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# Does professional knowledge management improve innovation performance at the firm level?

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## Non-technical summary


The resource-based view of the firm is characterized by the idea that capital, labor and natural resources are the factors influencing the economic growth of a company. In the last decades, the awareness of knowledge as an important driver of economic growth has increased, and led to the development of a knowledge-based theory of the firm stating that a firm has to create value through the generation, application and capitalization of knowledge.

Our objective is to investigate how knowledge management influences the innovation performance of a firm. While former studies mainly focused on knowledge management cycles in the firm, we investigate knowledge management from another perspective, i.e. different knowledge management techniques.

a) A firm can codify its explicit knowledge facilitating the use and distribution of this knowledge. Due to the rise of networked computers, codification, storage and sharing of knowledge becomes easier and cheaper.

b) Not all knowledge embedded in a firm’s staff is codifiable a-priori, therefore it is often referred to as tacit knowledge. For exchanging tacit knowledge, interpersonal contact is needed. It is important to stimulate employees to share knowledge e.g. via pecuniary reward systems or the creation of a collaborative knowledge-sharing environment.

c) Not all knowledge can be generated internally and therefore external sources of knowledge need to be generated. This external knowledge generation can be done by specific resources to detect and gather external knowledge or to attract external experts to cooperate with project groups. External experts can be universities and research institutions on the one hand or other companies on the other hand.

This study conducts an analysis based on the Belgian CIS survey. It shows the heterogeneous influence of three knowledge management techniques on product and process innovation. More specifically, if a firm wants to reduce costs, it is more valuable to invest in stimuli for employees to share knowledge and to implement a codified knowledge management policy. If a firm, however, aims at introducing new products, it appears to be more beneficial to source external knowledge. In conclusion, it is important for a firm to carefully select the techniques of knowledge management depending on the goals in its innovation strategy.

# Does professional knowledge management improve innovation performance at the firm level?*

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**Abstract**

The concept of knowledge has gained in interest since industrialized economics have induced a shift in importance from labor, capital and natural resources towards intellectual resources**.** This study investigates how the management of knowledge influences the innovation performance of a firm. While former studies mainly focused on knowledge management cycles, we distinguish different types of knowledge management techniques. It turns out that there is a difference between three knowledge management techniques and their influence on product and process innovation. The ability to source external knowledge positively affects the firm's introduction of new products and products new to the market. For obtaining cost reductions it is effective to stimulate employees to share knowledge. The availability of a codified knowledge management policy also positively affects the cost reduction possibilities of a firm. These results indicate that it is important for a firm to carefully select the tools of knowledge management in function of the kind of technical innovation it wants to proceed.

**Keywords:** Knowledge management, innovation performance
**JEL-Classification:** O31, O32

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# 1 Introduction

Empirical research indicates significant differences in performance across firms. Theories of the firm built on this and try to understand the factors which contribute to this performance difference across firms. Penrose (1959) indicated for the first time the importance of resources to the firm which led to the development of the resource based theory of the firm. Traditionally this was based on the view that a) capital, labor and natural resources are the factors of value creation, b) that these resources are scarce (Teece et al., 1997, Barney, 1986), and c) that they cannot be easily imitated by competitors (Penrose, 1959). Consequently, a firm possessing unique resources can create a competitive advantage through an effective and innovative management of these resources.

The concept of knowledge has gained in interest since industrialized economics have induced a shift in importance from (natural) resources towards intellectual assets (Hansen et al., 1999). This awareness of the importance of knowledge as a key driver of economic growth led to the development of a knowledge-based theory of the firm. For being able to create value, a firm has to possess knowledge with certain characteristics such as e.g. transferability, capacity of aggregation and appropriability (Grant, 1996; Teece et al., 1997; Wernerfelt, 1984). Grant (1996, 1997) characterizes the knowledge-based theory of the firm as an 'outgrowth' of the resource based theory because knowledge is perceived as the strategically most important resource. He argues that this is not yet a theory of the firm because there is not enough consensus when it comes to its precepts or purpose and its analysis and predictions.

Research concerning knowledge management so far has mainly focused on the knowledge management cycles e.g. knowledge creation, retention and transfer (Argote et al., 2003; Bhatt, 2001; Darroch, 2005; Kalling, 2003; Hall et al., 2003; Chen et al.;

2009; Zhen et al.; 2009). We investigate knowledge management from another perspective. We explore which type of knowledge management practice contributes to innovation performance where we differentiate between product market innovation and efficiency gains in production through newly implemented processes.

Hansen et al. (1999) distinguish two different knowledge management strategies. The codification strategy attempt s to codify explicit knowledge. The rise of networked computers has made this codification, storage and sharing of knowledge easier and cheaper. Not all knowledge embedded in a firm's staff is codifiable a-priori. Knowledge is often closely tied to the persons who developed it; therefore it is often referred to as tacit knowledge. Tacit knowledge needs to be shared via interpersonal interaction. It is realistic, however, that firms cannot create all the knowledge they need internally. External knowledge needs to be acquired then. In this context, Chesbrough (2004) indicates the importance of open innovation where external sources of knowledge and external channels to the market need to be added to the internal knowledge to generate additional value.

Based on this, we distinguish between three knowledge management techniques: a codified knowledge management policy, stimuli for employees to share (tacit) knowledge and the acquisition of external knowledge. Our empirical study investigates whether firms that use particular techniques realize a higher innovation performance with respect to new product sales (product innovation) and unit cost reduction of production (process innovation). Results point out that it is important for a firm to adjust their usage of knowledge management techniques based on the kind of innovation to be obtained. The use of external knowledge has a significant and positive effect on product innovation. If a firm wants to obtain a process innovation, stimuli for employees to share knowledge and a codified knowledge management policy appear to be of significant importance. These results hold in a number of robustness tests including instrumental variable specifications.

In the following section we will go into more detail concerning the use of knowledge management techniques discussing their advantages and drawbacks which leads to our hypotheses that will be explored empirically. Section 3 introduces the data, and presents descriptive statistics. In section 4 the econometric results are discussed. Section 5 concludes.

## 2 Background

Firms can obtain a competitive advantage over the other firms when they possess knowledge which is firm specific and if they manage knowledge in a way that is difficult to imitate (Earl, 2001). For a firm it is important to continually manage knowledge, internally and externally (e.g. Marqués and Simon, 2006; Darroch, 2005; Kalling 2003; Chesbrough, 2003; Bierly et al., 2009). Moreover, existing and emerging needs have to be evaluated (Quintas et al., 1997). From the managerial perspective of the firm, it is of course important to assess whether the benefits of the implementation of certain knowledge management tools outweigh the cost. Therefore we will discuss some possible advantages and drawbacks of knowledge management.

Hansen et al. (1999) distinguish two different knowledge management strategies based on observing management consulting companies. They also investigated these strategies in the ICT companies and health care providers, and argued that these strategies are applicable in multiple industries. [1]

[1] Hansen et al. (1999) point out that by focusing on one of the strategies and using the other in supporting role, a company can excel others. An optimal situation according to Hansen et al. is an 80-20 split. This model has been refined by Scheepers et al. (2004). They agree on the importance of an 80-20 split but this only at the onset of strategy implementation. This helps to set an initial strategic direction and suitable priorities. Over time though, it might be necessary for a firm to adjust its knowledge strategy mix towards a more balanced approach.

1. The codification strategy attempts to codify explicit knowledge. Codification makes it easier to disseminate knowledge across individuals, departments, divisions or subsidiaries, which makes the transfer possibly less accidentally, less time consuming and ultimately may yield economies of scope. Reusing and leveraging existing knowledge can also save time and costs relative to creating new knowledge from scratch (Watson et al. 2006). The rise of networked computers has made this codification, storage and sharing of knowledge easier and cheaper. When a firm wants to codify explicit information, IT is an important factor, also referred to as knowledge management systems. However, it should be noted that the successful implementation of a codification strategy does not come at zero cost. The relevant but not yet systematized knowledge has to be identified, codified, stored and, possibly most important, maintained and be kept up-to-date. This clearly requires time and effort in addition to the pure capital investment for an appropriate infrastructure, i.e. hardware and software (see e.g. Choi et al., 2003). The latter argument relates to a theoretical model by Watson et al. (2006) who emphasize that a successful implementation of knowledge management systems requires a) the willingness of individuals to contribute their knowledge to the system, and b) that employees access and reuse the knowledge embedded in this system.

2. Not all knowledge embedded in a firm’s staff is codifiable a-priori. Knowledge is often closely tied to the persons who developed it, and therefore it is frequently referred to as tacit knowledge. Tacit knowledge is personal and deeply rooted in the actions, skills, experience, ideals, values and emotions of individuals (Sveiby, 1997; Nonaka, 1994). Tacit knowledge needs to be shared via interpersonal interaction. This is done in brainstorming sessions and face-to-face conversations. Therefore it is necessary to stimulate employees to cooperate with each other and share

information within the company so that present tacit knowledge is distributed. When a firm has to deal with tacit knowledge, the role of IT is subordinate. Tacit knowledge is mostly transferred interpersonally since the analytic and creative skills are embedded in the person. One-on-one mentoring and informal training programs, which are costly and time consuming, are typically used to guide personnel (Choi et al.; 2003). It is also of importance that an environment where communication and cooperation are highly valued is created. Soliman et al. (2000) indicate the value of the creation of a culture that encourages the meeting of organizational goals via the free flow of knowledge. Sharing of knowledge can also be stimulated through personal incentives such as a pecuniary reward system.

So far, we have only discussed knowledge creation internally. It is realistic, however, that firms cannot create all desirable knowledge internally. The firm is part of a larger, complex environment. For a firm to be able to cope with this environment it needs to be flexible, e.g. by acquiring and internalizing external knowledge (see, among many others, von Hippel, 1988; Katila, 2002; Katila and Ahuja, 2002; Chesbrough, 2003; Laursen and Salter, 2006; Gassmann, 2006). With respect to knowledge management, Johannessen et al. (1999) develop a theoretical model that, among having relationships in teams and a performance culture as well as organizational learning systems, stresses the importance of external connections in addition to internal knowledge management.

3. External knowledge generation can be done via acquisition of external knowledge resources or through cooperation with external agents, such as consumers, suppliers, competitors, research institutions and consultants. In this context, it is important that the firm maintains the necessary absorptive capacity (see Cohen and Levinthal, 1990) to optimize the appreciation and utilization by the employees of newly gained

knowledge. The Not-Invented-Here (NIH) syndrome relates to the phenomenon that internal relative to external knowledge is highly valued, that is, a possible presence of internal resistance against external knowledge (see e.g. Katz and Allen, 1982; Lichtenthaler et al.; 2006). However, Menon and Pfeffer (2003) conducted case studies and used survey data for discussing the difference between the appreciations of managers towards the value of internal versus external resources. They find that organizational reality contradicts this NIH-view frequently and that firms do not only acquire external knowledge on a regular basis, but that frequently a preference for outsiders' knowledge exists (see Allen 1971, 1977, Brown and Eisenhardt, 1995, for earlier, related work). Besides potential drawbacks stemming from the NIH syndrome, transaction costs involved with the acquisition of external knowledge may be substantial. Cooperation with external partners involves uncertainty, e.g. frequency of transaction recurrence and how parties deal with the idiosyncratic aspect of the investment in collaborative effort. Clearly, the involvement of external consultants also induces monetary cost. Moreover, contracts can never be designed optimally for both parties (see e.g. Williamson, 1979). Thus, good coordination is required to optimally benefit from external knowledge, and the acquisition of external knowledge may be costly.

The trade-off between cost and benefits of implementing different knowledge management techniques calls for empirical investigations on the impact of knowledge management on firm performance.[2] While the importance of knowledge *assets* has long

[2] This study focuses on the impact of knowledge management on firm performance. Cantner et al. (2009), in contrast, analyze which firms engage in knowledge management practices with a large sample of German companies. They find that a) firms conducting R&D on a continuous basis and b) firms are primarily consumer-orientated are more likely to employ knowledge management systems (while controlling for industry heterogeneity and firm size).

been understood in the scholarly field[3], the literature on knowledge *management* and firm performance or innovation performance is scarce and ambiguous.

Marqués and Simon (2006) examine the relationship between knowledge management and firm performance using a sample of 222 firms in the Spanish biotechnology and telecommunications industries. They apply a factor analysis with a subsequent correlation analysis between factor loadings and a variety of firm performance measures, and find a positive relationship between knowledge management and firm performance. Darroch (2005) quantitatively investigates the importance of knowledge management as a coordination mechanism to improve innovation and overall firm performance using a sample of 443 firms across several sectors. Correlation analysis indicates that firms effectively managing knowledge are likely to be more innovative. No evidence is found, however, that firms managing knowledge are better overall performers. Further analysis using structural equation modeling indicates the same positive effect of knowledge management on innovation. Again, the multivariate results do not confirm a positive effect between knowledge and overall firm performance, though.

The positive link between knowledge management and firm performance is also questioned by Kalling (2003). For his analysis qualitative data from three knowledge ventures within a European manufacturing multinational company were used. His study

[3] In the economic literature, many empirical studies consider the market valuation of knowledge assets (see e.g. the survey by Czarnitzki et al., 2006), the productivity of knowledge assets (see, among many other papers, e.g. the book by Griliches, 1998) or profitability of knowledge assets (e.g. Ravenscraft and Scherer, 1982, Jaffe, 1986, Czarnitzki and Kraft, 2009). An example from the management literature that goes one step further is Decarolis and Deeds (1999). They quantitatively analyze the relationship between stock and flows of organizational knowledge and firm performance in the biotech industry and confirm that knowledge positively effects overall firm performance. Bogner and Bansal (2007) found similar results when relating measures of knowledge flows to profitability and growth. Their knowledge flows and management variables are constructed based on references in patent applications of the firm. For instance, a higher share of self-citations is interpreted in more efficient internal knowledge management. Wu and Shanley (2009) use patent information to build a knowledge stock. They find that the existing knowledge stock indicates a significant moderating role between exploration and innovative performance.

indicates that although knowledge development is a frequent phenomenon, the utilization of it is not so widespread. This may point to the high cost of proper maintenance and implementation of knowledge management practices. Even when knowledge is utilized, it may not always result in an improvement in profitability. Kalling emphasizes the importance of coupling specialists' knowledge with generalists' business overview. General Managers need to be active in managing the entire business, not just those activities that are directly affected by knowledge.

*Our research design and the contribution of this paper*

The existing literature documents a theoretical link between knowledge management and innovation performance and overall firm performance, but the empirical results are not so clear-cut. Utilizing a newly created firm-level database we distinguish three different knowledge management practices, as suggested by the theoretical contributions mentioned above, and relate these to innovation performance of the firm. However, we go one step further and break "innovation" into three different performance indicators. We differentiate between process innovation and product market innovation, where the latter is split into products new to the market and products only new to the firm, i.e. imitation.

We consider the following knowledge management practices: a) implementing and maintaining a codified knowledge management policy/system, b) stimuli for information sharing among employees, and c) the active acquisition and use of external knowledge sources.

The codification of knowledge makes it possible to use it more efficiently, and to re-use it. This saves work and reduces communication costs (Hansen, 1999, Watson et al., 2006). Codified knowledge management typically involves the availability of manuals and databases documenting firm-specific knowledge mainly concerning internal management practices and procedures. Therefore, we argue that the codified management policy does not only concern employees with management functions, but to a large extent also staff at the bench-level. Hence, we clearly expect a positive effect on process innovation.

*Hypothesis 1: The use of a codified knowledge management policy has a positive effect on process innovation.*

The rejection of this hypothesis may support the fact that the retrieval of documented data might be cumbersome and thus not frequently performed, i.e. the cost of utilizing this management practice may be too high.

A similar null hypothesis may be stated for product innovation:

*Hypothesis 1a: The use of a codified knowledge management policy has a positive effect on product innovation.*

However, we do actually not expect to find support for this hypothesis in our data. Although reviewing internal knowledge carefully and combining it in an innovative way, may certainly result in incremental product innovation, it may not lead to entirely new products that were not existing on any market beforehand, nor may it help to imitate existing products of rivals. As our product innovation measures do not account for incremental innovation, we do not expect broad support for hypothesis 1a in our specific application.

Second, implementing reward systems for stimulating the information sharing among employees supplements codified knowledge management policies for types of knowledge that are tacit and cannot be codified. Therefore, we also expect a positive effect on process innovation, as these originate from problems or opportunities a firm's staff is confronted with every day.

*Hypothesis 2: The use of stimuli for employees to share knowledge has a positive effect on process innovation.*

If this hypothesis is rejected it may indicate that the reward systems are not properly designed or that the firm is lacking human capital.

*Hypothesis 2a: The use of stimuli for employees to share knowledge has a positive effect on product innovation.*

Sharing ideas and insights among staff members may certainly contribute to product innovation, too. Similar to hypothesis 1, however, more detailed data than ours may be necessary to uncover such effects. Czarnitzki and Kraft (2008) had data where they could distinguish between reward systems aimed at staff with management tasks and others aimed at bench-level personnel. They confirm that bench-level measures foster process innovation. For product innovation, however, instruments aimed at managers or, for instance, at members of the marketing or sales department may be needed rather than assembly line staff that only focuses on the current production process of a good. Unfortunately, our data is not detailed enough to distinguish such instruments. Therefore, we do not necessarily expect strong effects on product innovation.

Third, external knowledge is certainly important for the introduction of new products (e.g. Brown and Eisenhardt, 1995). New products or services are introduced to satisfy customer needs, and thus these needs have to be identified. Good management of external communication with customers may influence the ability of a firm to impose a dominant design (Utterback, 1994) and in that way may give the firm an advantage over its competitors. Suppliers can also help to identify new features of a product. Since the environment of the firm is changing, it is possible that competitors are ahead when it comes to the development of a new product. Information obtained from competitors may therefore also supply valuable knowledge, especially for imitating new successful products. There is a high possibility that the resources or capabilities needed to produce a product satisfying new needs are not yet available in the firm. Therefore it is useful to generate knowledge from external sources.

*Hypothesis 3: The generation of external knowledge has a positive effect on product innovation that includes both market novelties and imitation.*

The rejection of this hypothesis may imply that it is difficult to collect unique knowledge exclusively used by the acquiring firm. Mansfield (1985) conducted a survey in U.S. high-tech industries, where managers estimated how long it takes that new, unique knowledge leaks out to competitors. The results were striking. The loss of knowledge due to spill-overs because of the transition of personnel, or information exchange through joint customers, suppliers or consultants has, on average, been much faster than the standard product life cycle predicts. Thus, it may turn out to be difficult for firms to outperform competitors with market novelties, for instance, when the firm is pursuing a very open innovation strategy that relies to a large extent on external experts.

*Hypothesis 3a: The generation of external knowledge has a positive effect on process innovation.*

Although it is surely possible to hire external experts to optimize processes within the firm, the majority of external knowledge that a firm may screen may not help to significantly improve processes with respect to cost savings as the knowledge involved in production processes is typically more tacit and not as accessible as information on products that are present on markets or documents in patents, for instance. Therefore, we do not expect strong support for hypothesis 3a in our data.

## 3 Data sources, variables and descriptive statistics

The data is taken from the Flemish Community Innovation Survey (CIS) 2007. The CIS is a European-wide, harmonized data collection on innovation, and it follows the guidelines of the Oslo Manual (Eurostat/OECD, 2005). The cross-sectional data refers to the years 2004-2006, and industries covered are the manufacturing sector, trade, transport and business services, such as ICT, technical services and others. Our final sample consists of 1282 observations at the firm level.

*Dependent variables*

Three different variables are used for measuring firms' innovation performance. For process innovation, the survey offers the opportunity to measure the achieved unit cost reduction of production because of process innovation in percent (COST%). The average unit cost reduction concerns production cost in 2006 where the potential reduction originates from new processes implemented between 2004 and 2006.

For product or service innovation, we use two different variables both based on the share of sales with new products/services in total sales. The sales share of new products is measured in 2006 on basis of products that were introduced to the market between 2004 and 2006. The first variable considers all product innovations at the firm level, i.e. products could have been new to the entire market or just new to the firm's product portfolio (= imitation). The share of sales with new products is called NEWPROD%. The second variable only considers those product innovations within NEWPROD% that were new to the market, i.e. there is no other firm that has previously sold this product (MARKET%).

For a robustness check we also use dummy variables instead of the percent information for all variables. Those are called MARKET, NEWPROD and COST, respectively.

*Explanatory variables: knowledge managements*

Within the CIS survey, firms were requested to indicate the usage of three different knowledge management practices. According to the OSLO-Manual, the guidelines for collecting innovation data within the CIS, knowledge management involves "[…] activities related to capture, use and sharing of knowledge by the organization" (Eurostat and OECD, 2005). KMEMPL focuses on the personnel side and indicates whether the company applies stimuli for active knowledge sharing among employees. KMCP indicates whether the firm implemented a codified knowledge management policy or if there is a regular updating and maintaining of internal databases or manuals related to the practices, and documentation of "learned lessons". The engagement of a firm in acquiring external knowledge is indicated by KMEXT. This defines if there are specific measures to detect and capture knowledge from outside the company or if there is a policy to involve external experts from universities, research institutes or other companies in project groups if necessary. The knowledge management variables could either be implemented in the time period 2004 to 2006, or before.[4]

*Explanatory variables: controls*

While we are mainly interested in the relationship between the knowledge management practices and the different dimensions of innovation performance, we control for a number of other factors in our regression analyzes.

A crucial innovation input is research and development (R&D). We measure a firm's R&D intensity (RDINT) as R&D divided by total sales. Furthermore, we include whether a firm makes use of formal intellectual property protection, as it may increase performance due to the blocking of imitation (at least to a certain extent). PATENT and

[4] We experimented with differentiating the knowledge management by time of implementation, i.e. before 2004 versus 2004-2006. This did not change or improve the results, though.

TRADEMARK are dummy variables indicating whether a company has filed a patent application or a trademark, respectively.

Furthermore, we control for market structure by including two dummy variables. The companies were asked to indicate how many competitors are active on their main product market. The variable HIGHCMPT is a dummy indicating more than 15 competitors. MEDCMPT indicates an oligopolistic market structure of 4 to 15 competitors. The reference category refers to a tight oligopoly of less than four competitors or a monopoly. In addition, we control for (lagged) firm size, as larger firms may realize economies of scope in their innovation process as they typically have multiple projects. EMPL stands for employment in 2004. The capital intensity (CAPINT) measured as tangible assets relative to employment for the year 2004 is also taken into account. Finally, we control for the age of the firm (AGE), and whether a firm is associated with a group of firms (GROUP). The latter may facilitate access to markets, and thus more innovation output. Twelve industry dummies capture unobserved heterogeneity across sectors which are not covered by any of the aforementioned variables. For the upcoming regression analysis, we use the logarithm of the variables EMPL, AGE and CAPINT.

Table 1 presents descriptive statistics of all variables used where the sample is split into firms that employ knowledge management practices versus others. (See Table 5 in the appendix for some descriptive statistics by industry including the sector description.)

50% of the firms that have some form of knowledge management introduce a new product, 40% of these firms introduce a product new to the market and 27% reduce their costs. For firms that do not have any form of knowledge management these percentages are lower with only 21% introducing a new product, 16% a product new to the market and 12% achieve a cost reduction. In terms of the extent of product and process innovation, the firms employing knowledge management also score higher. On average, they achieve 13% of their total sales with new products where about 7 percentage points stem from market novelties. With regard to cost reductions, they realize 2.4% on average. These numbers are about twice as high as the corresponding figures for the firms not employing any knowledge management practices.

66% of the firms that have at least some form of knowledge management use the stimuli for employees, 74% use the codified knowledge management policy and 65% the external knowledge.

Firms with some form of knowledge management are, on average, larger in terms of employment, 156 employees compared to 70 in companies without any form of knowledge management. They also have a higher R&D intensity, (2.3% versus 0.7%). Firms with some form of knowledge management also have a more developed intellectual property policy: 18% have filed at least one patent compared to 4%, and 19% have applied for at least one trademark compared to 7%. When it concerns market concentration, firms without knowledge management are more often in a market with high competition. 58% of the firms with knowledge management are part of a group compared to 40% of the firms without knowledge management. The two groups of firms are similar in terms of age and capital intensity.

**Table 1**: **Descriptive statistics (1282 observations)**

| | Firms with knowledge management 742 observations | | | | Firms without knowledge management 540 observations | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Mean | Std. Dev. | Min | Max | Mean | Std. Dev. | Min | Max |
| NEWPROD% | 13.484 | 22.508 | 0 | 100 | 6.23 | 18.54 | 0 | 100 |
| MARKET% | 7.299 | 16.416 | 0 | 100 | 3.161 | 11.191 | 0 | 100 |
| COST% | 2.364 | 5.842 | 0 | 60 | 1.113 | 4.58 | 0 | 60 |
| NEWPROD | 0.497 | 0.5 | 0 | 1 | 0.213 | 0.41 | 0 | 1 |
| MARKET | 0.392 | 0.489 | 0 | 1 | 0.161 | 0.368 | 0 | 1 |
| COST | 0.272 | 0.445 | 0 | 1 | 0.117 | 0.321 | 0 | 1 |
| KMEMP | 0.664 | 0.473 | 0 | 1 | 0 | 0 | 0 | 0 |
| KMCP | 0.741 | 0.438 | 0 | 1 | 0 | 0 | 0 | 0 |
| KMEXT | 0.65 | 0.477 | 0 | 1 | 0 | 0 | 0 | 0 |
| EMPL | 155.689 | 383.692 | 1 | 4089 | 69.648 | 138.828 | 1 | 1800 |
| CAPITALINT | 44.34 | 113.518 | 0.038 | 2027.5 | 47.488 | 274.499 | 0.031 | 6279.909 |
| RDINT | 2.304 | 6.504 | 0 | 0.5 | 0.676 | 3.334 | 0 | 0.458 |
| AGE | 33.481 | 31.543 | 2 | 260 | 30.539 | 22.465 | 2 | 132 |
| PATENT | 0.175 | 0.38 | 0 | 1 | 0.043 | 0.202 | 0 | 1 |
| TRADEMARK | 0.187 | 0.39 | 0 | 1 | 0.065 | 0.246 | 0 | 1 |
| LOWCMPT | 0.216 | 0.412 | 0 | 1 | 0.211 | 0.408 | 0 | 1 |
| MEDCMPT | 0.524 | 0.5 | 0 | 1 | 0.407 | 0.492 | 0 | 1 |
| HIGHCMPT | 0.241 | 0.428 | 0 | 1 | 0.328 | 0.47 | 0 | 1 |
| GROUP | 0.58 | 0.494 | 0 | 1 | 0.391 | 0.488 | 0 | 1 |

Note: 12 industry dummies not presented.

Based on the bivariate descriptive statistics, it turns out that firms maintaining some knowledge management are more successful in both introducing new products and processes. Yet, the two groups of firms also differ systematically in some characteristics, such as R&D input and firm size. This makes a multivariate analysis on performance necessary. It remains to be shown that implementing knowledge management techniques yields higher innovation output when other differences in firm characteristics are taken into account.

# 4 Estimation results

For the multivariate analysis, we employ standard microeconometric techniques. First, we perform Tobit regressions for the three variables MARKET%, NEWPROD% and COST%. We treat the variables as left-censored at zero for firms that did not report positive values for the innovation outcomes. The model to be estimated can be written as follows (see e.g. Greene, 2000, for further details):

(1) $$Y_i^* = X_i{}'\beta + \varepsilon_i \quad , \quad \text{with} \quad \varepsilon_i \sim N\left(0, \sigma^2\right)$$

where $Y^*$ is the unobserved latent variable and stands either for NEWPROD%, MARKET% or COST%. We observe

(2) $$Y_i = \begin{cases} Y_i^* & \text{if } X_i{}'\beta + \varepsilon_i > 0 \\ 0 & \text{otherwise} \end{cases}$$

where $X$ represents a matrix of regressors, $\beta$ are the parameters which have to be estimated and $\varepsilon$ is the disturbance term.

If the assumption of homoscedasticity is violated in Tobit models, regressions may result in inconsistent coefficient estimates. Consequently, we also estimated heteroscedastic models where we model the variance as groupwise multiplicative (see Greene, 2000: 913). The heteroscedasticity term includes size class dummies (based on employment) and the twelve industry dummies. Performing LR-Tests on heteroscedasticity showed that the assumption of homoscedasticity is rejected in all cases. Therefore, we only present the heteroscedastic models' results.

The coefficients in a Tobit model cannot, unlike in OLS models, directly be interpreted as marginal effects of the regressors. The coefficients describe $\partial E\left(y_i^* \mid X_i\right) / \partial x_{ik}$, that is, the effect on the latent variable. As we are more interested in the effect on the observed variable $y_i$, however, we directly report the marginal effects calculated as (see Greene, 2000: 909):

(3) $$\frac{\partial E\left(y_i \mid X_i\right)}{\partial x_{ik}} = \beta_k \Phi\left(\frac{X_i^{'}\beta}{\sigma_i}\right),$$

where Φ stands for the standard normal cumulative distribution function. As common in the literature, we report the marginal effects at the mean for the continuous regressors, and for a jump from 0 to 1 for dummy variables on the right-hand side. Standard errors for the marginal effects are obtained by the delta method (see Greene, 2000: 357-358).

The estimation results are reported in Table 2. As expected in our hypothesis 3, involving external knowledge in the innovation process has a positive impact on both NEWPROD% and MARKET%. The marginal effects amount to 3.7 percentage points and 1.9 percentage points, respectively. As already suspected, the other two knowledge management practices focusing more on internal processes have no significant effect on sales with new products or market novelties only (see hypotheses 1a and 2a). However, we find support for the hypotheses 1 and 2. The incentive mechanisms for knowledge sharing among employees have a significant and positive effect on the success of process innovations. Firms employing this management technique achieve 0.4 percentage points more cost reductions than other firms. Given that the overall average of COST% is about 1.8%, the marginal impact of KMEMPL is not negligible. In relative terms, firms using employee incentive systems reduce cost about 40% more than others. For the codified management policy, we also find a positive effect with respect to cost reductions, but it is only weakly significant at the 10% level. The marginal effect amounts to 0.3 percentage points. As we already argued, we do not find support for the hypothesis 3a, that is, there is no significant impact of external knowledge management on process innovation.

The results concerning the control variables are basically as expected. Larger firms achieve higher values on all three measures of innovation performance which is possibly due to economics of scope. The R&D intensity also has a positive effect on all three dependent variables, but is only significant at the 10% level for the cost reductions. We also find that both patents and trademarks have positive effects on the innovation performance as one would expect. The eleven industry dummies are jointly significant in all regressions indicating that there are differences in innovation performance across sectors that are not captured by the other covariates. Interestingly, the two dummies measuring competition are not individually significant. However, they are jointly significant in all three regressions at the 10% level, and describe a hump-shaped relationship. Firms in (wide) oligopolies achieve higher innovation output than firms in more monopolistic or very competitive markets.

**Table 2: Marginal effects of heteroscedastic Tobit regressions**

| | Dependent variable: | | |
|---|---|---|---|
| | NEWPROD% | MARKET% | COST% |
| Variable | $\partial y / \partial x_k$ (Std. err.) | $\partial y / \partial x_k$ (Std. err.) | $\partial y / \partial x_k$ (Std. err.) |
| KMEMPL | 1.044 | 0.341 | 0.442** |
| | (0.979) | (0.477) | (0.190) |
| KMCP | 1.492 | 0.298 | 0.322* |
| | (0.990) | (0.482) | (0.184) |
| KMEXT | 3.698*** | 1.935*** | -0.024 |
| | (1.024) | (0.541) | (0.176) |
| LN(EMPL) | 1.578*** | 0.696*** | 0.332*** |
| | (0.382) | (0.208) | (0.078) |
| LN(CAPINT) | 0.261 | 0.0538 | 0.116* |
| | (0.334) | (0.173) | (0.063) |
| RNDINT | 0.686*** | 0.385*** | 0.363* |
| | (0.960) | (0.060) | (2.096) |
| LN(AGE) | -0.582 | -0.395 | 0.023 |
| | (0.521) | (0.255) | (0.090) |
| PATENT | 2.750* | 1.829** | 0.138* |
| | (1.492) | (0.782) | (0.236) |
| TRADEMARK | 6.165*** | 2.702*** | 0.454* |
| | (1.536) | (0.786) | (0.241) |
| MEDCMPT | 1.502 | 0.490 | 0.364 |
| | (1.017) | (0.494) | (0.188) |
| HIGHCMPT | -0.737 | -0.690 | 0.022 |
| | (1.165) | (0.556) | (0.226) |
| GP | -1.347 | -1.036** | 0.210 |
| | (1.001) | (0.491) | (0.197) |
| Test on joint significance of industry dummies | $\chi^2(11)$ = 23.55** | $\chi^2(11)$ = 22.05** | $\chi^2(11)$ = 29.02*** |
| Test on joint significance of MEDCMPT and HIGHCMPT | $\chi^2(2)$ = 5.66* | $\chi^2(2)$ = 5.53* | $\chi^2(2)$ = 5.75* |
| Log Likelihood | -2761.96 | -2094.47 | -1384.79 |
| McFadden $R^2$ | 0.07 | 0.09 | 0.07 |
| Number of obs. | 1282 | 1282 | 1282 |
| Test on heteroscedasticity | $\chi^2(15)$ = 63.18*** | $\chi^2(15)$ = 94.74*** | $\chi^2(15)$ = 107.50*** |

Notes: Marginal effects are calculated at the sample mean for the continuous variables and calculated for jumps from 0 to 1 for the dummy variables. Standard errors of marginal effects in parentheses (obtained with the delta method). *** (**, *) indicate a significance level of 1% (5%, 10%). All models include an intercept not reported here. The heteroscedasticity term includes 4 size class dummies (based on employment) and the 11 industry dummies.

## *4.1 Robustness test: Probit estimation*

As first robustness check, we estimated Probit models with dummies as dependent variables. The variables NEWPROD, MARKET and COST take the value one if a firm reported a positive value on the corresponding performance variable and zero otherwise. The following regressions are equivalent to the Tobit analysis except that the percentages of the dependent variables are replaced with the dummy variables.

Again, the assumption of homoscedasticity is rejected in all cases. However, for the COST regression, the LR tests indicated that it is sufficient to include the four size class dummies in the variance term. As can be seen in Table 3, the results of the Tobit models are basically confirmed in all cases. Only in the cost equation, the significance levels of the knowledge management variables reduce slightly which is not surprising as the dependent dummy variables carry of course less information than the percentage variables. The marginal effects are calculated for the probability that $y_i$ = 1, i.e.

$$\frac{\partial P\left(y_1 = 1 \mid X_i'\right)}{\partial x_{ik}} = \phi\left(\frac{X_i'\beta}{\sigma_i}\right)\frac{\beta}{\sigma_i}$$

where $\phi$ denotes the standard normal density function.

A firm involving external knowledge acquisition or cooperation with external experts has a 12 percent higher probability of introducing new products. For the market novelties, this probability even amounts to almost 17%. The employee incentive systems and the codified management policy increase the chance of cost reductions by about 4% each. However, the effects are only weakly significant at the 10% level.

The results concerning the control variables are very similar to the Tobit case, and therefore not discussed in detail.

**Table 3: Marginal effects of heteroscedastic probit models**

| | Dependent variable: | | |
|---|---|---|---|
| | NEWPROD | MARKET | COST |
| Variable | $\partial y / \partial x_k$ (Std. err.) | $\partial y / \partial x_k$ (Std. err.) | $\partial y / \partial x_k$ (Std. err.) |
| KMEMPL | 0.019 | 0.006 | 0.046** |
| | (0.029) | (0.028) | (0.020) |
| KMCP | -0.006 | -0.020 | 0.045** |
| | (0.031) | (0.029) | (0.021) |
| KMEXT | 0.134*** | 0.142*** | 0.001 |
| | (0.031) | (0.032) | (0.020) |
| LOG(EMPL) | 0.054*** | 0.041*** | 0.053*** |
| | (0.011) | (0.011) | (0.008) |
| LOG(CAPINT) | 0.003 | 0.001 | 0.010 |
| | (0.010) | (0.010) | (0.007) |
| RNDINT | 0.084*** | 0.040*** | 0.005*** |
| | (0.014) | (0.008) | (0.002) |
| LOG(AGE) | -0.0001 | -0.008 | 0.005 |
| | (0.014) | (0.014) | (0.010) |
| PATENT | 0.098** | 0.137*** | 0.010 |
| | (0.048) | (0.049) | (0.023) |
| TRADEMARK | 0.174*** | 0.193*** | 0.035 |
| | (0.039) | (0.05) | (0.025) |
| MEDCMPT | 0.060** | 0.04 | 0.033 |
| | (0.029) | (0.028) | (0.021) |
| HIGHCMPT | 0.003 | -0.008 | -0.015 |
| | (0.034) | (0.033) | (0.026) |
| GP | -0.008 | -0.027 | 0.044* |
| | (0.029) | (0.028) | (0.026) |
| Test on joint significance of industry dummies | $\chi^2(11) = 8.14$ | $\chi^2(11) = 9.42$ | $\chi^2(11) = 17.95$* |
| Log Likelihood | -642.03 | -608.48 | -568.03 |
| McFadden $R^2$ | 0.24 | 0.22 | 0.12 |
| Number of obs. | 1282 | 1282 | 1282 |
| Test on heteroscedasticity | $\chi^2(15) = 69.69$*** | $\chi^2(15) = 49.09$*** | $\chi^2(4) = 21.00$*** |

Notes: Marginal effects are calculated at the sample mean for the continuous variables and calculated for jumps from 0 to 1 for the dummy variables. Standard errors of marginal effects in parentheses (obtained with the delta method). *** (**, *) indicate a significance level of 1% (5%, 10%). All models include an intercept not reported here. The heteroscedasticity term includes 4 size class dummies (based on employment) and the 11 industry dummies in case of NEWPROD and MARKET, but only 4 size class dummies in case of COST (the industry dummies were jointly insignificant in the variance term).

### *4.2 Further robustness test: endogeneity*

One might be concerned that the implementation of knowledge management techniques is to a certain extent endogenous to innovation performance. A firm that is highly innovative on all accounts may also be more likely to adopt knowledge management practices. Consequently, we tested for potential feedback effects from the dependent variables for our Tobit models (as the dependent variables contain more information than in the Probit case) applying the Smith-Blundell (1986) test. The implementation is as follows (this has been performed for each of the three knowledge management variables):

(1) We run a regression of the knowledge management practice on all exogenous variables and candidates serving as instrumental variables, and obtain the residuals from this regression.

(2) We run the Tobit model as estimated above, but now also include the residuals obtained in step 1.

(3) The standard t-statistic of the coefficient of the included residuals is a valid test on endogeneity of the corresponding knowledge management variable. If the hypothesis that the coefficient of the residuals is not statistically significant is not rejected, we do not find endogeneity.

Performing the Smith-Blundell test requires an instrumental variable that is (a) exogenous – meaning it is uncorrelated with any unobserved firm-specific factors affecting the firms' innovation performance; (b) relevant – meaning it has strong partial correlation with the potentially endogenous regressor to avoid weak instrument bias. According to Staiger and Stock (1997) a partial F-value of the instrumental variable in the first stage regression should exceed ten.

As common in the literature, we use industry level averages of the possibly endogenous regressor as instrument. We calculated the share of firms employing either knowledge management technique for 28 different industries, and use this detailed industry average as instrument for the respective knowledge management variable. Such an industry average should be exogenous to unobserved firm-specific factors that may affect current innovation performance. When estimating the first stage of the Smith-

Blundell test, we find that the instruments are positively related to the firm-specific likelihood for implementing a knowledge management technique. The partial F-values are around 10, so that we are not concerned about weak instrument problems. When we re-estimated all three Tobit models as presented above but including the residuals from the first stage regression (step 3 of the Smith-Blundell test), it turned out that the hypothesis of exogeneity was never rejected at any conventional level of significance. Therefore, we do not reject our assumption that the knowledge management practices are exogenous explanatory variables.

We also conducted an endogeneity test for the R&D variable. It may happen that there is some feedback from innovation success to R&D, as firms that are well performing in innovation output may also invest more into innovation input. Although we would prefer to use lagged R&D instead of its contemporaneous value, our database does not contain information on lagged R&D. Consequently, we repeated the Smith-Blundell test for R&D. As instruments, we use three dummy variables indicating whether the firm got R&D subsidies from the local, federal or European government, respectively. The subsidies should have a direct impact on current R&D, but should not depend on current innovation outcome (the subsidies are granted on submitted research proposals that may only lead to new products or processes in the distant future). Indeed, we find that our instruments are relevant with a partial *F*-statistic of 13.31 (p-value < 0.001). The Smith-Blundell test then rejects the exogeneity of R&D at the 1% level in all regressions. Although the coefficient estimates obtained in the second step of the Smith-Blundell test are consistent, the estimated standard errors are not asymptotically valid if exogeneity is rejected. Consequently, we re-estimated all three specifications as presented in Table 2 using a full information maximum likelihood estimator for IV-Tobit (see e.g. Wooldridge, 2002: 532-533). Basically all main results as discussed in

Table 2 are confirmed by the IV approach, except that the codified management policy loses the significance in the COST% equation. The estimation results are presented in Table 4 in the appendix.

## 5 Conclusion

In conclusion, this study shows that knowledge management techniques have a positive effect on the innovative performance of a firm, on average. It appears to be important for a firm to carefully select the techniques of knowledge management depending on the goals in its innovation strategy. More specifically, if a firm wants to reduce costs, it is more valuable to invest in stimuli for employees to share knowledge and to implement a codified knowledge management policy. If a firm, however, aims at introducing new products, it appears to be more beneficial to source external knowledge.

In order to complement our findings it would be interesting to look at the influence of the knowledge management techniques on overall firm performance. The management of knowledge is part of the broader organizational strategy. It does not limit its influence to innovation performance. Knowledge management also occurs in companies which are not involved in any form of technological innovation. Thus, to capture the whole effect of the knowledge management techniques it would be interesting to analyze the effect on broader performance measures such as sales growth or profitability.

In a further step, it would be interesting to link both knowledge management and innovation to firm performance. Earlier research studied the influence of innovation on firm performance frequently. It would be interesting to investigate whether firms that involve in technological innovation stimulated by knowledge management techniques produce superior innovations than other companies not employing specific knowledge management techniques. In a first step, this could possibly be explored within the framework of the frequently used Crepon et al. (1998) framework which explicitly links innovation input to intermediate output and finally overall firm performance. For future studies, however, it would be desirable to collect panel data to better investigate the time horizon between the implementation of such management techniques and their fruit.

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# Appendix

**Table 4: Heteroscedastic Full Information Maximum Likelihood IV Tobit§**

| | Dependent variable: | | |
|---|---|---|---|
| | NEWPROD% | MARKET% | COST% |
| Variable | Coefficient (std. error) | Coefficient (std. error) | Coefficient (std. error) |
| KMEMPL | 4.353 | 2.597 | 3.311*** |
| | (3.160) | (2.261) | (1.264) |
| KMCP | 2.356 | 0.007 | 1.615 |
| | (3.172) | (2.289) | (1.293) |
| KMEXT | 7.252** | 6.013*** | -0.493 |
| | (3.143) | (2.262) | (1.296) |
| LN(EMPL) | 6.105*** | 4.088*** | 2.570*** |
| | (1.324) | (1.009) | (0.549) |
| LN(CAPINT) | 1.160 | 0.436 | 0.917** |
| | (1.057) | (0.792) | (0.447) |
| RDINT (instrumented) | 6.161*** | 0.385*** | 1.237*** |
| | (0.977) | (0.060) | (0.398) |
| LN(AGE) | 0.078 | -0.627 | 0.431 |
| | (1.762) | (1.250) | (0.678) |
| PATENT | -13.744** | -6.998 | -4.258* |
| | (6.362) | (4.474) | (2.525) |
| TRADEMARK | 14.708*** | 9.726*** | 2.820* |
| | (3.770) | (2.608) | (1.446) |
| MEDCMPT | 6.705** | 3.548 | 2.570** |
| | (3.289) | (2.352) | (1.317) |
| HIGHCMPT | 0.0655 | -1.753 | 0.222 |
| | (3.830) | (2.768) | (1.608) |
| GP | -3.731 | -4.606** | 1.451 |
| | (3.168) | (2.286) | (1.395) |
| Test on joint significance of industry dummies | $\chi^2(11) = 21.80$** | $\chi^2(11) = 28.64$*** | $\chi^2(11) = 29.42$*** |
| Log Likelihood | -6528.85 | -5864.36 | -5161.2679 |
| Number of obs. | 1282 | 1282 | 1282 |
| Test on heteroscedasticity | $\chi^2(15) = 53.71$*** | $\chi^2(15) = 85.95$*** | $\chi^2(15) = 95.10$*** |

§ R&D intensity is instrumented with three dummy variables indicating subsidy receipt from local, federal and EU government respectively. First stage results are not presented in detail.

Notes: *** (**, *) indicate a significance level of 1% (5%, 10%). All models include an intercept not reported here. The heteroscedasticity term includes 4 size class dummies (based on employment) and the 11 industry dummies.

**Table 5: Descriptive statistics per industry**

| NACE-CODES | DESCRIPTION | #OBS | KMEMP | KMCP | KMEXT | Mean of NEWPROD% | TURNMAR% | REDUC% |
|---|---|---|---|---|---|---|---|---|
| 15,16 | FOOD, BEVERAGES, TOBACCO | 114 | 0.25 | 0.32 | 0.4 | 7.74 | 3.41 | 1.86 |
| 17,18,19 | TEXTILE, CLOTHING, FUR, LEATHER, SHOES | 61 | 0.36 | 0.43 | 0.49 | 9.44 | 5.1 | 1.25 |
| 20,21,22,36 | WOUD, PAPER, PRINTING, FURNITURE | 109 | 0.32 | 0.32 | 0.3 | 7.63 | 3.27 | 1.95 |
| 23,24,25 | CHEMICALS, RUBBER, PLASTICS | 107 | 0.42 | 0.51 | 0.51 | 13.14 | 5.79 | 2.94 |
| 26 | NON-METAL MINERAL PRODUCTS | 49 | 0.29 | 0.35 | 0.27 | 7.84 | 3.24 | 1.41 |
| 27,28 | METALS, METAL PRODUCTS | 118 | 0.33 | 0.32 | 0.32 | 5,26 | 2.03 | 1.69 |
| 29 | MACHINES, EQUIPMENT, TOOLS | 87 | 0.43 | 0.4 | 0.39 | 15.21 | 10.21 | 1.12 |
| 30,31,32,33 | ELECTRONICS, ICT, PRECISION INSTRUMENTS | 74 | 0.53 | 0.47 | 0.47 | 15.97 | 9.61 | 2.38 |
| 34, 35 | VEHICLES | 41 | 0.37 | 0.44 | 0.29 | 16.54 | 7.12 | 1.85 |
| 50,51,52 | TRADE | 171 | 0.39 | 0.47 | 0.39 | 7.26 | 3.65 | 1.56 |
| 60,61,62,63,64 | TRANSPORT | 155 | 0.26 | 0.32 | 0.18 | 1.65 | 0.97 | 1.09 |
| 70,71,72,73,74 | BUSINESS SERVICES | 196 | 0.58 | 0.63 | 0.48 | 20.35 | 12.15 | 2.5 |