The effect of knowledge management on environmental innovation

The empirical evidence from France

Tatjana Stanovcic
University of Montenegro, Kotor, Montenegro
Sanja Pekovic
University of Montenegro, Kotor, Montenegro and University of Paris-Dauphine, Paris, France, and
Amira Bouziri
Université d'Evry Val d'Essonne, Evry, France

Received 21 January 2015
Revised 3 March 2015
Accepted 30 March 2015

Abstract

Purpose – The purpose of this paper is to analyze whether knowledge management (KM) practices trigger environmental innovation. Additionally, distinguishing between two types of KM practices, the authors want to examine whether different types of KM practices have the same role for environmental innovation.
Design/methodology/approach – Employing two French surveys, namely, the Community Innovation Survey (2002-2004 and 2006-2008) and Annual Firm Survey (EAE, 2000), the authors analyze empirically the relationship between KM practices and environmental innovation. The theoretical relationship the authors propose is tested using bivariate probit model on 1,117 French manufacturing firms.
Findings – The econometric estimations show that the investment in KM practices trigger environmental innovation. Furthermore, the authors distinguish between two types of KM practices: a written policy of KM and a culture intended to promote KM sharing. The main results are also confirmed for both types of KM practices. Moreover, based on coefficients and significance levels, the empirical results indicate that a culture intended to promote KM sharing has a more substantial impact on green innovation than a written policy of KM.
Practical implications – KM can boost environmental innovation, which also enhances firm business performance. Therefore, managers should foster investment in KM capabilities. They need to create working atmosphere that generates, stores, transfers and applies knowledge in order to improve a firm's green innovativeness. Additionally, the study results show that managers can choose among different KM practices in order to enhance environmental innovation. However, managers should be aware that not all KM practices provide the full advantage in terms of performance improvement. They should know that different KM practices have differential impacts on different performance outcomes. In this sense, managers should implement KM practices that fit their performance strategy.
Originality/value – The relationship between KM and innovation performance has received increasing attention from researchers during the past years. However, even though scholars underline the importance of environmental innovation, the relationship between KM and environmental innovation remains significantly under-researched. The findings suggest that KM should be considered as an important source for environmental innovation improvement.

Keywords Organizational performance, Knowledge management
Paper type Research paper

1. Introduction

According to Porter and Van Der Linde (1995), environmental innovation is considered as an important way to reach a better ecological, financial and economic situation in a cost-effective manner. Therefore, environmental or green innovation has been the main

Baltic Journal of Management
Vol. 10 No. 4, 2015
pp. 413-431

1746-5265
DOI 10.1108/BJM-01-2015-0012

focus of interest for many researchers (e.g. Rennings, 2000; Rennings and Zwick, 2002; Beise and Rennings, 2005; Rennings *et al.*, 2006; Amores-Salvado *et al.*, 2014). It has been defined as new or modified practices, methods, systems and products to replace inefficient business activities and to decrease environmental harm (Kemp, 2000). Moreover, beyond environmental considerations, green innovation has economic benefits. Beise and Rennings (2005) state, for example, that environmental innovation allows for lower external costs compared with similar goods or services in the market. They conclude therefore that green innovation activities generate positive spillovers throughout the distribution stage, in the creation phase and also during market introduction. Similarly, Amores-Salvado *et al.* (2014) confirm that via environmental innovations, firms can improve their efficiency, cost reduction strategies and satisfy the demands of environmentally friendly consumers, and thus improve their financial and business profitability. Similar findings are also obtained by Wagner (2005) and Rennings *et al.* (2006).

Since investment in environmental innovation is expected to improve a firm's business performance, the pursuit of long-term profits motivates a firm to establish the strategies that will drive the firm's green innovative activities.

Knowledge management (KM) practices could enhance general innovation (e.g. Cantner *et al.*, 2011; Chen and Huang, 2009; López-Nicolás and Meroño-Cerdán, 2011; Lai *et al.*, 2014) since they improve the firm's skill in managing R&D projects, leverage the internal capability for knowledge acquisition and increase the stock of available knowledge (Gloet and Terziovski, 2004). Additionally, Zack *et al.* (2009) conclude that KM practices enhance the knowledge and organizational learning inside the firm which produces benefits in terms of innovation. Palacios *et al.* (2009) identify several KM abilities that are essential for innovation development, such as skills development, knowledge flow management, acquisition of internal knowledge, transfer, dissemination and internal application of accumulated knowledge and increase in the variety of the organizational memory.

KM is a famous perception since it has been the focus of many studies over the past several years (e.g. Scarbrough, 2003; Alavi and Leidner, 2001; Coombs and Hull, 1998; Davenport and Prusak, 1998). Previous studies consider KM as a helpful technique to add and create value thanks to the skills and expertise of individuals. In fact, as stated by Scarbrough (2003), "it represents a significant development in management practices, providing, for the first time, a systematic application of knowledge to the generation of knowledge." Similar reasoning is also supported by Darroch (2005), Lloyd (1996) and Lubit (2001). Moreover, from the firm's resource-based view (RBV), KM is seen as the construction and application of knowledge as a resource (Spender, 1996). Actually, KM practices are considered as the most strategically essential resources at a firm's disposal since they support the implementation of best practices and permanent progress, operational problem solving, functional assimilation and new product improvement (Grant, 1996; Ettlie and Pavlou, 2006; Marsh and Stock, 2006). The main role of KM practices is to identify and leverage the collective knowledge inside the firm to generate benefits for firm performance (Von Krogh, 1998). Accordingly, KM is also found to influence positively firm business performance (e.g. Lloyd, 1996; Lubit, 2001; Palacios and Garrigos, 2006; Tseng, 2014). In this sense, Tseng (2014) argues that a firm's ability to accumulate critical knowledge resources and manage their assimilation and exploitation will improve its performance. Additionally, the author empirically confirms the positive relationship between KM and firm performance. Similarly, Palacios and Garrigos (2006), using 222 Spanish firms in the biotechnology and

telecommunications industries, conclude that the firms that adopt KM practices obtain better performance results than their competitors.

However, to the best of our knowledge, the literature is silent regarding the effect of KM practices on environmental innovation. Building on previous contributions relating to the KM-innovation performance link, this study develops and tests a model concerning the relationship between KM practices and environmental innovation. Therefore, the main objective of this paper is to empirically answer the following research question:

RQ1. Do KM practices improve environmental innovation?

Thanks to two French surveys, i.e., the Community Innovation Survey (CIS 2002-2004 and 2006-2008) and the Annual Firm Survey (EAE, 2000), our paper aims to fill this research gap in existing literature by analyzing the relationship between KM practices and environmental innovation on 1,117 French manufacturing firms. Additionally, following previous researchers that argue that the impact of KM practices on innovation performance varies according to the type of KM that is considered (Darroch and McNaughton, 2002; Cantner *et al.*, 2011), this study contributes to the advance of KM research from a strategic point of view by distinguishing between a written policy of KM and a culture intended to promote KM sharing.

The design of this paper is structured as follows. In the next section, we provide a literature review that links KM practices and environmental innovation. In Section 3 we present data and the econometric method used. Section 4 is devoted to the main results while Section 5 concludes and draws some implications for policy makers.

2. Literature review

KM and innovation

An important argument supporting the idea that KM practices trigger environmental innovation is that general innovation and green innovation share many common traits and have closely related concepts and instruments. Therefore, drawing on the KM and general innovation literature, we propose a theoretical grounding that links KM and environmental innovation. The following discussion focusses on the relationship between KM and general innovation.

Several studies are devoted to analyzing general innovation since it is considered as an important driver of firm performance. In fact, innovation activities support a firm's competitive advantage and are considered as opportunities to respond to market requests and requirements (Brown and Eisenhardt, 1995; Porter and Van Der Linde, 1995). Damanpour (1991) defines innovation as "the generation, development, and adoption of novel ideas on the part of the firm."

According to Zack *et al.* (2009) KM practices promote the generation of new knowledge and organizational learning which is fundamental for achieving advantages based on innovation. In other words, firms are motivated to implement KM practices in order to minimize risk and increase efficiency which is reflected positively in innovation activities improvement (Carneiro, 2000). In this vein, Gloet and Terziovski (2004) argue that innovation processes depend greatly on knowledge. Similarly, Borghini (2005) suggests that knowledge contributes to producing creative thoughts which improve innovation performance.

As we said previously, effective KM is considered in the empirical literature as a tool for improving the firm's innovation capacity (e.g. Liao and Chuang, 2006; Cantner *et al.*, 2011; Chen and Huang, 2009; López-Nicolás and Meroño-Cerdán, 2011; Lai *et al.*, 2014).

Cantner *et al.* (2011) conclude, for instance, that firms that apply KM have more success with product innovations as well as market innovations compared to non-KM firms. Moreover, Liao and Chuang (2006) state that KM practices have an important role in the processing of knowledge inside the firm and therefore contribute positively to the rapidity of innovation. Implementing KM practices is to make knowledge perceptible and to promote a knowledge-intensive culture (Davenport and Prusak, 1998), which boost innovation performance. In the same sense, Ciabuschi and Martin Martin (2012) confirm that KM practices provide firms with an operative background for the implementation of their innovation approaches. This finding is further verified by Kiessling *et al.* (2009). The authors conclude that KM practices contribute significantly to product progress, employee innovation and firm innovation. They foster a firm's ability to collect knowledge resources and manage their assimilation and exploitation, which will improve firm performance (Holsapple and Wu, 2011).

Innovation activities depend on employees' knowledge, skills and experience in the value creation process. In this sense, KM tools help firms to ensure effective utilization of human capital in the development of organizational expertise for innovation (Chen and Huang, 2009). It has been argued that a positive correlation exists between human capital management, KM and innovation performance (e.g. Brockbank, 1999; Jaw and Liu, 2003). Brockbank (1999) states, for example, that training helps employees react to diversity of knowledge and gives them openness to new concepts. Moreover, investment in training improves employee knowledge and experience at all levels of the organization, which enables them to be more creative and boosts innovation performance (Torraco and Swanson, 1995). In addition, employees' involvement, which is another indicator of human capital management, encourages employees to develop new notions and share knowledge, which also enhances innovative results (Jiménez-Jiménez and Sanj-Valle, 2005).

Another important argument supporting the favorable effect of KM practices on innovation performance is derived from its positive link to competitive advantage. Von Krogh (1998) devotes special consideration to the crucial role of KM in creating sustainable competitive advantage and performance. The firm's performance will depend therefore on how managers organize all knowledge resources available and convert them into activities that create and optimize value (Von Krogh, 1998; Alavi and Leidner, 2001). Knowledge creation, maintenance and transfer, which are the essential parts of KM theory (Grant, 1996; Spender, 1996; Spicer and Sadler-Smith, 2006), are considered as the principal components of a firm's innovation and competitiveness (Nonaka, 1994; De Clerq and Arenius, 2006). Nonaka (1994) confirms, for example, that knowledge should be regarded as a very important attribute of advanced industrial growth. The same findings relating to the positive impact of knowledge and learning systems on innovation process and outcomes are shared by other scholars such as Wheelwright and Clark (1992) and Kessler *et al.* (2000).

However, several scholars argue that different KM practices have different impacts on the different types of innovation. For instance, Darroch and McNaughton (2002) show that incremental innovations do not come from firms that respond to knowledge about the market or have an effective marketing function but from firms that are sensitive to information about changes in the marketplace and respond to knowledge about technology. Moreover, the authors conclude that different KM activities are important for different innovation types. As we indicated previously, Cantner *et al.* (2011) find that firms which apply KM perform better in terms of shares of sales with innovative products. However, they do not find a significant relationship between KM and the share of cost reductions with process innovation.

Although the literature argues that the relationship between KM practices and innovation performance depends on the type of KM practices and innovation that are considered, due to significant importance of knowledge for environmental innovation (Darnall and Edwards, 2006), we expect a positive relationship between KM practices and environmental innovation.

Environmental innovation and its determinants

Environmental innovation can be summarized by the same mechanisms, instruments and procedures as general innovation but with the purpose of reducing negative impacts on the environment (Rennings, 2000; Kemp, 2000). Accordingly, environmental innovation embraces all innovations that enable a firm to decrease, progressively or drastically, its negative environmental impacts through new products, processes, services or methods (Horbach *et al.*, 2013). It is worth noting that the literature recognizes only two aspects that differentiate environmental innovation from other innovations such as the double externality problem and the regulatory push/pull effect (Rennings, 2000).

Moreover, several studies have been devoted to environmental innovation and its determinants (Rennings *et al.*, 2006; Horbach, 2008; Kammerer, 2009; Delmas and Pekovic, 2013). For example, Delmas and Pekovic (2013) find that the adoption of green innovations is significantly lower under perceived downturn market conditions, as compared to perceived steady or growth conditions. Furthermore, the authors' findings indicate that the firms with complementary environmental strategies, internal R&D, that are vertically integrated or that pursue general cost leadership strategies, tend to invest more in green innovation in downturns. Working on German manufacturers of electrical and electronic appliances, Kammerer (2009) underlines the important role of customer benefits for environmental product innovations. Horbach (2008) finds that the improvement in R&D, environmental regulation, environmental management tools and general organizational changes encourage and boost environmental innovation. Additionally, it has been concluded that strategic market goals as well as environmental regulation toward the adoption of environmental practices have positive impacts on green innovation (Rennings *et al.*, 2006).

We can note consequently that different determinants of green innovation have been studied but the link between KM practices and environmental innovation remains sketchy in the literature.

KM and environmental innovation

The RBV of the firm indicates that competitive advantages depend on valuable, rare, hard-to-imitate and non-substitutable resources (Barney, 1991). Furthermore, it recognizes that intangible resources, such as knowledge, drive firms to sustainable competitive advantage (McEvily and Chakravarthy, 2002). In the same sense, several scholars conclude that criteria for resource-based advantages can be obtained by environmental performance improvement (Hart, 1995; Hart and Ahuja, 1996; Aragon-Correa and Sharma, 2003). Grant (1996) underlines that environmental activities can be considered as a source of competitive advantage especially if a firm has suitable knowledge assets associated with environmental activities. In line with the knowledge-based view, Branzei *et al.* (2002) confirm that specific knowledge is the main component of environmental performance improvement.

Our reasoning related to the positive link between KM and environmental innovation is further reinforced by the evidence from Reed *et al.* (2014) who using an

empirical analysis of interviews with 32 researchers and stakeholders across 13 environmental management research projects, each of which included elements of knowledge co-creation and sharing in their design-identified five principles for effective practice of knowledge exchange that have the potential to enhance the impact of environmental management research, policy and practice. Moreover, Huang and Shih (2009) find that the China Steel Corporation – which has applied environmental knowledge circulation process – improves its environmental and financial performance through environmental knowledge creation, environmental knowledge accumulation, environmental knowledge sharing, environmental knowledge utilization and environmental knowledge internalization. Moreover, Branzei *et al.* (2002) find that specialized knowledge of environmental management increases firms' environmental innovation in three quite different national contexts – Canada, Japan and China. The authors suggest that specialized knowledge of environmental management may be a critical component of environmental performance, in keeping with the argument that tacit, rare, inimitable resources are more likely to be associated with sustainable performance.

Therefore, based on previous discussions, this study proposes the following hypothesis:

H1. KM practices improve environmental innovation performance.

3. Empirical strategy

Data

We employ two French surveys, namely, the CIS (2002-2004 and 2006-2008) and Annual Firm Survey (EAE, 2000). The CIS was conducted by the Institute for Statistics and Economic Studies based on the Oslo Manual drawn up by the OECD. Firms were asked to answer questions about the type of innovation introduced over the three year period, specific innovation activities carried out in the same period, expenditures and human resources allocated to such activities, and a set of more qualitative information about the sources of information, objectives pursued and hampering factors associated with the innovation process. CIS data have been used in over 100 recent academic articles, mainly in economics and management. For the empirical purposes of this paper, we use two editions of the CIS survey, CIS4 that covers the period from 2002 to 2004, and CIS8 that covers the period from 2006 to 2008. The EAE survey is a mandatory annual survey established by the Institute for Statistics and Economic Studies to collect basic data on the structure of firms. The EAE is the principal source of economic data regarding firms' activities, structure and performance, except for the banking sector. The matching of the two data sets results in 1,117 usable firms from the manufacturing sector.

Dependent variable

A dependent variable denoted *GREEN_INNO* is created. It indicates whether a firm has introduced between 2006 and 2008 a product, process, organization or marketing innovation delivering environmental benefits for the production process. More precisely, our dependent variable equals 1 if a firm introduced a reduction in raw material use; or a reduction of energy consumption; or a reduction of CO_2 emissions; or a substitution for polluting raw materials; or a substitution for hazardous products, a reduction of soil, water, or air pollution; or recycling of waste, water, or raw materials.

Independent variable

In order to examine the impact of KM on firms' investments in environmental innovation, we use a variable indicating whether a firm during the three years from 2002 to 2004 introduced new or significantly improved KM systems. Furthermore, we distinguish between two types of KM: a written policy (guidelines) of KM (*KM_POLICY*) and; a culture intended to promote KM sharing (*KM_CULTURE*). Generally, KM is measured by means of four categories: sharing and communication of knowledge and information; training and mentoring; policies and strategies and; knowledge capture and acquisition (Edler, 2002). The two KM practices used in this paper are part of KM category called policy and strategy, which refers to the extent to which firms are dedicated to KM practices (Edler, 2002). A written policy of KM is considered as explicit knowledge that can be passed on to others and absorbed by those who understand those polices (Berg Jensen *et al.*, 2007). Lin (2007) defines knowledge sharing as a social interaction culture involving the exchange of employee knowledge, experiences and skills through the whole department or organization. It is argued that a firm can create a culture that supports knowledge sharing by directly incorporating knowledge in its business strategy and by changing employee attitudes and behavior to promote willing and consistent knowledge sharing (Lee and Choi, 2003).

Controls

Size. Cantner *et al.* (2009, 2011), Earl and Gault (2003) and Davenport and Prusak (1998) find that large firms tend to apply more and different KM practices than smaller firms. Therefore, we expect that firm size influences positively KM practices implementation. Previous scholars (e.g. Rennings *et al.*, 2006; Delmas and Pekovic, 2013) confirm that investment in environmental innovation increases with firm size. Firm size is measured by the number of employees within the firm in 2002.

Group. Firms may acquire knowledge and information through cooperation activities among network members which could facilitate implementation of KM practices (Swan *et al.*, 1999). Being part of a group company plays an important role in the adoption of environmental innovation, which is confirmed empirically (Delmas and Pekovic, 2013; Grolleau *et al.*, 2014). The variable *GROUP* presents a dummy variable that takes a value of 1 when the firm belongs to a group company. The information on this variable is obtained from CIS4 data.

EBITDA. Investigating drivers of KM practices, Davenport *et al.* (1998) and Davenport and Probst (2002) stress the importance of performance measures for ensuring successful implementation of KM initiatives. Therefore a positive effect is expected between KM practices and the *EBITDA* variable which represents firm financial performance. Firms with a better financial situation are expected to invest in environmental innovation (Delmas and Pekovic, 2013). Therefore, we include a continuous variable called *EBITDA* that indicates a firm's earnings before interest, taxes and depreciation in 2000. Based on previous findings, we expect a positive and significant relationship between environmental innovation and *EBITDA*. Here we note that *EBITDA* refers to the French Excédent Brut d'Exploitation (EBE), which is almost the same thing since the major difference concerns amortization, which is not referred to in the French EBE.

R&D. The literature suggests that R&D is positively associated with investment in KM (e.g. Cantner *et al.*, 2009, 2011) and environmental innovation (e.g. Horbach, 2008; Delmas and Pekovic, 2013; Grolleau *et al.*, 2014). Similar signs are expected for both KM

and environmental innovation. R&D is a binary variable equal to 1 if the firm undertakes its R&D development activities internally or externally. The information on this variable is obtained using CIS4 data.

Innovation. The positive relationship between KM and innovation is confirmed by previous researchers (e.g. Carrillo and Gaimon, 2004; Chen and Huang, 2009; López-Nicolás and Meroño-Cerdán, 2011; Lee *et al.*, 2013; Lai *et al.*, 2014), so we expect to confirm those findings. Previous experience with similar innovative activities could lead a firm to invest in environmental innovation because of "learning-by-doing" and economies of scale (e.g. Grolleau *et al.*, 2007; Pekovic, 2010). We introduce a dummy variable (from CIS4 data) that indicates whether a firm innovates in four areas, that is, product/services, process, organization and marketing.

The variables used in the estimation, their definitions and sample statistics are presented in Table I. No problem of multicollinearity has been detected (the Appendix).

Econometric model

The same unobservable factors may have an impact on both KM and the firm's likelihood of investing in environmental innovation. Hence, this potential unobserved heterogeneity will result in the correlated error terms of variables that present environmental innovation and KM practices. Thus, we apply a bivariate probit model in order to correct for endogeneity of the variable *KM* (Greene, 2003). Our model is formulated as a system of two latent-variable equations with normally distributed and correlated disturbances: one for a firm's KM introduction decision and a second for an environmental innovation investment decision. Moreover, Maddala (1986) and Greene (1998) argue that this is a specific case of the bivariate probit model, denoted by Greene (2003) as a recursive model. The bivariate probit model relies on a simultaneous estimation approach in which the factors that determine a firm's KM introduction are estimated simultaneously with the factors that determine environmental innovation investment. The two equations are jointly estimated using maximum likelihood.

Our observed variables, Y_1 and Y_2, corresponding, respectively, to KM and environmental innovation are defined by:

$$\begin{aligned} Y_1 &= 1 \quad if \quad Y_1^* > 0, \\ Y_1 &= 0 \quad \text{otherwise.} \end{aligned} \tag{1}$$

$$\begin{aligned} Y_2 &= 1 \quad if \quad Y_2^* > 0, \\ Y_2 &= 0 \quad \text{otherwise.} \end{aligned} \tag{2}$$

Y_1^* and Y_2^* are latent variables influencing the probability of KM and environmental innovation investment, respectively. We consider the following bivariate probit model:

$$\begin{cases} Y_1^* = \alpha_1 + \beta_1 X_1 + \delta Z_1 + \mu_1 \\ Y_{2k}^* = \alpha_2 + \beta_2 X_2 + \gamma Y_1 + \mu_2 \end{cases} \tag{3}$$

where X_1 and X_2 are a vector of exogenous variables including constant firm characteristics (*SIZE*, *GROUP*, *EBITDA*, *R&D* and *INNOVATION*).

The vector of variables Z_1 represents the instrumental variable, which usually guarantees the identification of the model and helps to estimate correlation coefficients (Maddala, 1986). In order to identify the bivariate probit, we generally need an

Variables	Definition	Mean	SD	Min.	Max.
Dependent variables					
ENV_INNO	A firm introduced between 2006 and 2008 a product, process, organization or marketing innovation providing environmental benefits in the business production process Dummy variable (= 1 if yes)	0.64	0.48	0.00	1.00
Main explanatory variables					
KM_GENERAL	A firm introduced between 2002 and 2004 new or significantly improved knowledge management systems (KM) Dummy variable (= 1 if yes)	0.37	0.48	0.00	1.00
KM_POLICY	A firm introduced between 2002 and 2004 a written policy of knowledge management Dummy variable (= 1 if yes)	0.06	0.25	0.00	1.00
KM_CULTURE	A firm introduced between 2002 and 2004 a culture intended to promote knowledge management sharing Dummy variable (= 1 if yes)	0.09	0.29	0.00	1.00
Control variables					
SIZE	Firm size, measured by the number of employees Continuous variable	694.55	1,607.92	6.00	26,305
GROUP	A firm is part of a holding company Dummy variable (= 1 if yes)	0.82	0.38	0.00	1.00
EBITDA	The logarithm of a firm's earnings before interest, taxes and depreciation Continuous variable	10.19	1.84	3.71	16.18
R&D	A firm undertakes its R&D activities internally or externally Dummy variable (= 1 if yes)	0.70	0.46	0.00	1.00
INNO	A firm innovates in product/services, process, organization and marketing Dummy variable (= 1 if yes)	0.58	0.49	0.00	1.00
EXPORT Instrumental variable	Logarithm of a firm's exports in 2000 Continuous variable	10.80	2.67	0.00	17.19

Note: $n = 1{,}117$

Table I. Definition of variables and sample statistics

additional variable that will explain the probability of KM introduction but that will not explain environmental innovation. The difficulty here is that we can expect very similar factors to influence both the probability of KM and environmental innovation investment. Since a formal econometric test that could indicate the correct specification of the model is not available, any argument as to why specific variables are expected to influence one equation and not the other has to be of a substantive, theoretical nature. In this paper, we use the export (*EXPORT*) as an instrumental variable.

The choice of the variable *EXPORT* is based on the effect called "learning-by-exporting," in which firms learn to improve their business through contact with more advanced foreign competitors in global export markets (Branstetter, 2006). Moreover, Hedlund (1994) considers export activities as an important source of knowledge acquisition. In this sense, export supports transfer and implementation of knowledge

inside a firm, which increases the firm's chance of investing in KM practices. Moreover, previous papers (e.g. De Marchi, 2012; Grolleau *et al.*, 2014) find that exports do not explain the adoption of eco-innovations in the context of developed countries.

β_1, β_2, δ and γ are slope coefficients to be estimated. α_1, α_2, μ_1 and μ_2 are the intercepts and disturbance terms for the two equations, respectively.

ρ is the correlation between the error terms in the KM and environmental innovation equations. Residuals of the equations above follow a normal bivariate distribution with zero means and a covariance matrix that is written, after normalizations to 1 of the diagonal elements, as follows:

$$\begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix} \rightarrow N\left(0, \sum\right), \quad where \quad \sum = \begin{pmatrix} 1 & \rho_{12} \\ \rho_{12} & 1 \end{pmatrix}$$

A Wald test of the significance of ρ is a direct test of the endogeneity of Y_1 and Y_2 (Wooldridge, 2002). When ρ is statistically different from zero, that is, the probability that a relationship exists between KM and environmental innovation, simultaneous estimation procedures are essential to appropriate estimation.

One may argue that it is improved environmental innovations which allow firms to adopt KM practices. In order to overcome this reverse-causality issue, our estimations are performed using lagged information. While the implementation of KM practices is observed between 2002 and 2004, environmental innovation is observed between 2006 and 2008.

4. Results

Bivariate probit estimation results are presented in Tables II-IV, together with goodness-of-fit measures (maximum-likelihood estimation).

ρ is significantly different from 0 for the models with KM in general and KM culture (Tables II and IV). This means that the variables representing KM practices are endogenous, and it confirms the interest in using the bivariate probit model. On the other hand, in the model with KM policy, ρ is not significantly different from 0, indicating that a simple univariate probit model would also provide unbiased

	KM_GENERAL		*ENV_INNO*	
Variables	Estimate	*z*-value	Estimate	*z*-value
Intercept	−2.28***	−8.40	−1.06***	−3.23
KM_GENERAL	–	–	1.21***	3.68
SIZE	0.00	1.44	0.00***	2.22
GROUP	0.27**	2.07	0.08	0.71
EBITDA	0.04	0.17	0.06*	1.68
R&D	0.41***	3.93	0.36***	2.68
INNO	0.32***	3.63	−0.14	−1.51
EXPORT	0.07***	3.41	–	–
Likelihood ratio	−1,291.27			
Waldχ^2(36)	481.28			
ρ	−0.60**			
Wald test of $\rho = 0$ χ^2(1)	3.19*			
Number of observations	1,117			

Note: *,**,***Significant at the 10, 5 and 1 per cent levels, respectively

Table II.
Bivariate probit estimates of the effect of knowledge management practices (*KM_GENERAL*) on environmental innovation

Variables	*KM_POLICY* Estimate	*z*-value	*ENV_INNO* Estimate	*z*-value
Intercept	−2.78***	−6.48	−1.31***	−4.50
KM_POLICY	–	–	1.04*	1.80
SIZE	−0.00	−0.93	0.00***	3.02
GROUP	0.12	0.59	0.19*	1.68
EBITDA	−0.02	−0.31	0.09***	2.73
R&D	0.03	0.18	0.56***	5.62
INNO	0.22*	1.65	−0.03	−0.36
EXPORT	0.11***	2.70	–	–
Likelihood ratio	−890.0556			
Waldχ^2(36)	208.14			
ρ	−0.46			
Wald test of $\rho = 0$ χ^2(1)	1.21			
Number of observations	1,117			

Note: *,**,***Significant at the 10, 5 and 1 per cent levels, respectively

Table III. Bivariate probit estimates of the effect of knowledge management practices (*KM_POLICY*) on environmental innovation

Variables	*KM_CULTURE* Estimate	*z*-value	*ENT_INNO* Estimate	*z*-value
Intercept	−2.06***	−5.73	−1.44***	−5.01
KM_CULTURE	–	–	1.41***	3.61
SIZE	−0.00	−0.77	0.00***	2.78
GROUP	−0.10	−0.60	0.20*	1.83
EBITDA	−0.03	−0.71	0.09***	2.96
R&D	0.55***	3.64	0.44***	3.82
INNO	0.08	0.69	−0.02	−0.21
EXPORT	0.06**	2.02	–	–
Likelihood ratio	−968.51			
Waldχ^2(36)	274.16			
ρ	−0.64*			
Wald test of $\rho = 0$ χ^2(1)	2.35			
Number of observations	1,117			

Notes: *,**,***Significant at the 10, 5 and 1 per cent levels, respectively

Table IV. Bivariate probit estimates of the effect of knowledge management practices (*KM_CULTURE*) on environmental innovation

results (Table III). Nevertheless, implementing the bivariate probit model is necessary to check for the exogeneity of this variable.

We first present the estimation results regarding the factors that may influence firms to invest in KM. The results concerning KM practices in general indicate that, as expected, the variables *GROUP*, *R&D* and *INNOVATION* are significant, which confirms previous findings (Table II). Furthermore, looking at the model with KM policy, we observe that only the variable representing innovation has positive influence on a KM written policy (Table III), while R&D activities are positively associated with a culture intended to promote KM sharing (Table IV). Surprisingly, variables *SIZE* and *EBITDA* are not significant for all three models (Tables II-IV). Finally, as expected our instrumental variable is positive and significant for all three models (Tables II-IV).

The main hypothesis of paper, that is, KM is positively related to environmental innovation, is confirmed for all three models (Tables II-IV: third column). This result is

consistent with that of several studies (e.g. Liao and Chuang, 2006; Cantner *et al.*, 2011; Chen and Huang, 2009; López-Nicolás and Meroño-Cerdán, 2011; Lai *et al.*, 2014) which show that KM practices help knowledge communication and the exchange required in the innovation process, and further enhance innovation performance. In other words, KM practices could be considered as the main strategic tool that improves the firm's competitive advantage. Therefore, in today's dynamic business environment, firms will achieve sufficient green innovations only with their internal knowledge creation. Moreover, a deeper analysis of the results underlines that different KM strategies such as KM policy and KM culture also positively influence environmental innovation (Tables III and IV). Hence, we may conclude that a firm's ability to strategically use different forms of knowledge determines its level of green innovation. However, we may observe that the coefficient as well as the significance level of the KM culture variable is higher (Table IV) than for the KM policy variable (Table III). In light of these results, we may argue that the importance of KM practices for green innovation depends on the nature of knowledge. This finding suggests that KM culture is to some extent more important for green innovations than KM policy.

Finally, our analysis also provides information about the determinants of environmental innovation. We may notice that generally the variables *SIZE*, *GROUP*, *EBITDA* and *R&D* are significant, as expected (Tables II-IV).

5. Conclusion

Summary of research

In recent years, KM has been considered as a critical tool for firm competitiveness since it can generate important strategic benefits for firm performance (Lloyd, 1996). Moreover, the positive effect of KM practices on innovation performance has been also recognized (e.g. Cantner *et al.*, 2011; Chen and Huang, 2009). Given the growing importance of environmental innovation for firm business performance, there is a need for empirical analysis concerning the relationship between KM and green innovation. Therefore, in this paper we analyze the impact of KM on environmental innovation, a subject which is quite limited in the existing literature.

The main conclusion of our research is that KM could be considered as a significant tool to enhance environmental innovation performance. In fact, it has been argued that implementation of this kind of management practices makes knowledge visible, increases the rapidity of innovation activity and consequently promotes a knowledge-intensive culture (Liao and Chuang, 2006; Kiessling *et al.*, 2009; Cantner *et al.*, 2011; Chen and Huang, 2009) which enhances environmental innovation performance. Thus, we may argue that firm environmental innovation can be achieved through knowledge improvement. Additionally, we use two types of KM: a written policy of KM and a culture intended to promote KM sharing. Our results for both types confirm a pivotal role of KM in supporting and fostering green innovation performance. It should be noted that when we compare the coefficients of KM policy and KM culture, as well as significance level on green innovation, we may notice that KM culture is more important for environmental innovation than KM policy. In our case, the reason for the higher coefficient of KM culture (compared to KM policy) on environmental innovation could be due to the fact that KM culture refers to knowledge sharing, which is identified as essential tool when considering complex environmental initiatives (Darnall and Edwards, 2006). Accordingly, we may suggest that a culture intended to promote KM sharing is more relevant for environmental improvement.

Comparison with previous research

Considering that general innovation and environmental innovation share similar concepts and objectives, our findings support previous scholars that confirm a positive relationship between KM practices and innovation (e.g. Cantner *et al.*, 2011; Chen and Huang, 2009; López-Nicolás and Meroño-Cerdán, 2011; Lai *et al.*, 2014). Moreover, our results go in the same direction as those of Reed *et al.* (2014), Huang and Shih (2009) and Branzei *et al.* (2002), which conclude that knowledge is essential for environmental performance. Our results partially support previous scholars indicating that different KM practices impact differently on different types of innovation activities (Darroch and McNaughton, 2002; Cantner *et al.*, 2011).

Overall, by demonstrating that KM practices influence environmental innovation, this study contributes to both the KM and environmental management literature.

Policy implications

Our results carry an important implication for policy makers. Our study contributes to management practice by providing evidence that superior KM practices are associated with superior green innovation performance. Managers can use these findings as an argument to support implementation of KM practices. By implementing KM practices, firms can generate long-term efficiency through environmental innovation. Therefore, greater weight should be given to the adoption of knowledge practices and its diffusion. Managers need to create a working atmosphere that generates, stores, transfers and applies knowledge in order to improve the firm's green innovativeness. Additionally, the study results show that managers can choose among different KM practices in order to enhance environmental innovation. However, our results reveal that KM culture practices have a higher coefficient and significance level on green innovation than KM policy practices. Therefore, managers should be aware that it is possible that not all types of KM practices generate firm performance improvement. They should know that different KM practices have differential impacts on different performance outcomes. In this sense, managers should implement KM practices that fit their performance strategy.

Limitations and future research

Although the results of this study should aid scholars and managers in understanding the importance of KM practices for environmental innovation, they have limitations that can serve as avenues for future research. First, since we investigate only French manufacturing firms, a potential limitation may exist due to institutional and sector factors that may influence both KM practices and environmental innovation. Second, since our findings reveal that different types of KM influence environmental innovation differently, future studies could try to analyze more types of KM practices. Similarly, this study does not distinguish between different types of environmental innovation (e.g. reduction in raw material use; or reduction of energy consumption; or reduction of CO_2 emissions; or substitution of polluting raw materials; or of hazardous products, reduction of soil, water or air pollution; or recycling of waste, water or raw materials) despite the possible variations within the same variable. Third, even though we lagged KM variables, a bi-probit model is a cross-section method and it is incapable of confirming the causal relationships between KM and environmental innovation. Finally, the CIS3 database covers only the period until 2003, which could provide limited findings concerning the relationship between KM practices and environmental innovation.

These limitations could be overcome in the following way. First, future research should do additional work to generalize the results by employing data from other countries and sectors. Second, future research would benefit from additional examination of different types of environmental innovations and KM practices. More precisely, approaches that define environmental innovation in a more specific manner may be necessary to provide a complete picture concerning the link between KM and environmental innovation. Additionally, it would be important to identify what types of KM practices are the most beneficial for environmental innovation. Third, the usage of a panel data model instead of cross-section data could be more appropriate since it takes into account both individual and temporal dimensions and so it would allow the drawing of causal relationship. Finally, future research should employ more recent data to verify the consistency of our results over time.

References

Alavi, M. and Leidner, D.E. (2001), "Review: knowledge management and knowledge management systems: conceptual foundations and research issues", *MIS Quarterly*, Vol. 25 No. 1, pp. 107-136.

Amores-Salvadó, J., Martín-de Castro, G.E. and Navas-López, J. (2014), "Green corporate image: moderating the connection between environmental product innovation and firm performance", *Journal of Cleaner Production*, Vol. 83 No. 15, pp. 356-365.

Aragon-Correa, J.A. and Sharma, S. (2003), "A contingent resource-based view of proactive corporate environmental strategy", *Academy of Management Review*, Vol. 28 No. 1, pp. 71-88.

Barney, J.B. (1991), "Firm resources and sustained competitive advantages", *Journal of Management*, Vol. 17 No. 1, pp. 99-120.

Beise, M. and Rennings, K. (2005), "Lead markets and regulation: a framework for analyzing the international diffusion of environmental innovations", *Ecological Economics*, Vol. 52 No. 1, pp. 5-17.

Berg Jensen, M., Johnson, B., Lorenz, E. and Lundvall, B. (2007), "Forms of knowledge and modes of innovation", *Research Policy*, Vol. 36 No. 5, pp. 680-693.

Borghini, S. (2005), "Organizational creativity: breaking equilibrium and order to innovate", *Journal of Knowledge Management*, Vol. 9 No. 4, pp. 19-33.

Branstetter, L. (2006), "Is foreign direct investment a channel of knowledge spillovers? Evidence from Japan's FDI in the United States", *Journal of International Economics*, Vol. 68 No. 2, pp. 325-344.

Branzei, O., Jennings, P.D. and Vertinsky, I. (2002), "A knowledge-based view of environmental performance in different cultural contexts: Canada, Japan, and China", paper presented at the Academy of Management Conference, Organizations and the Natural Environment Division, Denver, CO, 9-14 August.

Brockbank, W. (1999), "If HR were really strategically proactive: present and future directions in HR's contribution to competitive advantage", *Human Resource Management*, Vol. 38 No. 4, pp. 337-352.

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

Cantner, U., Joel, K. and Schmidt, T. (2009), "The use of knowledge management by German innovators", *Journal of Knowledge Management*, Vol. 13 No. 4, pp. 187-203.

Cantner, U., Joel, K. and Schmidt, T. (2011), "The effects of knowledge management on innovative success: an empirical analysis of German firms", *Research Policy*, Vol. 40 No. 10, pp. 1453-1462.

Carneiro, A. (2000), "How does knowledge management influence innovation and competitiveness", *Journal of Knowledge Management*, Vol. 4 No. 2, pp. 87-98.

Carrillo, J.E. and Gaimon, C. (2004), "Managing knowledge-based resource capabilities under uncertainty", *Management Science*, Vol. 50 No. 11, pp. 1504-1518.

Chen, C.J. and Huang, J.W. (2009), "Strategic human resource practices and innovation performance – the mediating role of knowledge management capacity", *Journal of Business Research*, Vol. 62 No. 1, pp. 104-114.

Ciabuschi, B. and Martin Martin, O. (2012), "Knowledge ambiguity, innovation and subsidiary performance", *Baltic Journal of Management*, Vol. 7 No. 2, pp. 143-166.

Coombs, R. and Hull, R. (1998), "Knowledge management practices' and path dependency in innovation", *Research Policy*, Vol. 27 No. 3, pp. 237-253.

Damanpour, F. (1991), "Organizational innovation: a meta-analysis of effects of determinants and moderators", *The Academy of Management Journal*, Vol. 34 No. 3, pp. 555-590.

Darnall, N. and Edwards, D. Jr (2006), "Predicting the cost of environmental management system adoption: the role of capabilities, resources and ownership structure", *Strategic Management Journal*, Vol. 27 No. 4, pp. 301-320.

Darroch, J. (2005), "Knowledge management, innovation and firm performance", *Journal of Knowledge Management*, Vol. 9 No. 3, pp. 101-115.

Darroch, J. and McNaughton, R. (2002), "Examining the link between knowledge management practice and types of innovation", *Journal of Intellectual Capital*, Vol. 3 No. 3, pp. 210-222.

Davenport, T.H. and Probst, G. (2002), *Knowledge Management Case Book: Siemens Best Practices*, Wiley, New York, NY.

Davenport, T.H. and Prusak, L. (1998), *Working Knowledge*, Harvard Business School Press, Boston, MA.

Davenport, T.H., De Longand, D.W. and Beers, M.C. (1998), "Successful knowledge management projects", *Sloan Management Review*, Vol. 39 No. 2, pp. 43-57.

De Clercq, D. and Arenius, P. (2006), "The role of knowledge in business start-up activity", *International Small Business Journal*, Vol. 24 No. 4, pp. 339-358.

De Marchi, V. (2012), "Environmental innovation and R&D cooperation: empirical evidence from Spanish manufacturing firms", *Research Policy*, Vol. 41 No. 3, pp. 614-623.

Delmas, M. and Pekovic, S. (2013), "Resource efficiency strategies and market conditions", *Long Range Planning*, Vol. 48 No. 2015, pp. 80-94. doi: 10.1016/j.lrp.2013.08.014.

Earl, L. and Gault, F. (2003), "Knowledge management: size matters", in OECD/Minister of Industry Canada (Ed.) *Measuring Knowledge Management in the Business Sector*, OECD Publications Service, Paris, pp. 169-186.

Edler, J. (2002), *OECD Survey on Knowledge Management*, Fraunhofer Institute for Systems and Innovation Research, Karlsruhe, available at: www.oecd.org/dataoecd/23/30/2756424.pdf

Ettlie, J.E. and Pavlou, P.A. (2006), "Technology-based new product development partnerships", *Decision Sciences*, Vol. 37 No. 2, pp. 117-147.

Gloet, M. and Terziovski, M. (2004), "Exploring the relationship between knowledge management practices and innovation performance", *Journal of Manufacturing Technology Management*, Vol. 15 No. 5, pp. 402-409.

Grant, R.M. (1996), "Toward a knowledge-based theory of the firm", *Strategic Management Journal*, Vol. 17 No. 2, pp. 109-122.

Greene, W. (1998), "Gender economics courses in liberal arts colleges: further results", *Journal of Economic Education*, Vol. 29 No. 4, pp. 291-300.

Greene, W.H. (2003), *Econometric Analysis*, Prentice Hall, New Jersey, NJ.

Grolleau, G., Mzoughi, N. and Pekovic, S. (2007), "The characteristics of chemical firms registering for ISO 14001 or responsible care", *Economic Bulletin*, Vol. 12 No. 29, pp. 1-13.

Grolleau, G., Mzoughi, N. and Pekovic, S. (2014), "Environmental management practices: good or bad news for innovations delivering environmental benefits? The moderating effect of market characteristics", *Economic of Innovation and New Technology*, Vol. 24 No. 4, pp. 339-359. doi: 10.1080/10438599.2014.946312.

Hart, S.L. (1995), "A natural-resource-based view of the firm", *Academy of Management Review*, Vol. 20 No. 4, pp. 986-1014.

Hart, S.L. and Ahuja, G. (1996), "Does it pay to be green? An empirical examination of the relationship between emission reduction and firm performance", *Business Strategy and the Environment*, Vol. 5 No. 1, pp. 30-37.

Hedlund, G. (1994), "A model of knowledge management and the N-form corporation", *Strategic Management Journal*, Vol. 15 No. S2, pp. 73-90.

Holsapple, C.W. and Wu, J. (2011), "An elusive antecedent of superior firm performance: the knowledge management factor", *Decision Support System*, Vol. 52 No. 1, pp. 271-283.

Horbach, J. (2008), "Determinants of environmental innovation – new evidence from German panel data sources", *Research Policy*, Vol. 37 No. 1, pp. 163-173.

Horbach, J., Oltra, V. and Belin, J. (2013), "Determinants and specificities of eco-innovations compared to other innovations – an econometric analysis for the French and German industry based on the community innovation", *Industry and Innovation*, Vol. 20 No. 6, pp. 523-543.

Huang, P. and Shih, L. (2009), "Effective environmental management through environmental knowledge management", *International Journal of Environmental Science and Technology*, Vol. 6 No. 1, pp. 35-50.

Jaw, B. and Liu, W. (2003), "Promoting organizational learning and self-renewal in Taiwanese companies: the role of HRM", *Human Resource Management*, Vol. 42 No. 3, pp. 197-295.

Jiménez-Jiménez, D. and Sanz-Valle, R. (2005), "Innovation and human resource management fit: an empirical study", *International Journal of Manpower*, Vol. 26 No. 4, pp. 364-381.

Kammerer, D. (2009), "The effects of customer benefit and regulation on environmental product innovation. Empirical evidence from appliance manufacturers in Germany", *Ecological Economics*, Vol. 68 Nos 8-9, pp. 2285-2295.

Kemp, R. (2000), "Technology and environmental policy – innovation effects of past policies and suggestions for improvement", OECD workshop on Innovation and Environment, Paris, June 19.

Kessler, E.H., Bierly, P.E. and Gopalakrishnan, S. (2000), "Internal vs external learning in new product development: effects on speed, cost and competitive advantage", *R&D Management*, Vol. 30 No. 3, pp. 213-223.

Kiessling, T.S., Richey, R.G., Meng, J. and Dabic, M. (2009), "Exploring knowledge management to organizational performance outcomes in a transitional economy", *Journal of World Business*, Vol. 44 No. 4, pp. 421-433.

Lai, Y.L., Hsu, M.S., Lin, F.J., Chen, Y.M. and Lin, Y.H. (2014), "The effects of industry cluster knowledge management on innovation performance", *Journal of Business Research*, Vol. 67 No. 5, pp. 734-739.

Lee, H. and Choi, B. (2003), "Knowledge enablers, processes and organizational performance: an integrated view and empirical examination", *Journal of Management Information Systems*, Vol. 20 No. 1, pp. 179-228.

Lee, V., Leong, L., Hew, T. and Ooi, K. (2013), "Knowledge management: a key determinant in advancing technological innovation?", *Journal of Knowledge Management*, Vol. 17 No. 6, pp. 848-872.

Liao, C. and Chuang, S.H. (2006), "Exploring the role of knowledge management for enhancing firm's innovation and performance", *System Sciences, 2006 proceedings of the 39th Annual Hawaii International Conference*, *HI, Kauai*, pp. 1530-1605.

Lin, H.-F. (2007), "Effects of extrinsic and intrinsic motivation on employee knowledge sharing intentions", *Journal of Information Science*, Vol. 33 No. 2, pp. 135-149.

Lloyd, B. (1996), "Knowledge management: the key to long-term organizational success", *Long Range Planning*, Vol. 29 No. 4, pp. 576-580.

López-Nicolás, C. and Meroño-Cerdán, A.L. (2011), "Strategic knowledge management, innovation and performance", *International Journal of Information Management*, Vol. 31 No. 6, pp. 502-509.

Lubit, R. (2001), "Tacit knowledge and knowledge management: the keys to sustainable competitive advantage", *Organizational Dynamics*, Vol. 29 No. 4, pp. 164-178.

McEvily, S. and Chakravarthy, B.S. (2002), "The persistence of knowledge-based advantage: an empirical test for product performance and technological knowledge", *Strategic Management Journal*, Vol. 23 No. 4, pp. 285-305.

Maddala, G.S. (1986), *Limited-Dependent and Qualitative Variables in Econometrics*, Cambridge University Press, New York, NY.

Marsh, S.J. and Stock, G.N. (2006), "Creating dynamic capability: the role of intertemporal integration, knowledge retention, and interpretation", *Journal of Product Innovation Management*, Vol. 23 No. 5, pp. 422-436.

Nonaka, I. (1994), "A dynamic theory of organizational knowledge creation", *Organization Science*, Vol. 5 No. 1, pp. 14-37.

Palacios, D. and Garrigos, F. (2006), "The effect of knowledge management practices on firm performance", *Journal of Knowledge Management*, Vol. 10 No. 3, pp. 143-156.

Palacios, D., Gil, I. and Garrigos, F. (2009), "The impact of knowledge management practices on innovation and entrepreneurship in the biotechnology and telecommunications industries", *Small Business Economics*, Vol. 32 No. 3, pp. 291-301.

Pekovic, S. (2010), "The determinants of ISO 9000 certification: a comparison of the manufacturing and service sectors", *Journal of Economic Issues*, Vol. 44 No. 4, pp. 895-914.

Porter, M. and Van Der Linde, C. (1995), "Toward a new conception of the environment-competitiveness relationship", *Journal of Economic Perspectives*, Vol. 9 No. 4, pp. 97-118.

Reed, M.S., Stringer, L.C., Fazey, I., Evely, A.C. and Kruijsen, J. (2014), "Five principles for the practice of knowledge exchange in environmental management", *Journal of Environmental Management*, Vol. 146 No. 15, pp. 337-345.

Rennings, K. (2000), "Redefining innovation – eco-innovation research and the contribution from ecological economics", *Ecological Economics*, Vol. 32 No. 2, pp. 319-332.

Rennings, K. and Zwick, T. (2002), "The employment impact of cleaner production on the firm level: empirical evidence from a survey in five European countries", *International Journal of Innovation Management*, Vol. 6 No. 3, pp. 319-342.

Rennings, K., Ziegler, A., Ankele, K. and Hoffmann, E. (2006), "The influence of different characteristics of the EU environmental management and auditing scheme on technical environmental innovations and economic performance", *Ecological Economics*, Vol. 57 No. 1, pp. 45-59.

Scarbrough, H. (2003), "Knowledge management, HRM and the innovation process", *International Journal of Manpower*, Vol. 24 No. 5, pp. 501-516.

Spender, J.C. (1996), "Making knowledge the basis of a dynamic theory of the firm", *Strategic Management Journal*, Vol. 17 No. 2, pp. 45-62.

Spicer, D.P. and Sadler-Smith, E. (2006), "Organizational learning in smaller manufacturing firms", *International Small Business Journal*, Vol. 24 No. 2, pp. 133-158.

Swan, J., Newell, S., Scarbrough, H. and Hislop, D. (1999), "Knowledge management and innovation: networks and networking", *Journal of Knowledge Management*, Vol. 3 No. 4, pp. 262-275.

Torraco, R.J. and Swanson, R.A. (1995), "The strategic roles of human resource development", *Human Resource Planning*, Vol. 18 No. 4, pp. 10-21.

Tseng, S. (2014), "The impact of knowledge management capabilities and supplier relationship management on corporate performance", *International Journal of Production Economics*, Vol. 154, pp. 39-47, available at: www.sciencedirect.com/science/article/pii/S0925527314001248.

Von Krogh, G. (1998), "Care in knowledge creation", *California Management Review*, Vol. 40 No. 3, pp. 133-153.

Wagner, M. (2005), "How to reconcile environmental and economic performance to improve corporate sustainability: corporate environmental strategies in the European paper industry", *Journal of Environmental Management*, Vol. 76 No. 2, pp. 105-118.

Wheelwright, S.C. and Clark, K.B. (1992), *Revolutionizing Product Development – Quantum Leaps in Speed, Efficiency, and Quality*, Free Press, New York, NY.

Wooldridge, J. (2002), *Econometric Analysis of Cross Section and Panel Data*, MIT Press, Cambridge, MA.

Zack, M., McKeen, J. and Singh, S. (2009), "Knowledge management and organizational performance: an exploratory survey", *Journal of Knowledge Management*, Vol. 13 No. 6, pp. 392-409.

Further reading

Brunnermeier, S.B. and Cohen, M.A. (2003), "Determinants of environmental innovations in US manufacturing industries", *Journal of Environmental Economics & Management*, Vol. 45 No. 2, pp. 278-293.

Corresponding author
Sanja Pekovic can be contacted at: sanja.pekovic@dauphine.fr

Appendix

	ENV_INNO	KM_GENERAL	KM_POLICY	KM_CULTURE	EXPORT	SIZE	GROUP	EBITDA	R&D	INNO
ENV_INNO	1.00	–	–	–	–	–	–	–	–	–
KM_GENERAL	0.20	1.00	–	–	–	–	–	–	–	–
KM_POLICY	0.06	0.34	1.00	–	–	–	–	–	–	–
KM_CULTURE	0.10	0.42	−0.08	1.00	–	–	–	–	–	–
EXPORT	0.31	0.26	0.11	0.08	1.00	–	–	–	–	–
SIZE	0.18	0.17	0.02	0.01	0.38	1.00	–	–	–	–
GROUP	0.22	0.19	0.06	0.04	0.39	0.15	1.00	–	–	–
EBITDA	0.32	0.25	0.08	0.05	0.69	0.48	0.44	1.00	–	–
R&D	0.31	0.25	0.06	0.13	0.37	0.18	0.26	0.34	1.00	–
INNO	0.11	0.18	0.06	0.06	0.13	0.02	0.13	0.09	0.39	1.00

Note: $n = 1,117$

Table AI. Pearson correlation coefficients