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IS KNOWLEDGE EXCHANGE AND COMBINATION ALWAYS USEFUL FOR INNOVATION?

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Abstract

Using the resource-based view, this paper aims to provide a better understanding of the effect of knowledge on innovation. With this general aim in mind, we relate knowledge's nature (tacit vs. explicit) and the process (e.g., knowledge exchange and combination) to innovation. Using a sample of 105 marketing and 176 R&D managers from 105 innovative firms, we find a positive linear effect of tacit knowledge on innovation and a U-shaped relationship between knowledge exchange and combination and innovation. We also find an enhancing effect of tacit knowledge on the first part of the curvilinear relationship between knowledge exchange and combination and innovation.

Keywords: Knowledge tacitness, Knowledge exchange and combination, patents

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INTRODUCTION

It is a widely held view that, in highly industrialized nations, the long-term growth of businesses stems from their ability to continually develop and produce innovative products and services (Sternberg, 2000). A key premise in the literature is that the rate of new product introduction is a function of a firm's ability to manage, maintain and create knowledge (Cohen & Levinthal, 1990; Smith, Collins & Clark, 2005). Therefore, the better we understand the process of creating knowledge, the more likely innovative behaviors can be fostered in organizations (Von Krogh, Ichijo & Nonaka, 2000).

Innovation, defined as new or significant changes in products or services, depends upon the individual and collective expertise of employees (Leonard & Sensiper, 1998). Some of this expertise is captured and codified in manuals, processes and software (explicit knowledge). However, tacit knowledge—knowledge that is nonverbalizable, intuitive and unarticulated (Polanyi, 1966)—is also an important determinant of innovations. Furthermore, as Von Krogh et al. (2000) proposed, tacit knowledge, not explicit knowledge, is generally the source of a firm's innovation. Therefore, knowledge, and more specifically "tacit knowledge" is at the heart of innovation and competitiveness.

Research on knowledge can be divided into two streams or approaches (Hargadon & Fanelly, 2002; Smith et al., 2005). The first studies how knowledge is distributed among a firm's employees, technologies, resources, routines and procedures. The emphasis of this stream has been static, focusing on how existing tacit or explicit knowledge can be exploited to affect

certain outcomes, such as financial performance (Levitt & March, 1988). The second approach has been more dynamic, emphasizing how knowledge, and especially new knowledge, leads to the creation of new knowledge and the generation of novel outcomes, such as new products or services (Kogut & Zander, 1992).

There is an important symbiosis between these two streams. For example, as Galunic and Rodan (1998) proposed, firms are encouraged to innovate by searching out new knowledge or new ways of using their existing knowledge. Therefore, they could use some level of existing tacit or explicit knowledge to develop new knowledge, and this new knowledge must lead at some point to new products or services (Hargadon & Fanelly, 2002; Smith et al., 2005).

The knowledge–innovation relationship has been widely acknowledged by the literature. However, the literature lacks conclusive empirical results about the nature of knowledge (e.g., tacit vs. explicit) and process (e.g., the exchange and combination of knowledge) that would better explain innovation (e.g., Cavusgil, Calantone & Zhao, 2003; Smith et al., 2005). Therefore, the aim of this paper is to deepen the knowledge–innovation relationship. With this general aim in mind, we independently analyze the relationships between knowledge tacitness (linear relationship), and knowledge exchange and combination (curvilinear relationship), and the introduction of new products into the market. As a second step, we study the joint effect of knowledge tacitness and knowledge exchange and combination on innovation.

The ability to create new knowledge results from the collective ability of employees to exchange and combine knowledge (Nahapiet & Ghoshal, 1998). Based on this statement and using the resource-based-view framework, this paper pursues three research questions. Is knowledge tacitness linearly and positively related to innovation? Is it always beneficial to increase knowledge exchange and combination in order to develop more innovations? Does tacit

knowledge moderate the relationship between knowledge exchange and combination and innovation?

In answering our research questions, we make the following contributions to the literature. First, previous research has usually analyzed the tacit knowledge–innovation relationship theoretically (e.g., Galunic & Rodan, 1998; Leonard & Sensiper, 1998; Nonaka, 1994). Our paper shows empirically such a theoretical relationship. Second, the literature highlights the importance of knowledge exchange and combination. The reason is that the ability to create new knowledge, which enables firms to both innovate and outperform their rivals in the current dynamic environments (Grant, 1996; Kogut & Zander, 1992), results from the collective ability of employees to exchange and combine knowledge (Nahapiet & Ghoshal, 1998). Our research has shown that innovative companies are highly focused on knowledge exchange and combination. Furthermore, we have found that, taking into account this high involvement on knowledge exchange and combination, it is more useful at its minimum level. This means that increases on knowledge exchange and combination at certain levels could lead to a possible waste of resources. Third, the paper shows that, for innovation, high levels of tacit knowledge make knowledge exchange and combination more profitable until a certain point were increases in knowledge exchange and combination do not make any additional contributions to innovation, whatever the degree of tacit knowledge.

The paper proceeds as follows. The next section presents the theoretical background that led us to establish the hypotheses. The following sections empirically test such relationships. Finally, the main conclusions, contributions, limitations and future lines of research are presented.

THEORY AND HYPOTHESES

Knowledge has been a central subject of debate in philosophy and epistemology. An old concept, dating back to 400 BC, is being heralded today as one of the newest ideas in management (Nonaka & Takeuchi, 1995). Nevertheless, a review of the knowledge literature reveals that there is no consensus on its precepts and objectives. From Plato to Popper, conceptualizing knowledge has become one of the most difficult tasks for researchers (Grant, 1996; Nonaka, 1994; Nonaka & Takeuchi, 1995). Knowledge could be defined in a wide sense as what is known (Grant, 1996) or, using Nonaka and Takeuchi's (1995) proposal, as the validated understanding and beliefs in a firm about the relationship between the firm and its environment. In this definition, knowledge is static, reflecting current viewpoints on how existing resources should be configured and exploited for advantage (Smith et al., 2005).

While this static view of knowledge is important, researchers have also taken a more dynamic perspective on knowledge, emphasizing that the creation of new knowledge is essential for a company's competitiveness (Leonard & Sensiper, 1998). "This literature suggests that organizational knowledge creation is dependent on the ability of organization members to exchange and combine existing information, knowledge and ideas" (Smith et al., 2005: 347).

We theorize that tacit knowledge and knowledge exchange and combination independently and jointly affect innovation. Arguments supporting this statement are developed next.

The Influence of Tacit Knowledge on Innovation

Recent research and especially the work on the resource-based view (e.g., Barney, 1991; Wernerfelt, 1984) has placed greater emphasis on the properties of resources and, in particular, distinguishes between more tangible and knowledge-based resources (e.g., Galunic & Rodan,

1998; Kogut & Zander, 1992; Nonaka & Takeuchi, 1995; Teece, Pisano & Shuen, 1997). Knowledge-based resources generally refer to the ways in which the more tangible input resources are manipulated and transformed to add value (Teece et al., 1997). In essence, they are the organizing principles, skills and processes that direct organizational actions (Galunic & Rodan, 1998).

Among knowledge-based resources, the distinction between tacit and explicit knowledge is the key to understanding organizational knowledge (Nonaka & Takeuchi, 1995). This is a familiar category (Gopalakrishnan, Bierly & Kessler, 1999; Grant, 1996; Nonaka, 1994; Polanyi, 1966) and generally describes the extent to which knowledge is or is not codifiable (Galunic & Rodan, 1998). Polanyi (1966) classifies human knowledge into two categories. On the one hand, he distinguishes explicit or codified knowledge, which is the knowledge that can be transferred through a formal language. That is, it is the knowledge that can be transmitted without the loss of its integrity if the transmitter and receiver share the syntactic rules necessary for its decipherment (Kogut & Zander, 1992). On the other hand, he defines tacit knowledge as having a personal quality that makes its formalization and communication difficult (Nonaka, 1994). Spender (1996) suggested that tacit knowledge could be understood best as knowledge that has not yet been transformed into practice. It is knowledge that has been transformed into habit, i.e., it is highly context-specific and has a personal quality (Nonaka, 1994).

While explicit knowledge is expressed verbally or in writing, tacit knowledge is not verbalized or may even be nonverbalizable, intuitive and not articulable (Hedlund, 1994). Explicit knowledge is easy to process whereas tacit knowledge is difficult to articulate and to transmit in a systematic and logical form (Gopalakrishnan et al., 1999). Tacit knowledge is knowledge that is understood and applied by those possessing it and yet is not easily

communicated to others. This knowledge is difficult to replicate or imitate, and often even those possessing it cannot fully describe it. As Polanyi (1966: 4) said, "We can know more than we can tell". An example of this statement could be that the skills of an artist are not learned from a textbook or class but through years of experience and apprenticeship.

Knowledge creation is considered an effective and efficient form of achieving successful innovations (Nonaka, 1994). This is a continuous process (Nonaka, Toyama & Konno, 2000) that can be defined as the capacity of a company to generate new knowledge, to disseminate it among the members of the organization and to materialize it into products, services and systems. One of the basic pillars of the knowledge creation process is the dynamic interaction between tacit and explicit knowledge (Nonaka, 1994; Nonaka & Takeuchi, 1995; Nonaka et al., 2000; Seidler-de Alwis & Hartmann, 2008). Indeed, it is through the conversion of existent tacit knowledge into new tacit or explicit knowledge, that knowledge is created (Nonaka, 1994; Nonaka & Takeuchi, 1995; Nonaka et al., 2000; Seidler-de Alwis & Hartmann, 2008) and, therefore, tacit knowledge could be considered the seed of innovation. Furthermore, as Von Krogh et al. (2000) proposed, tacit knowledge, not explicit knowledge, is generally the source of a firm's innovation. In relation to this statement, it is important to highlight that it is rare to find absolute tacit or absolute explicit knowledge (Cavusgil et al., 2003). That is, the distinction between explicit and tacit knowledge should not be viewed as a dichotomy but as a spectrum with the two knowledge types at either end (Inkpen & Dinur, 1998). Therefore, instead of talking about tacit and/or explicit knowledge, we will talk about tacitness of knowledge. Thus, we predict that higher degrees of knowledge tacitness will positively influence innovation.

Hypothesis 1. Knowledge tacitness is positively related to innovation.

The Influence of Knowledge Exchange and Combination on Innovation

The ability to create new knowledge enables firms to both innovate and outperform their rivals, i.e., it is related to innovation (Grant, 1996; Kogut & Zander, 1992). Collins and Smith (2006) state that such ability results from the collective ability of employees to exchange and combine knowledge (Nahapiet & Ghoshal, 1998; Smith et al., 2005). That is, when the knowledge possessed by individuals is transferred to the group and/or the organization level as a whole, then it can be applied, giving rise to innovations (Nonaka & Takeuchi, 1995).

Innovation (defined as new or significant changes in products, processes or services) can result from new combinations of knowledge and other resources (Cohen & Levinthal, 1990; Kogut & Zander, 1992; Molina-Morales & Martínez-Fernández, 2009). Through the exchange and combination of knowledge between members of the group, ideas are shared, tacit knowledge is converted into explicit knowledge and final products can be developed (Nonaka, 1994). The relevance of knowledge exchange and combination for innovation has been theoretically argued and empirically supported in several studies. Cohen and Levinthal (1990) consider that the interaction between individuals who possess different knowledge improves the organization's ability to innovate. Hargadon and Sutton (1997) suggested that knowledge is imperfectly spread across individuals in an organization and that ideas from one group can solve the problems of another if exchanges are made between groups. They also explained that, when these exchanges are made, existing ideas from one group appear new to the other, and vice versa, resulting in potentially new products and services. Smith et al. (2005) demonstrated that the rate of new product and service introduction was a function of an organization member's ability to combine and exchange knowledge. Collins and Smith (2006) found that knowledge sharing was a great indicator of firm performance (understanding firm performance as the revenue from new

products and services). Seidler-de Alwis and Hartmann (2008) found that organizations that promote knowledge sharing processes are more successful in innovation.

In contrast to the arguments presented above, an approach positing a curvilinear relationship has also been developed. This approach recognizes that increases in knowledge exchange and combination may not be associated with parallel increases in outcomes. Knowledge exchange and combination is related to the idea that employees might see benefits from sharing ideas with one another and thus they are willing to do it. It is also related to the belief of workers that, by exchanging and combining ideas, they can move projects or initiatives forward more quickly than by working alone, and can learn (Collins & Smith, 2006). Therefore, knowledge exchange and combination will be useful for innovation. However, we theorize that there will be a point where more interaction will not be more useful. Consequently, the time and effort invested in social interactions may not be cost-efficient in certain situations or at certain levels (Adler & Kwon, 2002). The reason is that knowledge exchange and combination is just one of the elements necessary to innovate (Smith et al., 2005). However, as Zahra and George (2002) explained, innovation represents the capability of a company to transform and exploit external acquired knowledge. Therefore, being too focused on knowledge exchange and combination could lead to companies lacking other essential activities for the innovation process (Zahra & George, 2002). Thus, the utility of knowledge exchange and combination would begin to decline.

Therefore, we predict a positive relationship between innovation and knowledge exchange and combination. However, if people interact too much, there will not be a parallel increase in innovation. For that reason, the positive relationship will decline as knowledge exchange and combination increases and eventually become negative. The nonlinear inverted U-shaped

relationship is the one that best captures expectations based on these arguments. We formulate this relationship as follows:

Hypothesis 2. Knowledge exchange and combination is quadratically (inverted U-shaped) related to innovation.

The Moderating Effect of Tacit Knowledge on the Relationship between Innovation and Knowledge Exchange and Combination

Knowledge creation empowers those accountable for innovation with the capacity, resources and responsibility to think outside the box and to tear down functional boundaries (Von Krogh et al., 2000). Tacit knowledge is learned through collaborative experience and is difficult to articulate, formalize and communicate (Cavusgil et al., 2003; Nonaka & Takeuchi, 1995). Tacit knowledge could be held by individuals or held collectively, in shared collaborative experiences and interpretations of events.

As previously discussed, it is possible to develop a theory positing a curvilinear relationship between innovation and knowledge exchange and combination. What it is proposed here is that firms using more tacit knowledge will amplify the effect of knowledge exchange and combination on innovation. That is, the curvilinear relationship between knowledge exchange and combination and innovation will be particularly strengthened when it involves difficult to transfer information (based on tacit knowledge). Therefore, knowledge exchange and combination will be more useful when sharing more tacit knowledge.

There are, at least, two explanations for the enhancing effect of knowledge tacitness on the relationship between innovation and knowledge exchange and combination. The first is that, as Nonaka and Takeuchi (1995) argued, companies create knowledge through exchange and

combination. The knowledge creation process is a continuous, self-transcending process that converts tacit existing knowledge into explicit knowledge. Tacit knowledge is the seed of idea generation (Nonaka, 1994), which makes its exchange and combination more useful for innovation. The second reason is that tacit knowledge has a personal quality that makes its formalization and communication difficult (Polanyi, 1966) and, therefore, close interactions among members will be necessary. That is, we theorize that high degrees of knowledge tacitness will increase the utility of knowledge exchange and combination and will retard its declining effect. Therefore, knowledge tacitness makes knowledge interactions more useful in terms of developing innovations. Thus:

Hypothesis 3. Knowledge tacitness strengthens the nonlinear (inverted U-shaped) effect of knowledge exchange and combination on innovation.

RESEARCH METHOD

Research Design and Sample

To test our hypotheses, we needed a sample consisting of firms that were involved in the launch of new products. We therefore started out with a sampling frame covering Spanish firms from the industries most likely to exhibit innovative behaviors.[2] We used the SABI/AMADEUS

[2]The National Statistical Institute (INE) of Spain, in its latest available Spanish Technological Innovation in Companies Survey (INE, 2007), identified the manufacturing industry (NACE 29: mechanical machinery and equipment) and the service industries (NACE 73: software or computer programming services and NACE 722: research and development) as those containing the most "innovative" firms. These industries have a relatively high percentage of innovative companies (i.e., companies developing a successful product or process innovation in the 2003–2005 period).

database[3] to identify all companies in these industries. There were 1292 firms with more than 20 workers in our target industries.[4]

The data were collected during 2008. First, all of our target firms were contacted by telephone. During the telephone interview, we first verified that the firm belonged to the sample frame, i.e., that it operated within one of the target sectors and met our criterion for number of employees. Firms that did not meet these requirements were excluded from our population. We asked the remaining 537 firms if we could send them our questionnaire. In total, 181 firms responded to this questionnaire. Because the unit of analysis adopted in this study was the company, multiple respondents from the same firm were required. Specifically, we asked two R&D managers to respond to all the questions and one marketing manager to respond to questions regarding innovation. In this way, we reduced the potential common method variance bias. We asked R&D managers because these employees are critical to creating new knowledge or developing innovations within their organizations (Boland & Tenkasi, 1995; Smith et al., 2005). We asked marketing managers questions regarding innovation because they are involved in product launches.

Of the initial 181 responses, we had 90 companies with two R&D managers' responses, 70 companies with one R&D manager response, and 144 marketing managers' responses. However, to guarantee the absence of common method variance bias, we used only those companies where the responses to the independent (innovation) and the dependent variables (knowledge tacitness and knowledge exchange and combination) were by different persons. There were 105 full

[3]The SABI/AMADEUS database is the most comprehensive database of company information in Spain. It is a directory of Spanish and Portuguese companies and collects general information and financial data. It covers more than 95% of Spanish companies.

[4]We added the number-of-workers restriction to guarantee a minimum number of people who could exchange and combine knowledge.

responses, which corresponds to a response rate of 19.55% of the firms in our target population. Of those 105 firms, 71 had two R&D and one marketing response and 34 had one R&D and one marketing response. Previous studies have used from one to three respondents per firm (Ramani & Kumar, 2008).

To check for nonresponse bias, we applied a chi-squared test (using Yates' correction for continuity) to a contingency table with the companies of the population included and not included in the final sample and the activity categories (manufacturing and services). The outcome was not statistically significant ($\chi^2_{(1)} = 2.36$, $p > 0.05$). The *t* test of equality of means for independent samples showed that the difference in the mean score was not statistically significant between both groups of companies in terms of the number of employees ($t_{(535)} = 0.37$, $p > 0.05$), turnover ($t_{(535)} = -0.01$, $p > 0.05$) and age ($t_{(535)} = 0.61$, $p > 0.05$). Therefore, it seems that we did not have a problem of nonresponse bias in our data pertaining to industry, company size or age.

Within-firm agreement between the two R&D managers that responded to the independent variables was assessed by the interrater agreement measure, r_{wg}, developed by James, Demaree and Wolf (1984, 1993). This indicator ranges from 0 (complete disagreement) to 1 (complete agreement). In general, the median r_{wg} values obtained suggest an acceptable degree of agreement or consistency among the respondents (Chen, Chang & Hung, 2008). Therefore, we averaged the scale items from the 71 cases with two respondents to form single ratings for each independent variable and company.

Measures

Many of the constructs included in the study were measured with multi-item scales. All of these multi-item scales have been adapted from measurement scales that have been used previously and, in most cases, validated by other researchers. We took several steps to ensure data validity and reliability. First, we pretested all measures in 25 interviews with R&D managers and asked them to review carefully the survey to ensure the clarity of the questions and to ascertain whether the scales captured the desired information. We then revised any potentially confusing items before submitting the questionnaire.

Given that the measurement scales used were based upon an exhaustive review of the relevant literature concerning the constructs under study, we can initially affirm its content validity. An exploratory factor analysis was performed separately for each dimension or construct, and those factors with eigenvalues greater than 1 were selected. All the items in each dimension or construct loaded in only one factor (unidimensionality). With regard to reliability (see Appendix), Cronbach's alpha exceeded the minimum value of 0.7 recommended by Nunnally and Bernstein (1995) for all the measures.

Number of innovations. We asked firms to state the number of new products or services they had introduced into the market over the past five years. As Smith et al. (2005) stated, Damanpour (1991) found in its meta-analysis that this is a robust measure of innovation over a wide range of research settings.

Knowledge tacitness. We measured knowledge tacitness by applying the Subramaniam and Venkatraman (2001) scale (see Appendix). The Cronbach's alpha of the scale was 0.81, suggesting high internal consistency and reliability.

Knowledge exchange and combination. We measured knowledge exchange and combination by applying the Collins and Smith (2006) scale (see Appendix). The Cronbach's alpha of the scale was 0.95, suggesting high internal consistency and reliability.

Control variables. *Size:* Firm size was measured by the natural logarithm of the number of employees as in previous research (Cardinal, 2001). *Age*: Following Sørensen and Stuart (2000), we also controlled for firm age (2010 minus the year the company was founded). *Industry*: We used one dummy variable to control the industry effect (see Appendix). The information on these three control variables was obtained from the SABI/AMADEUS database.

ANALYSES AND RESULTS

Descriptive statistics and correlations for the relevant variables are displayed in Table 1. Over the past five years, firms have launched an average of 22.90 innovations. It is remarkable that the mean of knowledge exchange and combination is 5.71, which shows a strong bias towards sharing knowledge. Furthermore, the minimum value of this construct is 4.33. This means that all of the companies in our sample were highly involved in knowledge exchange and combination. Taking into account that our sampling frame covered Spanish firms from the industries most likely to exhibit innovative behaviors, this finding is consistent with previous studies as Smith et al. (2005). In reference to tacit knowledge, we could say that most of our companies moved in the center of the tacit–explicit continuum (mean = 3.34 and standard deviation = 0.88). Concerning correlations, we note that there is a high correlation between size and the company's age. Tacit knowledge, on the other hand, is hardly correlated with any of the other variables. To assure that multicollinearity was not an issue, Value Inflation Factors (VIFs)

were computed (but are not reported here because of space limitations). No VIFs were greater than 2, indicating that we did not encounter multicollinearity.

Insert Table 1 about here

Given that our dependent variable is a count variable with overdispersion of zeroes, we relied on negative binomial regression analysis. We used hierarchical entry of independent variables because an interaction effect exists only if the interaction term gives a significant contribution over and above the direct effects of the independent variables.

Table 2 shows the results of the hierarchical negative binomial regression analyses. We start out by examining the control variables entered in the base model. Firm size had a positive influence on innovation, suggesting that larger firms develop more innovations. This is consistent with previous papers such as Damanpour (1991). The software or computer programming services industry (NACE 722) and company's age had negative impacts on innovation. In the next step, the research variables were entered, which led to a statistically significant improvement in model fit ($\Delta\chi^2 = 4.28$; $p < 0.05$). Knowledge tacitness had a positive influence on innovation ($\beta = 0.25$; $p < 0.05$). This finding supports Hypothesis 1.

Insert Table 2 about here

The proposed U-shape relationship is entered in the next step as recommended in the literature (Cohen et al., 2003). To justify statistically the proposed inverted U-shape, we ran a regression analysis with curvilinear estimation to find a quadratic relation. The introduction of these

variables led to a statistically significant improvement in model fit ($\Delta\chi^2 = 4.75$; $p < 0.05$). The regression coefficients, both knowledge exchange and combination ($\beta = -12.86$; $p < 0.01$) and squared knowledge exchange and combination ($\beta = 1.05$; $p < 0.01$), are significant. The sign of the squared value of knowledge exchange and combination in the U-shaped model is positive, indicating a U-shaped relationship (see Table 2). As we can see in Figure 1, the curvilinear model attempts to validate the existence of a nonlinear relationship between knowledge exchange and combination and innovation. However, consistent with our findings in Table 2, we found the opposite curvilinear effect. That is, although we expected to find that the effect of knowledge exchange and combination would have an inverted U-shaped association with innovation, we found a U-shaped association. Thus, we did not find support for Hypothesis 2. What we found was that increasing knowledge exchange and combination erodes innovation until a certain point where additional increases are positively associated with innovation. In relation with this finding, we should remind that all the companies in our sample are highly involved in knowledge exchange and combination (its minimum value is 4.22). Therefore, it seems that, departing from this point, increases on knowledge sharing reduce the number of innovations developed by a firm until a point were increases in the use of knowledge exchange and combination turns to be positively associated to innovation.

Insert Figure 1 about here

Finally, the contingent model (see Table 2) introduced the interaction terms, which reflect the moderating influence of knowledge tacitness on knowledge exchange and combination. The introduction of these variables led to a statistically significant improvement in model fit ($\Delta\chi^2 =$

11.05; $p < 0.01$). The regression coefficients, both the first-order interaction between knowledge exchange and combination and tacit knowledge ($\beta = -11.15$; $p < 0.01$) and squared knowledge exchange and combination ($\beta = 0.91$; $p < 0.01$) are significant. These results show that the first-order interaction relates negatively to innovation, whereas the second-order interaction affects innovation positively. To gain more insight into the interaction effects, we plotted the relationship in Figure 2. We split the tacit knowledge variable into two groups (high and low) and estimated the effect for both levels. Afterwards, it was possible to show that, compared with low tacit knowledge; high tacit knowledge strengthens the positive effect of knowledge exchange and combination on innovation and combination on innovation for the lowest values of knowledge exchange and combination. Then, as companies increase their knowledge exchange and combination above the last quartile of the scale, increases in knowledge exchange and combination do not make important contributions to innovation whatever the degree of tacit knowledge.

Insert Figure 2 about here

DISCUSSION

This research was designed to answer three questions. Is knowledge tacitness linearly and positively related to innovation? Is it always beneficial to increase knowledge exchange and combination in order to develop more innovation? Does tacit knowledge moderate the relationship between knowledge exchange and combination and innovation? We found that knowledge tacitness linearly and positively impacts innovation, and that increases in knowledge exchange and combination are not always useful. That is, departing from the highly involvement

that all of our firms have on knowledge exchange and combination; we found that it is more useful at its minimum levels. Then its utility has a strong decrease until a degree where increases in its use start to be positively associated with innovation. Nevertheless, we have found that, in general terms, when sharing tacit knowledge, knowledge exchange and combination becomes more important. That is, for similar levels of knowledge exchange and combination, sharing tacit knowledge relates to the development of more innovations until a point where increases in knowledge exchange and combination do not make important contributions to innovation whatever the degree of tacit knowledge.

The linear and positive relationship between tacit knowledge and innovation is consistent with the literature (e.g., Nonaka, 1994; Nonaka & Takeuchi, 1995; Nonaka et al., 2000; Seidler-de Alwis & Hartmann, 2008). However, much of this research is theoretical. Therefore, we believe that our empirical finding is an important contribution to the literature and is of utility to practitioners who could focus on tacitness and creativity to enhance their innovative capability.

Our surprising U-shaped relationship between knowledge exchange and combination and innovation needs further discussion. The first important remark is that companies in our sample are highly focused on knowledge exchange and combination. It might be surprising that some low levels of knowledge exchange and combination could lead to higher levels of innovation as much higher levels of knowledge exchange and combination. We propose two possible explanations for this finding. First, as we have just said, all of our companies are highly involved on knowledge exchange and combination. Therefore, it seems that after that level of knowledge sharing its utility starts to decrease until a point where it becomes a bit more important again. Second, the different utilities of knowledge exchange and combination could be related with the nature of the knowledge exchanged and combined (more or less tacit); and the nature of the

innovation developed (more or less radical). For example, low levels of exchange and combination of highly tacit knowledge could lead to innovations based on very specific knowledge that can be developed by one person without interaction; whereas high levels of exchange and combination of highly tacit knowledge could lead to innovations based on heterogeneous knowledge that needs the interaction of different members. This explanation leads us to the introduction of the moderating effect of tacit knowledge.

We prove that, when exchanging and combining the same amount of knowledge, lower levels of tacit knowledge lead to lower levels of innovation until a point where increases on knowledge exchange and combination have little influence on the number of innovations launched for any degree of knowledge tacitness. Nevertheless, our U-shaped relationship between the sharing of tacit knowledge and innovation leads us to a new dilemma. We have said before that one possible explanation to the U-shaped relationship between knowledge exchange and combination and innovation could be the nature of knowledge. However, here we have already taken into account this nature and we still find that low levels of knowledge exchange and combination lead to higher levels of innovation than much higher levels of knowledge exchange and combination.

Thus, the only possible explanations for this finding are the following. First, as Smith and colleagues (2005) among others proposed, knowledge exchange and combination are needed for innovation. However, as Nonaka (1994) among others stated, the knowledge creation needed for innovation is a complex process that also requires a lot of individual expertise and autonomous work. Therefore, it seems that in general after a minimum use of knowledge exchange and combination, its increases start to produce a waste of time until a point where, for different causes its utility starts to increase again. These "different causes" could be based on our second explanation. That is, the nature of innovation developed. It would be interesting to explore if

radical and incremental innovations require similar or different amounts of knowledge exchange and combination. Even more, showing the impact of knowledge tacitness on this relationship could be of interest for future research.

CONCLUSIONS

This paper has made the following contributions to the literature. First, whereas most previous research has analyzed theoretically the tacit knowledge–innovation relationship (e.g., Galunic & Rodan, 1998; Leonard & Sensiper, 1998; Nonaka, 1994), our paper shows the relationship empirically. Second, the literature highlights the importance of knowledge exchange and combination. The reason is that the ability to create new knowledge, which enables firms to both innovate and outperform their rivals in the current dynamic environments (Grant, 1996; Kogut & Zander, 1992), results from the collective ability of employees to exchange and combine knowledge (Nahapiet & Ghoshal, 1998). Our research has shown that a moderated use of knowledge exchange and combination get its highest utility. Therefore, increases in knowledge exchange and combination could lead to a waste of resources. Third, the paper shows that, in general, for innovation, high levels of tacit knowledge make knowledge exchange and combination more profitable.

It is important to highlight that this paper has shown the relationship between static or existing knowledge (tacit or explicit) in a firm and the more dynamic knowledge exchange and combination. That is, we have found that, when tacit knowledge and knowledge exchange and combination interact, they are very important for innovation. In future research, it would be interesting to explore if this joint effect changes when the nature of the innovation (its novelty and radicalness) is taken into account.

This research has some limitations. First, as discussed above, other variables could explain the complex issue of innovation. Furthermore, given the complexity of "knowledge", its other characteristics (e.g., its heterogeneity among the members exchanging and combining knowledge, and whether it is more or less technical) should be taken into account. Second, the sample of companies was small and included only three Spanish industries. Therefore, there is no guarantee that the results obtained can be generalized to other sectors. Third, the use of cross-sectional analysis provided results at just one point in time. Longitudinal studies would be necessary to clarify whether our results change over time.

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FIGURE 1

Curvilinear effects

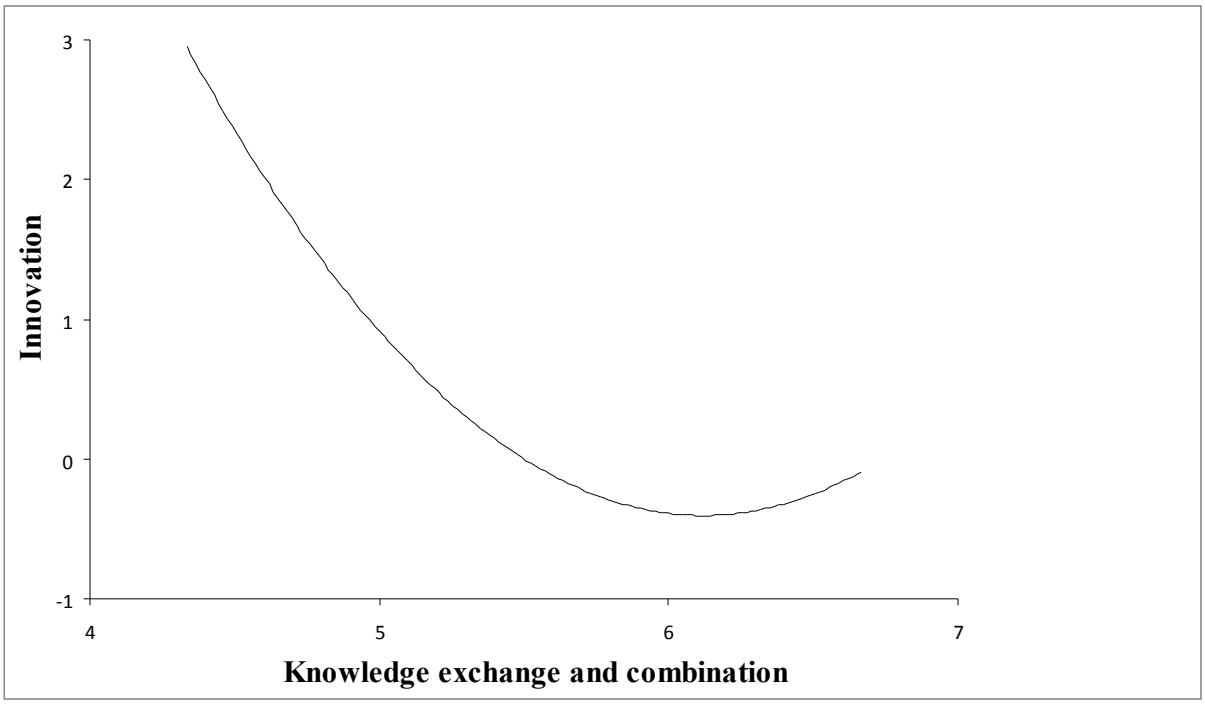

FIGURE 2

Interaction effects

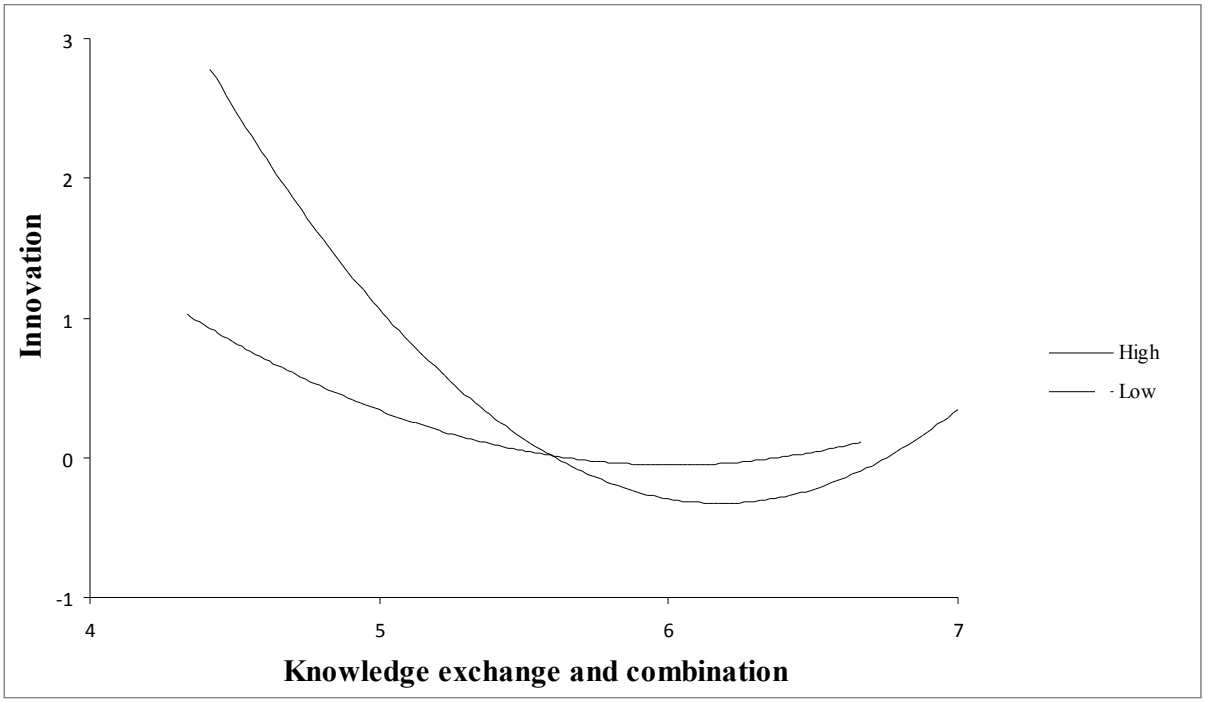

TABLE 1

Descriptive statistics and correlations[a]

	Mean	s. d.	Min.	Max	1	2	3	4
1. Innovation	22.90	60.01	1.00	500.00				
2. Size	4.58	0.84	3.00	8.78	.24*			
3. Age	25.04	14.04	5.00	75.00	–.11	.36**		
4. Tacit knowledge	3.34	0.88	1.40	5.60	.09	–.05	.01	
5. Knowledge exchange and combination	5.71	0.60	4.33	7.00	–.23*	–.01	–.04	–.01

[a] n = 105

* $p < 0.05$

** $p < 0.01$

TABLE 2

Hierarchical Negative Binomial regression analysis

Dependent variables	Base Model		Independent Model		U-Shaped Model		Contingent Model	
	β	SE	β	SE	β	SE	β	SE
Control variables								
Industry 722	–0.99**	0.30	–1.02**	0.30	–0.11	0.28	–0.11	0.27
Industry 73	–0.07	0.27	–0.14	0.27	0.37	0.27	0.56*	0.56
Size	0.72**	0.13	0.73**	0.13	0.50**	0.13	0.52**	0.52
Age	–0.05**	0.01	–0.05**	0.01	–0.01	0.01	–0.01	0.01
Direct effects								
Tacitness			0.25*	0.12	0.08	0.13	33.92**	0.13
Sharing					–12.86**	3.55	28.44*	3.55
Sharing²					1.05**	0.31	–2.33†	0.31
Interactions								
Sharing * Tacitness							–11.15**	4.03
Sharing² * Tacitness							0.91**	0.34
Model								
Log likelihood	–406.84		–404.70		–402.32		–396.80	
χ^2	41.00**		45.28**		50.03**		61.08**	
Delta χ^2			4.28*		4.75†		11.05**	
Pseudo R^2	0.048		0.053		0.059		0.072	

† $p < 0.10$

* $p < 0.05$

** $p < 0.01$

APPENDIX

Measurement Scales

Dependent Variable
Innovation: total number of products/services introduced by the company in the last five years
Independent Variables
Tacit Knowledge (Subramaniam and Venkatraman, 2001)
T.1. It is easy to comprehensively document in manuals and report (reversed)
T.2. It can be precisely communicated through written documents (reversed)
T.3. It is easy to comprehensively understand from written documents (reversed)
T.4. It is obvious to all competitors (reversed)
T.5. It is easy to identify without personal experience in the area (reversed)
Knowledge Exchange and Combination (adapted from Collins and Smith, 2006)
K1. Employees see benefits from exchanging and combining ideas with one another
K2. Employees believe that by exchanging and combining ideas they can move new projects or initiatives forward more quickly than by working alone
K3. At the end of each day, our employees feel that they have learned from each other by exchanging and combining ideas
K4. Employees at this company are proficient at combining and exchanging ideas to solve problems or create opportunities
K5. Employees in this company are capable of sharing their expertise to bring new projects or initiatives to fruition
K6. The employees in this company are willing to exchange and combine ideas with their co-workers

Control Variables
Firm Size: LN number of employees
Age: 2010, company's foundation date
Industry: Dummy for industries 722, 73 and 29