time allocated by managers to innovation related activities, etc.) and that in 4% of the cases the innovation was not measured. In this last case, the authors often asked the respondents about the main

[2] See Amara et al. (2004) for further details on the conceptualizations and operationalizations of innovation radicalness.

innovation determinants without operationally measuring the concept.

4.2. The driving forces of technological innovations

A considerable number of explanatory variables of the innovative behavior of firms have been considered by authors. In accordance with the proposed framework, we will present the results of the examined literature in two parts: (1) results concerning the internal determinants of innovation, and (2) those specific to the contextual determinants.

4.2.1. The internal factors

Identifying the distinguishing characteristics of highly innovative companies at the micro/firm-level has been the aim of organizational theorists since the late 1960s (Souitaris, 2002). Our systematic review identified about forty determinants concerning the characteristics of innovating firms. In order to draw up a comprehensive and instructive overall picture of these variables we grouped them together in various categories (Table 3). Our categorization was strongly inspired by the literature from the strategic management planning school (Mintzberg et al., 1998) which seemed quite appropriate for the presentation

Table 3
Internal determinants of innovation

Category	Subcategory	Variables	Selected references
Firms' general characteristics	–	Size of the firm	Bertschek and Entorf (1996) and Greve (2003)
		Age of the firm	Jung et al. (2003) and Sørensen and Stuart (2000)
		Ownership structure	Bishop and Wiseman (1999) and Love et al. (1996)
		Past performanc	Tsai (2001) and Zahra (1993)
Firms' global strategies	Strategy definition	The firm has a defined strategic orientation	Souitaris (2002)
	Corporate strategy	Diversification strategy	Ahuja (2000), Ahuja and Katila (2001), and Hitt et al. (1997)
		Export/internationalization	Landry et al. (2002) and Romijn and Albaladejo (2002)
		External vs. internal growth	Belderbos (2001) and Hitt et al. (1996, 1997)
	Business strategy	Differentiation strategy	Beneito (2003) and Galende and De la Fuente (2003)
		Cost reduction strategy	Motwani et al. (1999); Zahra (1993)
		Protection mechanisms	François et al. (2002) and Veugelers and Cassiman (1999)
Firms' structure	Formalization	Formal structure	Koberg et al. (1996)
		Flexible structure	Darroch and McNaughton (2002) and Wu et al. (2002)
	Centralization	Centralization of decision making	François et al. (2002) and Koberg et al. (1996)
		Empowerment of employees	Gudmundson et al. (2003) and Wu et al. (2002)
	Interaction	Interaction between firm's units	Lukas and Ferrell (2000) and Parthasarthy and Hammond (2002)
Control activities	–	Financial versus strategic control	François et al. (2002) and Hitt et al. (1996)
Firms' culture	–	Resistance to change	Veugelers and Cassiman (1999)
		Total quality management(TQM)/ continuous improvement	Baldwin and Johnson (1996), François et al. (2002), and Motwani et al. (1999)
		Culture of support for innovation	Jung et al. (2003)
Management team	Leadership variables	Presence of a project leader	Chandy and Tellis (1998) and Souitaris (2002)
		CEO characteristics	Papadakis and Bourantas (1998)
		CEO change	Sørensen and Stuart (2000)
	Manager related variables	Qualification and experience	Baldwin and Johnson (1996) and Romijn and Albaladejo (2002)
		Perception of cost/risk related to innovation	François et al. (2002) and Veugelers and Cassiman (1999)
		Perception of innovation returns	Coombs and Tomlinson (1998) and Keizer et al. (2002)
Functional assets and strategies	R&D	R&D assets and strategies	Hall and Bagchi-Sen (2002) and Parthasarthy and Hammond (2002)
	Human resource	Personnel qualification/experience	Guangzhou Hu (2003) and Romijn and Albaladejo (2002)
		Human resource strategies	Michie and Sheehan (2003) and Rhyne et al. (2002)
	Operation and production	Advanced equipment/technologies	Kam et al. (2003) and Landry et al. (2002)
		Degree of capacity utilization	Smolny (2003)
	Marketing	Marketing strategies	Koschatzky et al. (2001) and Souitaris (2001)
		Monitoring of competitors	François et al. (2002) and Lukas and Ferrell (2000)
	Finance	Financial autonomy	Beneito (2003) and Hitt et al. (1997)
		Turnover/profit	Love and Roper (1999) and MacPherson (1994)
		Budget/funds availability	Greiger and Cashen (2002) and Souitaris (2002)

of our findings. We thus identified seven main categories of internal variables, namely those related to: (1) the general characteristics of the firm, (2) its global strategies, (3) the structuring of its activities, (4) control activities, (5) the firm's culture, (6) its top management team, and (7) its functional assets and strategies. We will examine, in detail, what the literature has to say about the role these variables play as innovation determinants.

4.2.1.1. Variables related to the firms' general characteristics. The firms' general characteristics comprise four variables: (1) the firm's size, (2) its age, (3) its ownership structure, and (4) its past performances. The debate on the effect of size on innovation goes back to Schumpeter's fundamental work in which he proposes two contradictory assumptions. In *The Theory of Economic Development*, Schumpeter (1934) suggests that entrepreneurs and start-ups represent the foremost source of new ideas and technologies. However, in *Capitalism, Socialism, and Democracy*, Schumpeter (1942) states that innovation activity increases more than proportionally with firm size. The debate was thereby launched and size became one of the variables most studied as a determinant of innovation. More than half (55%) of the studies included in our review viewed firm size as an explanatory variable of innovating behavior. Though the results are mainly in favor of Schumpeter (1942) proposal -36 studies concluded that size has a significant positive effect on innovation -this assumption is refuted by other authors. Indeed, 4, 11, 5, and 3 studies respectively found the relation between firm size and innovation to be negative, not significant, bell-shaped, or U-shaped (Fig. 9).

Two main arguments indicate a positive effect of size on innovation: (1) large companies have more resources to innovate and support risky activities than do SMEs (Damanpour, 1992; Majumdar, 1995; Tsai, 2001), and (2) large firms can benefit from economies of scale in R&D, production and marketing (Stock et al., 2002). As for research whose results were contrary to Schumpeter (1942) assumption, that of Bertschek and Entorf (1996) is particularly interesting. In studying the effect of size on innovation in Germany (two data sets: 1984 and 1989), France and Belgium, the authors found a negative relationship in the case of Belgium, a U-shaped curve in the cases of France and Germany-1984, and a hump-shaped curve in the case of Germany-1989. They explained these results by the fact that the innovation-firm size relationship might be influenced by other factors such as industry conditions, market structure, etc. This explanation agrees with the results of Acs and Audretsch (1987) who found that the innovation activities of small and large companies are dependant, to a large degree, on different technological environments. More recently, Veugelers and Cassiman (1999) found a significant effect of industry characteristics on the relation between size and innovativeness. In another study, MacPherson (1994) found a negative correlation between employment growth and process innovations but noticed that the relationship between the two variables is more complicated than a simple rank-order correlation might imply.

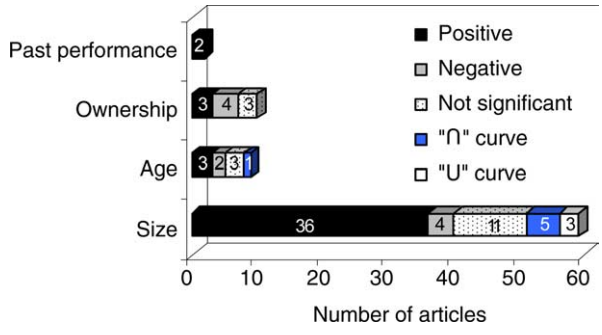

Fig. 9. Firms' general characteristics as determinants of innovation.

In conclusion, the cumulative results seem to suggest a positive correlation between firm size and innovativeness. Even the studies having found a different relationship seem to admit this, since rather than looking for explanations in their results, they often seek to justify not to having found a positive relationship. However, following in the steps of Bertschek and Entorf (1996) and MacPherson (1994), we believe that the relation between a firm's size and innovation is rather complex and could be influenced by several factors. It would therefore be wise to temper these results so as not to fall into abusive generalizations. This call for prudence is all the more justified by the fact that some research (e.g. Love and Ashcroft, 1999; MacPherson, 1998) has found that, with regards to innovation performance (i.e. innovation output moderated by firm size), small companies rank better than large ones. This suggests that small firms are a disproportionately important source of innovation by being more efficient in their innovation efforts.

As for the effect of a firm's age on innovation, two hypotheses are plausible. The first one stipulates that with age, a company will accumulate the experience and knowledge necessary to innovate. This suggests not only a positive relationship between firm age and innovation but also that the innovations of older companies would have more influence than those of younger ones (Sørensen and Stuart, 2000). The second assumption suggests that older firms develop established procedures and routines that create a resistance to the integration of major external advances and thus represent a barrier to innovation (Freel, 2003). The few studies of this topic do not make it possible to settle the argument between these two positions (Fig. 9).

The results are also mixed as concerns the effect of ownership structure on innovation. Whereas some research (e.g. Love and Ashcroft, 1999; Love et al., 1996; Michie and Sheehan, 2003) maintains that foreign ownership is positively and significantly correlated with innovation, other studies find that this relationship is rather negative (Love and Roper, 1999, 2001; Martinez-Ros, 1999) or not significant (Bishop and Wiseman, 1999; De Propris, 2000).

Arguments for a negative relationship stem mainly from the relative lack of important management and operational functions (especially R&D) in an externally-owned firm. However, opponents of this position argue that, in this case, the transfer of scientific resources (e.g. technologies, knowledge, R&D results) and non-scientific ones (e.g. finance, marketing, etc.) from a foreign parent will compensate for this lack and will make it possible for the company to raise its innovative capacity. It is worth noting, moreover, that a good past performance seems to provide companies with the necessary resources and to encourage them to innovate in order to reinforce their competitive position and increase their market share and profits (Tsai, 2001; Zahra, 1993).

4.2.1.2. Variables related to the firms' global strategies and control activities. Does a company with a clearly defined strategic orientation have more chance of being innovative than another which has none? Only one study (Souitaris, 2002) has answered the question empirically. The results show that a well-defined strategy distinguished the more innovative firms in specialized supplier industries such as small mechanical and instrumental engineering. It is clear that no generalization can be drawn from these results and that future research is needed before reaching a consensus.

With regard to corporate growth strategy (concentration/specialization versus diversification), the results do not seem to support the diversification strategy. Indeed, all the studies which found a significant relationship negatively associated diversification strategies with innovation (Fig. 10). Since Adam Smith, specialization has been associated with a higher level of workers alert to improvements. Specialization might also foster innovation by increasing the number of competing units searching for a solution to a specific problem (Robertson and Langlois, 1995). As for diversification, it is often accompanied by formal and financial controls that can discourage technological activity (Ahuja, 2000; Galende and De la Fuente, 2003; Tallman and Li, 1996). Moreover, this last argument is reinforced by studies which investigated the relationship between control activities and innovation (Fig. 10). These studies found that financial controls can produce a short-term orientation and risk-averse actions and thus undermine the innovation process (François et al., 2002; Hitt et al., 1996; Kochhar and David, 1996). Conversely, strategic controls focus on long-term performance which promotes increased managerial commitment to innovation (Hitt et al., 1996).

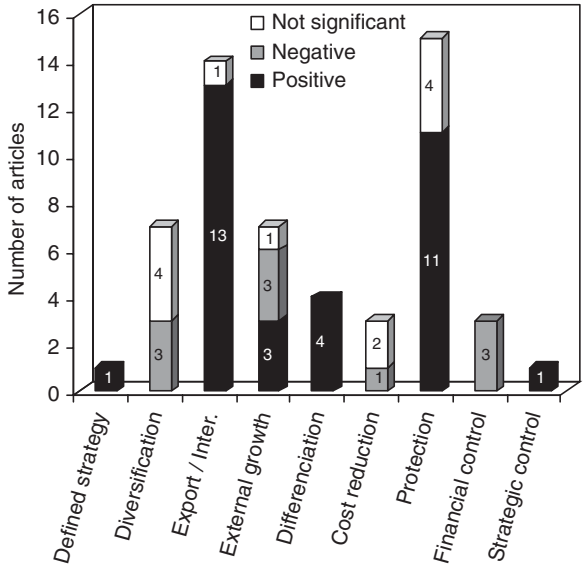

Fig. 10. Firms' global strategies and control activities as determinants of innovation.

Whether it is specialized or diversified, a company is often confronted with two choices: (1) should it limit its activities to the local market or become more international?; and (2) should it pursue its growth internally or externally (i.e. develop alliances such as subcontracting, mergers and acquisitions)? With regard to the first choice, research is almost unanimous (Fig. 10): export and internationalization have a positive significant effect on innovation (Galende and De la Fuente, 2003; Landry et al., 2002; Romijn and Albaladejo, 2002). To remain competitive on the international market, a company has no another choice than to constantly innovate (Veugelers and Cassiman, 1999). As for the second choice, the results seem to be split between a positive and a negative significant association between external growth and innovation. A positive relationship is accounted for by the access to new technologies that external growth provides (Belderbos, 2001) whereas a negative relationship is explained by the drop in productivity which an acquisition, for instance, can generate following the disruption of acquiring firm established routines and the complexity of post-acquisition management (Ahuja and Katila, 2001; Hitt et al., 1996).

As for business strategies, one of the most widespread typologies is that developed by Porter (1990). According to the source of the firm's competitive advantage, Porter distinguishes between two 'generic' competitive strategies: differentiation and cost leadership. The results of our systematic review (Fig. 10) show that the differentiation strategy is positively correlated with innovation (Beneito, 2003; Debackere et al., 1996; Galende and De la Fuente, 2003; Zahra, 1993). Such a strategy encourages companies to innovate intensively and to accelerate their innovation rate in order to be well ahead of competitors and achieve a greater competitive advantage (Zahra, 1993). Conversely, a cost leadership strategy seems to be negatively associated with innovation (Zahra, 1993). In order not to increase their costs, the companies which adopt this strategy often limit their innovative efforts to imitating the innovations made by differentiators (Porter, 1980). It is worth noting that this result seems to be, once again, related to the disproportionate interest granted to product over process innovations. One could imagine that a company which seeks to minimize

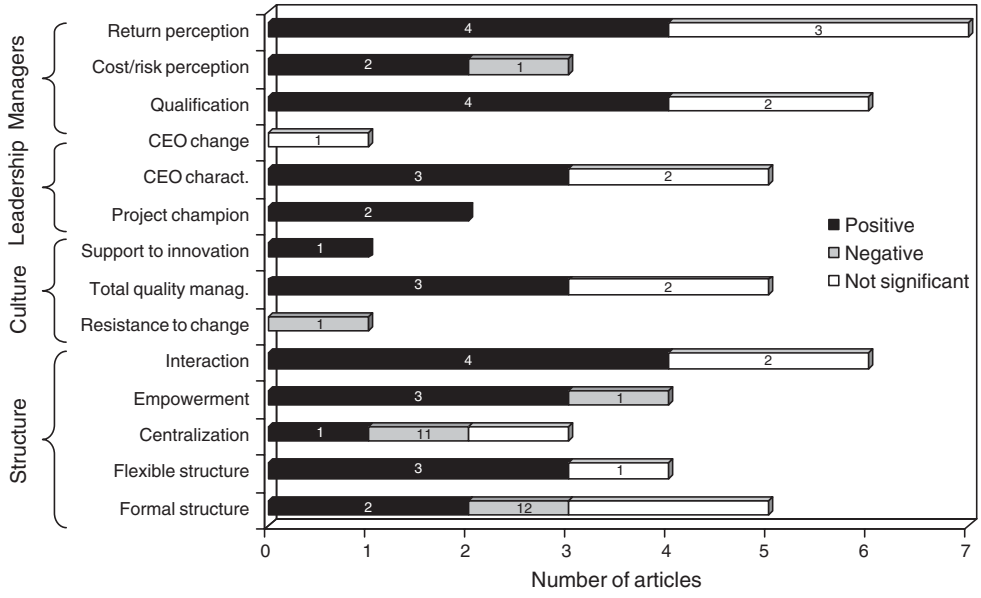

Fig. 11. Structure, culture, and management team variables as determinants of innovation.

costs might be very dynamic in developing new efficient processes. Further empirical studies are, however, necessary to confirm or refute this assumption.

A critical issue related to business strategies is that of competitive advantage protection. The reviewed studies are almost unanimous about the significant positive effect of protection against the imitation on innovation (Fig. 10). Indeed, protection-be it through patents, technology complexity, industrial secrecy, keeping key people in the firm, maintaining a lead time over competitors or other mechanisms-leads rival firms to abandon the race for technological innovation (François et al., 2002). This enhances a firm's appropriation of its innovation benefits (Veugelers and Cassiman, 1999) which in turn feeds the company with the necessary will and resources to innovate more (Malerba et al., 1997).

4.2.1.3. Variables related to structure, culture, and the management team. Relatively few studies have viewed variables related to the organization's structure, its culture and its top management team as determinants of a firm's innovative capacity. Fig. 11 recapitulates their main conclusions. It shows, among other things, that the effect of structural formalism and centralized decision making on innovation is rather unclear. Basing their argument particularly on the work of Van de Ven (1980, 1986), Walsh and Dewar (1987), and Koberg et al. (1996) propose a very judicious explanation of these mixed results by introducing the moderating effect that the life-cycle of the firm could have on the relation between these two variables and innovation. According to these authors, formalism allows young companies to clarify the roles and to reduce ambiguity, thereby allowing them to concentrate their efforts and limited resources. This, in turn, promotes effectiveness, improves morale, and increases innovation. In the same way, centralization in these companies, which are distinguished from other companies by the absence of bureaucratic hierarchy, will give the entrepreneur the necessary freedom to be assertive and commit resources. On the other hand, in an older company, the widening of the activity spectrum and the establishment of a relatively long chain of command weakens the firm's innovative capacity through this sophisticated formalism and increased centralization of decisions.

The same logic might also explain the significant positive effect on innovation of structure flexibility, empowerment and the interaction between a firm's various functional units (Fig. 11). Indeed, if young SMEs can be innovative when formalizing their rules and procedures and centralizing decision-making in the entrepreneur's hands, an older company must ensure that its structure remains flexible, that decentralized decision-making is possible and that cross-functional communication and coordination are stimulated if it wants to be innovative.

Furthermore, the few studies published about organizational culture determinants suggest that innovation is significantly and positively correlated with the implementation of a total quality management (Baldwin and Johnson, 1996; François et al., 2002) and continuous improvement (Motwani et al., 1999) culture within the firm[3]. Two other studies found that the effect on innovation of the resistance to change (Veugelers and Cassiman, 1999) and the employee's perception of the support for innovation (Jung et al., 2003) is negative in the first case and positive in the second.

[3] For further details on these two variables see McAdam et al. (1998).

The literature on the top management team determinants of innovation enabled us to distinguish two types of variables: (1) leadership related variables, and (2) those related to managers. In general, the majority of these variables are significantly and positively correlated with innovation (Fig. 11). Chandy and Tellis (1998) and Souitaris (2002) found that the presence of a 'project leader' in the company represents a crucial factor favoring innovation. The project leader is a person who enthusiastically supports innovation projects and who is personally committed to them. Moreover, these results confirm those found in former research such as that of Cooper (1979) and Rothwell (1992).

Other studies (e.g. Jung et al., 2003; Morris et al., 1993; Papadakis and Bourantas, 1998) have found a significant positive influence of the Chief Executive Officers' (CEO) characteristics on their firm's innovative capacity. An entrepreneur/CEO with a transformational leadership and a high need for achievement often sets challenging goals, always seeks to do things better and does not hesitate to embark upon innovation projects. Great importance attributed by the CEO to company goals of reputation and power is also found to be positively correlated with innovation since innovation is a powerful means for the company to achieve these goals. Other personality characteristics like locus of control and risk aversion were not found to be significant. However, some CEO's demographic characteristics, namely tenure in the firm and education level, are positively correlated with innovation.

The managers' qualifications and cumulative experience are likewise important determinants of innovation (Baldwin and Johnson, 1996; Romijn and Albaladejo, 2002; Souitaris, 2002). A seemingly counter intuitive result found by François et al. (2002) and Veugelers and Cassiman (1999) shows a significant positive association between innovation and managers' perception of its costs and risks. However, these authors proposed that this result be interpreted differently: the perceived high risks and costs of innovation do not deter firms from innovating. Finally, the managers' perception of innovation repercussions (including projected profits, appropriation, cost reduction, improvement of the firm's competitive position, etc.) is a powerful factor encouraging firms to innovate (Coombs and Tomlinson, 1998; Souitaris, 2002).

4.2.1.4. Variables related to functional assets and strategies. Today, in-house research and development (R&D) is largely admitted to be a crucial determinant of innovation. More than half of the studies included in our review viewed R&D as an explanatory variable of innovation and nearly 80% of them found a significant positive relationship between the two variables (Fig. 12). The role that internal R&D plays as an innovation determinant is varied. It helps companies to create, exploit and transform new knowledge into new products and/or processes (Graves and Langowitz, 1996; Keizer et al., 2002; Landry et al., 2002; Li and Simerly, 2002; Sternberg and Arndt, 2001). It also helps them to absorb (i.e. acquire, assimilate, transform and exploit) new technologies appearing on the market (Cohen and Levinthal, 1990; Debackere et al., 1996) and to attract collaborative partners (Hall and Bagchi-Sen, 2002; Pisano et al., 1988). Also, doing R&D internally is particularly important for innovation in new-technology settings where it is very costly and particularly difficult, even impossible, to acquire new technologies produced by competitors (Lee, 1995).

The positive effect of R&D on innovation has encouraged research into what is today known as the 'technology push' theory of innovation. In this theory, basic research and industrial R&D are the sources of new products and services. The results of these research efforts then follow a linear process allowing firms to define, design, produce and market their innovations. However, the limits of the

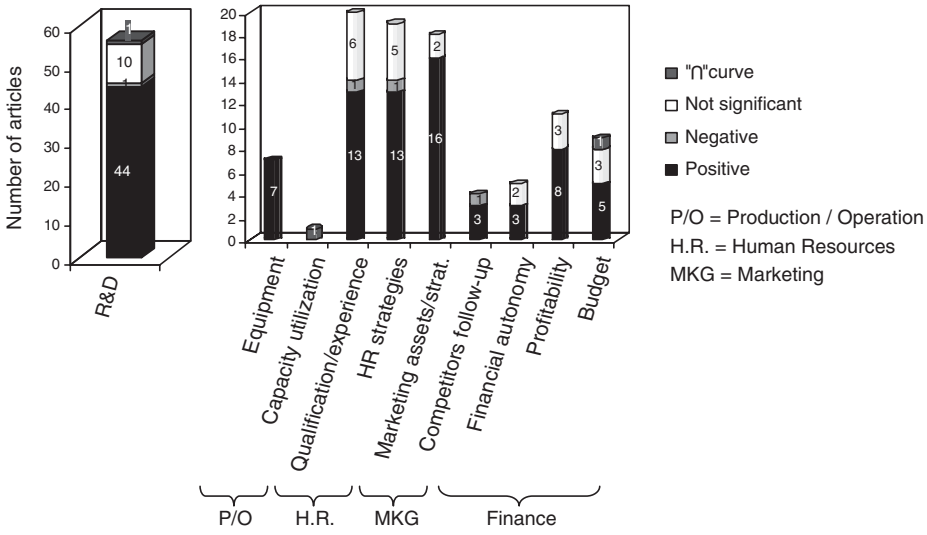

Fig. 12. Functionnal assets and strategies as determinants of innovation.

technology push theory led to, in the 1960s, an alternative view known as the 'demand/market pull' theory, which states that the ideas for solutions also originate in the market (Freeman, 1994; Landry et al., 2002). Several empirical studies have confirmed the market pull hypothesis by finding a significant positive relationship between innovation, on the one hand, and, on the other, market studies aiming to gather customer feedback and to detect the evolution of customer needs (Darroch and McNaughton, 2002; Koberg et al., 1996; Koschatzky et al., 2001; Souitaris, 2001, 2002). Monitoring of competitors (François et al., 2002; Souitaris, 2001, 2002) as well as other marketing strategies like advertising (Koeller, 1995, 1996) and the management of pairs of (products/markets) (Baldwin and Johnson, 1996) have also been proved to be beneficial to innovation (Fig. 12). In general, a good marketing strategy contributes to commercial success, and even to the exporting of new products/processes, thereby encouraging firms to innovate more (Baldwin and Johnson, 1996).

Being on the look-out for new technologies and acquiring sophisticated equipment and production technologies have a significant positive effect on innovation (Darroch and McNaughton, 2002; Evangelista et al., 1998; Kam et al., 2003; Landry et al., 2002; Martinez-Ros, 1999). It is noteworthy that a company must measure the degree to which it uses its production capacity if it wants to remain innovative. Smolny (2003) found that the degree of capacity utilization and innovation are positively correlated but that installations used beyond 95% of their capacity risk, on the contrary, reducing innovation.

Staffing companies with highly educated, technically qualified and experienced personnel with diverse backgrounds is also an important determinant of innovation (Freel, 2003; Guangzhou Hu, 2003; Koeller, 1996; Koschatzky et al., 2001; Romijn and Albaladejo, 2002; Shefer and Frenkel, 1998; Souitaris, 2002). Other human resource strategies such as training (Baldwin and Johnson, 1996; Kam et al., 2003; Koschatzky et al., 2001; Souitaris, 2002), job security (Michie and Sheehan, 2003), motivation via the compensation system (Baldwin and Johnson, 1996; Koberg et al., 1996), and the annualization or modulation of work time (François et al., 2002) have also proved to be positively correlated with innovation. All these human resource strategies help companies to have a qualified and motivated workforce-including employees, engineers and technicians-capable of creating new technologies and absorbing outside-developed ones (Hoffman et al., 1998; Romijn and Albaladejo, 2002).

Finally, financial autonomy-the amount of equity compared to debt-a good financial performance, available funds and budgeting for innovation-related activities all seem to have a positive and significant effect on innovation. Financial autonomy and profitability increase the probability of carrying out investments, of doing in-house R&D and of generating innovations internally rather than importing them (Beneito, 2003; Hitt et al., 1997; Love and Roper, 1999; MacPherson, 1994; Souitaris, 2002). Also, as innovative activities are also high risk activities, a high debt, even if it does not undermine the development of incremental innovations, seriously discourages the development of radical ones (Galende and De la Fuente, 2003). It is worth noting results found by Greiger and Cashen (2002), which suggest that funds availability is a crucial determinant for innovation but that too high a level of available and recoverable resources may create a relaxed environment encouraging managers to neglect innovation efforts. They concluded that the relation between funds availability and innovation is bell-shaped rather than linear.

4.2.2. The contextual factors

The contingency theory (Burns and Stalker, 1961; Chandler, 1962; Lawrence and Lorsch, 1967; Woodward, 1970) states that an organization is above all an adaptive system which evolves by reacting to its environment. Indeed, environment has a determining impact on firms' strategies, structuring and behavior. An examination of the articles included in our systematic review brought up approximately twenty contextual determinants of innovation. They consisted in variables related to the physical or institutional environment to which the company belongs. In order to better tackle these variables, we grouped them into six categories, namely the variables related to: (1) the industry to which the firm belongs, (2) the region where it is located, (3) networking relations with various actors of its environment, (4) the acquisition of knowledge and technologies, (5) government and public sector policies, and (6) the surrounding culture (Table 4).

4.2.2.1. Industry, region and networking variables. The significant effect of industry and regional characteristics on the innovative capacity of firms is widely accepted in the literature. The results of our review confirm this since the broad majority of the studies that examined these two variables found a significant relationship with innovation (Fig. 13). On the industry side, the three main characteristics investigated in the literature have been: (1) technological dynamism, (2) demand growth, and (3) industry structure. The results suggest that the first two variables have a significant effect on innovation. With regard to technological dynamism, some studies (e.g. Evangelista et al., 1997; Kalantariridis and Pheby, 1999; Kam et al., 2003; Quadros et al., 2001; Uzun, 2001) found that high-tech industries (e.g. telecommunication, aerospace, pharmaceutical) are more innovative than traditional ones (e.g. textile, wood, food). Other studies (e.g. Souitaris, 2002) used the taxonomy suggested by Pavitt (1984) to show that a firm's ability to innovate and the determinants of its innovative behavior vary according to whether the company belongs to one or another of the four categories suggested by Pavitt, namely supplier dominated, scale intensive, specialized suppliers or science-based firms. The positive and

Table 4
Contextual determinants of innovation

Category	Variables	Selected references
Firm's industry related variables	Sector	Evangelista et al. (1997), Kam et al. (2003), and Quadros et al. (2001)
	Demand growth in the industry	Crépon et al. (1998) and Zahra (1993)
	Industry concentration	Baptista and Swann (1998), Blundell et al. (1999) and Smolny (2003)
Firm's regional variables	Geographic location of the firm	Blind and Grupp (1999) and Sternberg and Arndt (2001)
	Proximity advantage	MacPherson (1998), Romijn and Albaladejo (2002), and Stuart (1999)
Networking	Interaction with universities/research centres/competitors/industrial and professional associations/consultants and service providers/ suppliers/customers	Fritsch and Meschede (2001), Keizer et al. (2002), Koschatzky et al. (2001), Landry et al. (2002), Mansfield (1998), Mansfield and Lee (1996), and Romijn and Albaladejo (2002)
Knowledge/technology acquisition	Formal and informal knowledge and technology acquisition	Ahuja and Katila (2001), Landry et al. (2002), Lee (1995), Liu and White (1997), and Love and Roper (2001)
Government and public policies	Government policies	Coombs and Tomlinson (1998) and Lanjouw and Mody (1996)
	External financial support	Beugelsdijk and Cornet (2002) and Keizer et al. (2002)
Surrounding culture	Power distance/risk avoidance/feminity-masculinity/collectivism-individualism/temporal orientation	Morris et al. (1993), Rhyne et al. (2002), Shane (1993), and Wu et al. (2002)

significant effect of demand growth on innovation has been proven by several studies (e.g. Baptista and Swann, 1998; Michie and Sheehan, 2003; Zahra, 1993) confirming once again the 'demand pull' theory hypothesis of innovation.

As for the effect of industry structure on innovation, the results are mixed (Fig. 13). Significant results suggest that industry concentration has a negative effect on innovation (Blundell et al., 1999; Koeller, 1995, 1996; Zahra, 1993). However, two studies (Nielsen, 2001; Smolny, 2003) found a positive relationship between the two variables whereas other research concluded that there is a bell-shaped (Debackere et al., 1996) or an insignificant relationship (Baptista and Swann, 1998; Beneito, 2003; Love and Ashcroft, 1999). We should note that this debate was begun by Schumpeter, whose two proposals were later baptized the Schumpeter Mark I and Schumpeter Mark II patterns. Schumpeter Mark I industries (also called widening or 'creative destruction' patterns), are characterized by low technological entry barriers and a high competition level. In these industries, new entrepreneurial firms are the major innovators (Schumpeter, 1934). In Schumpeter Mark II industries (also called deepening or 'creative accumulation' patterns), economies of scale raise entry barriers, favoring large established firms which use their monopolistic power and accumulated knowledge, resources and competencies to move to the forefront of the innovation process (Schumpeter, 1942)[4].

In light of the above results, we can assert that empirical research in the manufacturing sector supports the widening patterns' positive effect on innovation. However, in the case of the deepening pattern, it seems that an industry concentrated in the hands of a limited number of companies leads gradually to a stable market where the market shares are harmoniously negotiated and attributed. It is thus counterproductive and less than desirable to introduce new products on the market since they will disturb the attained equilibrium (Zahra, 1993). This situation will hold until the introduction of a radical innovation by a newcomer firm. This will move the industry to a widening pattern favorable to innovation development (Breschi et al., 2000).

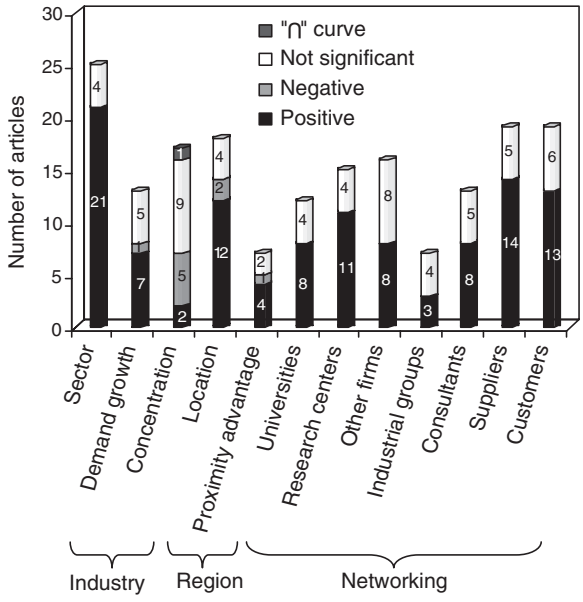

Fig. 13. Industry, region and networking variables as determinants of innovation.

[4] For a more detailed summary of these two Schumpeterian pattern characteristics see Breschi et al. (2000).

The region where a firm is based also has a significant effect on its innovative capacity (Brouwer et al., 1999; Evangelista et al., 1997; Kaufmann and Tödtling, 2001). This effect follows from several factors, in particular infrastructure and a specialized-workforce (Baptista and Swann, 1998; Blind and Grupp, 1999; Koberg et al., 1996; Sternberg and Arndt, 2001). Likewise, the proximity to potential partners such as suppliers, customers, universities, R&D and financial institutions significantly and positively influences innovation (MacPherson, 1998; Romijn and Albaladejo, 2002; Uzun, 2001). Proximity facilitates tacit knowledge transfer (Cooke et al., 1997; Storper and Harrison, 1991), reduces communication costs, supports interpersonal interactions (Dicken et al., 1994), and develops trust and a social capital between partners which reduces the risk and uncertainty related to innovation (Landry et al., 2002; Lundvall, 1993; Romijn and Albaladejo, 2002).

Finally, it is important to emphasize the exceptional performance of networking as a determinant of innovation. As Fig. 13 shows, none of the studies found that networking has a significant negative effect on innovation. All the studies revealed that the correlation between innovation and the interaction with customers, suppliers, universities, research centers and other actors of a firm's environment is either positive (Beugelsdijk and Cornet, 2002; Coombs and Tomlinson, 1998; Kaufmann and Tödtling, 2001; Landry et al., 2002; Ritter and Gemünden, 2003; Souitaris, 2002) or insignificant (Debackere et al., 1996; Freel, 2002, 2003; Love and Roper, 2001; Papadakis and Bourantas, 1998). These interactions help the firm to bridge gaps in its information, scientific knowledge, resources and competencies (Romijn and Albaladejo, 2002). These results corroborate the now widely accepted idea that the innovation process is not necessarily linear but it is often an evolutionary, non-linear, and interactive process between a firm's departments and the firm and its environment (Dosi et al., 1988; Kaufmann and Tödtling, 2001; Kline and Rosenberg, 1986; Malecki, 1997).

It should be pointed out that this proven effect of industry and regional characteristics, networking and proximity on innovation has played a driving role in the development in many countries of geographic clustering, the 'milieux innovateurs' and national and regional innovation system approaches to promoting innovation (Asheim and Isaksen, 1997; Kaufmann and Tödtling, 2001; Romijn and Albaladejo, 2002).

4.2.2.2. Other contextual explanatory variables. As suggested by the literature, the acquisition of knowledge and technologies, the government and public sector policies and the culture of the country where the firm is based are all potential contextual determinants of innovation. Knowledge and technology acquisition can take several forms, such as the purchase of equipment, licenses and sponsorship agreements, the attendance of conferences and specialized

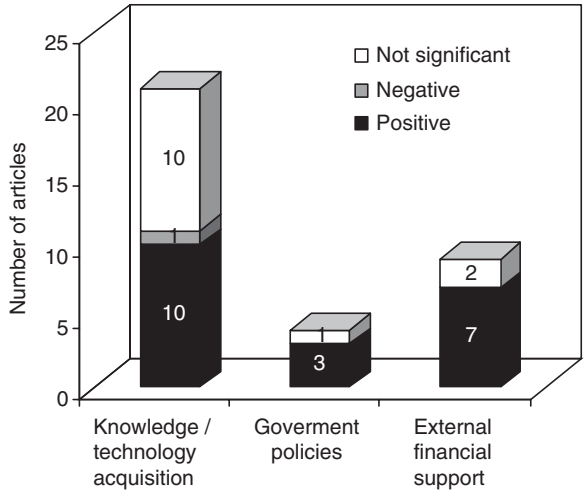

Fig. 14. Knowledge acquisition and government/public policies as determinants of innovation.

fairs, or simply the informal exchanges with various actors in a firm's environment. With regard to this variable, the results are split between a positive significant effect (Ahuja and Katila, 2001; Koschatzky et al., 2001; Love and Roper, 1999; Souitaris, 2001; Uzun, 2001) and a non-significant effect (Kaufmann and Tödtling, 2001; Lee, 1995; Liu and White, 1997; Love and Roper, 2001) on innovation (Fig. 14). This lack of consensus could be explained by the fact that the effectiveness with which knowledge and technology acquisition acts as a determinant of innovation is greatly weighted in practice by the firm's absorptive capacity (Landry et al., 2002; Lee, 1995; Liu and White, 1997). Firms which are able to assimilate, adapt and transform acquired knowledge and technologies have more chance of using them to innovate than those which are unable to do so.

Government policies such as, for instance, fostering certain sectors, substituting for imports, and promoting environmental management in turn have a significant positive effect on innovation (Coombs and Tomlinson, 1998; Lanjouw and Mody, 1996; Oyelaran-Oyeyinka et al., 1996). Likewise, the financial support granted by governments, professional organisms and industry-oriented financial institutions encourage firms to innovate more (Beugelsdijk and Cornet, 2002; Caird, 1994; Keizer et al., 2002; Romijn and Albaladejo, 2002; Souitaris, 2001). This financial support can take the form of subsidies, grants, awards or loans.

Finally, with respect to the firm's surrounding culture, empirical research is extremely rare. Those studies that have examined this determinant operationalized this variable by using Hofstede's dimensions (Hofstede, 1980; Franke et al., 1991), namely: (1) power distance, (2) uncertainty avoidance, (3) individualism versus collectivism, (4) masculinity versus femininity, and (5) time orientation. The results are quite varied and often not significant. The few significant results suggest that innovation has more

chance of developing within an individualistic culture marked by uncertainty acceptance and long-term orientation (Shane, 1993; Wu et al., 2002). With regard to power distance, two studies (Rhyne et al., 2002; Shane, 1993) led to opposite conclusions. Except for these results, all the other tests proved to be non-significant.

5. Conclusion and implications

Innovation in the manufacturing sector is a very complex process which is propelled by numerous factors. This conclusion is drawn by practically all the research in the field. Our systematic review has confirmed this complexity by assessing the main internal and contextual variables which influence the innovative capacity of manufacturing firms. In addition to the significant number of explanatory variables, our results show that the relationship linking several of these variables with innovation is often moderated by an interaction with other variables. This fact, coupled with the diversity of the measurements and methodologies used by researchers, makes analyzing and understanding this phenomenon challenging and any attempt to compare and generalize the results difficult. We must also point out the main limit of our study, namely that it only includes articles published in peer review journals. As noted in the presentation of our inclusion criteria, we did not consider other types of research reports (conference proceedings, books, newspapers articles, etc.) which eliminate some of the knowledge produced about innovation. For these reasons, we propose that our results be considered as suggestions so as not to fall into abusive generalizations. Though we are conscious of the specificity of each company, the results of our study highlight several avenues which would help managers and policy makers to better foster innovation and researchers to better channel their efforts in studying the phenomenon. We will summarize the main avenues in the following passages.

For managers, encouraging innovation begins, among other things, with a clear and precise definition of their firm's strategies. They should encourage, as much as possible, a specialization built on the firm's distinctive competencies, with a differentiation business strategy. Internationalization through, at least, export and the protection of their firm's competitive advantage by patenting and other appropriation mechanisms are recommended. The structure should remain flexible and encourage the employees' empowerment and the interaction between the various company units. Managers should also establish a control system using primarily strategic indicators rather than purely financial ones. They should also seek to establish an organizational culture of innovation support inspired by the total quality management and continuous improvement principles. At the functional level, managers should encourage R&D activities, staff their company with qualified and experienced personnel and furnish their installations with advanced technologies. Improvement and training programs should be planned for executives and employees. A strategy for good marketing of products and a good monitoring of competitors and the evolution of customer needs is also recommended. Managers should ensure the financial autonomy of the company by avoiding an excessive debt to equity ratio.

An important strategic action for managers consists in finding an optimal size for their firm. We saw above that even if the general tendency of the results supports a positive correlation between firm size and innovation, several authors have affirmed that this relation is more complex than it first appears and that it is influenced by several other factors such as industry characteristics and market structure. Managers can increase firm size through internal development or mergers and acquisitions. To reduce their firm size, they can proceed by disinvestment, downsizing, reengineering and outsourcing. Several factors should be taken into consideration to assess the optimal size of a company. Among others, we identified industry standards, firm and industry specialization levels, and the number and specificity of a firm's distinctive competencies. Managers must likewise think about their business units' location. Location decisions must take into consideration regional workforce endowment and infrastructure but also the proximity to certain stakeholders such as customers, suppliers, universities, research centres, etc. They must take advantage of this proximity to create various cooperative relationships with these potentially valuable partners.

For policy makers, one of the most important decisions in fostering innovation would be to encourage competition in the various economic sectors by banishing entry barriers and preventing strategies developed by firms from leading to a monopoly or quasi-monopoly situation in the industry. They must also develop and communicate clear policies to promote the sectors where they want to foster innovation. These policies must include a precise statement of the objectives to be reached and, particularly, an adequate financial support in the form of subsidies, preferential rate loans, tax credits, etc., for companies which wish to undertake innovation related activities. It is also recommended to set up institutions to help companies internationalize their activities. This may consist of public institutions doing foreign market prospecting and insurance companies covering internationalization-related risks. Policy makers can also encourage innovation through the creation of meeting places and occasions where the various economic entities (i.e. enterprises, financial institutions, research institutes, etc.) belonging to the same sector or related sectors can meet and exchange ideas. Even better, they can foster innovation by establishing geographical clusters and technopoles and by encouraging firms to settle there. These initiatives could be supported by establishing

specialized infrastructure, strategically planning the location of universities and specialized research centres, providing financial and tax benefits for firms which settle in the targeted area, and so on.

As mentioned above, these recommendations are only suggestions since previous research suffers from several weaknesses which prevent us from making generalizations. The main weaknesses are related to the measurement of the studied variables and the approaches used to answer the research questions and hypotheses. As we saw above, innovation was measured by various indicators which do not necessarily measure the same construct. Several other explanatory variables were also differently operationalized by the authors. R&D, for instance, was sometimes measured by a binary variable indicating if the company had or did not have an R&D department. In other studies, it was measured by R&D expenditures or by the percentage of personnel devoted to R&D. Firm size was in turn measured by various indicators such as the number of employees and firm sales. All these indicators are not necessarily correlated, which creates a result comparability problem. Consequently, it is strongly recommended that future research standardize the investigation methods and the definition and measurement of variables. In the case of firm-based surveys, it is important to develop indicators that assess the degree of innovation newness rather than conduct an unqualified dichotomous measure that only notes whether firms innovated or not. Further endeavors beyond those put forward by the OECD in the Oslo Manual are needed if the above suggestions are to be implemented.

In addition, we seen it, process innovations are largely understudied. Paradoxically, these innovations play an important strategic role within companies by allowing productivity improvement and new product development. Thus, future studies must further investigate this particular type of innovation. They must also clearly distinguish between product and process innovations since several studies (e.g. Freel, 2003; Gopalakrishnan et al., 1999; Lager and Hörte, 2002; Michie and Sheehan, 2003; Papadakis and Bourantas, 1998; Sternberg and Arndt, 2001) have shown that these two types of innovations follow different paths and do not necessarily have the same determinants.

Several studies have also shown that certain variables strongly distinguish innovative firms from non-innovative ones. Size and industry seem to be the two main variables. The majority of the reviewed studies included these variables in their innovation equation by presupposing that their relationship to innovation is linear and without considering their discriminating power. Such an approach considerably limits the interpretation of their results and does little to help us gain a better understanding of the phenomenon. So as to reduce this gap, we recommend that future research not only consider factors distinguishing between innovative and non-innovative firms but also examine those factors that discriminate between innovative firms themselves. We suggest a twofold approach. First, researchers should identify, in addition to size and industry, the main discriminating variables between various innovative firms (e.g. region, country culture, etc.). They must then study the innovation determinants by discriminating variable category (e.g. small versus medium versus large companies, high-tech versus traditional industries, Pavitt sectors, collectivist versus individualistic culture, etc.). By so doing, researchers will be able to develop configurations of innovation determinants according to the discriminating variable(s) used which will help managers, policy makers and researchers to better understand the phenomenon and better promote it.

Appendix. Strategy used in computerized databases search

ScienceDirect [October–November 2003, update March 2004]

- Keyword: ‘innovation’ within ‘Title’
- Sources: ‘Journals’
- Subject: ‘Business, Management and Accounting’ AND ‘Economics, Econometrics and Finance’
- Dates: ‘1993’ to ‘2003’

ABI/INFORM (Proquest) [January–February 2004]

- Keywords: ‘innovation’ in ‘Article title’ AND ‘measure*’ in ‘Article text’
- Database: ‘Multiple databases’
- Date range: ‘Specific date range’, ‘01/01/1993’ to ‘12/31/2003’
- Limit results to ‘Full text articles only’ AND ‘Scholarly journals, including peer-reviewed’

Business Source Premier (EBSCO) [April–May 2004]

- Keywords: ‘TI innovation’ AND ‘TX measure’
- Full text
- Scholarly (peer reviewed) journals
- Published date: ‘Jan 1993’ to ‘Dec 2003’

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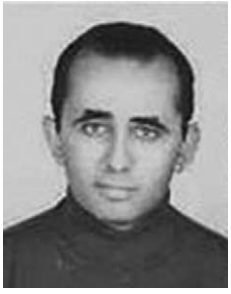

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