Departamento de Dirección de Empresas

Working paper series

WP BSAD 10.01

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UNIVERSIDAD PABLO DE OLAVIDE SEVILLA

DEPARTMENT OF BUSINESS ADMINISTRATION

HOW DOES KNOWLEDGE MATTER PATENTING INVENTIONS? [1]

March, 2010

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Abstract

While there is robust empirical evidence that firm patenting is positively associated with various measures of overall performance and competitiveness, less is known about what determines the patenting choice. For this reason, this paper examines whether R&D expenditure and the type of knowledge used in the invention determine the decision to patent. With this aim, we use a sample of firms and the European Patent Office to analyse how the combination of R&D expenditure and knowledge codifiability, observability and simplicity influences the patent decision. Our results contribute to the literature and assist R&D managers by showing that both R&D and codified knowledge have a positive impact on the number of inventions patented by a firm, while observable knowledge has a negative impact on patents. Furthermore, we find that the effect of R&D expenditure on the propensity to patent inventions is negatively moderated by knowledge observability and simplicity.

Keywords: R&D, patents, knowledge, inventions

[1]Financial support from the Ministry of Science and Technology of Spain, Grant SEC2003-07741, is gratefully acknowledged

HOW DOES KNOWLEDGE MATTER PATENTING INVENTIONS?

1. Introduction

Past research in strategic management argues that the ability to invent is an important driver of firm success (Cohen and Levinthal, 1990; Eisenhardt and Martin, 2000; Nerkar and Shane, 2007). One aspect closely related to inventions is the patenting decision. However, while prior work focuses on patenting performance (Mansfield et al., 1981; Somaya et al., 2007), less is known about the factors that lead companies to decide to patent their inventions. Therefore, an important question is: what explains differences in the disposition of firms to patent their inventions? In this sense, research examines patenting almost exclusively through the lens of firm internal R&D (hereafter R&D), which has been shown to have a significant positive relationship with patenting (Somaya et al., 2007). However, although R&D is an important resource for creating new ideas, the generation of such technological inventions is only one aspect of explaining firms' patenting choices. If not all inventions from R&D departments are patented, there should be other aspects (besides R&D) that condition the decision of a company to patent its inventions. Hence, the objective of this paper is to understand why there are different patenting propensities among R&D-intensive companies, when there is robust empirical evidence that firm patenting is positively associated with various measures of overall firm performance (see Somaya et al., 2007, for a review).

This paper proposes that another factor affecting the disposition of a firm to patent its inventions is knowledge. That is, we assume that the type of knowledge used by a firm in the invention process will condition the number of inventions patented by such a firm (Nerkar and Shane, 2007). Specifically, we propose that knowledge codifiability will positively influence patenting activity, while knowledge observability and simplicity will negatively influence the patenting choice. In other words, we believe that companies will patent inventions obtained from codified, unobservable and complex knowledge. There are two reasons that support this proposition. First, inventions based on codified knowledge are easily imitated (Grant, 1996) and thus companies will patent them to guarantee their returns. Second, unobservable and complex knowledge will lead to real inventions and not to mere imitations (Nonaka, 2007). That is, we believe that only those companies that obtain inventions based on unobservable and complex knowledge will have an invention that is patentable, while the output of observable and simple knowledge is always an imitation.

The exclusive focus in the literature on the relationship between R&D and patenting has meant that, to date, questions remain about how other different types of resources, such as knowledge, could enhance or harm patenting activity in conjunction with R&D. Answers to this question can provide deeper theoretical insights into how and under what conditions different combinations of resources as types of knowledge and R&D expenditure determine the patenting choice. In this sense, we propose that the positive relationship between R&D expenditure and the choice of patenting will be moderated by the degree of knowledge codifiability, observability and simplicity used in the invention process.

Our study makes two important contributions. First, we extend the innovation literature by examining how firms' strategic choices to deploy and combine different types of knowledge with R&D expenditure are important predictors of firm patenting activity. Second, we contribute to the RBV research by explaining how the appropriate use of resources such as knowledge and R&D leads to higher levels of patents and by extension to higher levels of competitiveness. That is, based on the RBV, which proposes that deploying different bundles or combinations of resources leads to higher levels of value (Penrose, 1959), and on robust empirical evidence that confirms that firm patenting is positively associated with performance

(Somaya et al., 2007), we assume that patenting activity leads to higher levels of competitiveness. Thus, we propose that through an understanding of the patenting activity, we help both managers and researchers to understand how to increase companies' competitiveness.

The paper proceeds as follows. In the following section, we present the theoretical background and develop hypotheses relating R&D expenditure, knowledge and the patenting choice. Next, we present our method and empirically test these relationships. Finally, we present the main conclusions, contributions, limitations, and future lines of research that result from this paper.

2. Theory and Hypotheses

The RBV suggests that a key determinant of a firm's competitive advantage is whether or not the firm has accumulated the appropriate types of resources (Barney, 1991; Penrose, 1959). In this paper, we build on the RBV concept of VRIO (valuable, rare, inimitable and non-substitutable) resources (Barney, 1991) to argue that firms will increase their patenting propensity through the suitable use of their R&D expenditure and types of knowledge. However, before analysing how R&D expenditure and knowledge influence the patenting choice of companies, we should start explaining the main features of patents.

The patent system legally protects innovators against imitators. Therefore, as Blind et al. (2006) point out, the traditional motive to patent is the protection of one's own inventions from imitations. That is, it is one of the most common appropriability mechanisms used by firms (Teece, 1986; González-Álvarez and Nieto-Antolín, 2007). In this sense, the company that owns the patent enjoys a temporary monopoly during which the investment (for example, R&D expenditure) can generate returns. However, Levin et al. (1987) point out a range of reasons why, in the majority of industries, patents are not always used as mechanisms to protect against imitators. Among others, some reasons that lead companies to avoid patenting are: the fact that it is often not easy to demonstrate the novelty of the innovation; the high costs involved in obtaining and defending the patent; the fact that imitators can legally copy around the patented technology; and the fact that the patent can reveal important information on the technology used by the company (González-Álvarez and Nieto-Antolín, 2007). By patenting, the patent holder discloses information about its inventions to competitors. Therefore, there is a trade-off between the disclosures of detailed information by the inventor against the insurance of a limited monopoly awarded by the state. Next, we explain how the R&D expenditure and the type of knowledge used in the invention process influence the decision of companies regarding patenting their inventions.

2.1. R&D as a determinant of patenting choice

In examining which resources enhance patenting, extant research in management has primarily focused on knowledge accumulated by firms through R&D (Somaya et al., 2007). Therefore, R&D is seen as an input into the production of knowledge, which in turn facilitates the identification, assimilation, and exploitation of information generated both within and outside the firm (Cohen and Levinthal, 1990).

Many studies argue that invention is the result of idea generation and a problem-solving process (Gruber and Marquis, 1969; Utterback, 1971; Rogers, 1983; Nonaka, 1994, 2007). In this sense, a key element for idea generation is creativity, defined as the personal ability to recognize unusual patterns and relations, and to produce novel ideas (Tang, 1998). Companies interested in developing ideas need people involved in creative activities, that is, people working on R&D. These activities are considered the principal input to the knowledge creation process and therefore they play a fundamental role in the inventing process. Additionally, we find evidence in the literature that companies that are most intensively engaged in R&D activities are more innovative (Bierly and Chakrabarti, 1996; Stock et al., 2001), and because invention occurs prior to innovation, by extension, these companies will develop a larger number of inventions. Furthermore, there are authors that consider that patenting can represent an objective measure of the performance of the R&D expenditure (Blind et al., 2006; González-Álvarez and Nieto-Antolín, 2007). Therefore, although the creation of new ideas may be unanticipated, the literature suggests that firms invest in internal R&D to increase their options to generate ideas that can be materialized as patentable inventions (Somaya et al., 2007). Additionally, taking into account the debate about the trade-off between the disclosures of detailed information by the inventor against the insurance of a limited monopoly awarded by the state, we assume that higher levels of R&D expenditure will motivate companies to ensure the appropriability of the invention results through patenting. Thus, we propose our first hypothesis.

H1: There is a positive relationship between R&D expenditure and the number of inventions patented by a firm.

2.2. Knowledge as a determinant of patenting choice

Based on the RBV, we know that companies that have VRIO resources will be able to achieve and maintain sustainable competitive advantages (Barney, 1991). Of these four characteristics, inimitability is the most important (Hoopes et al., 2003) and is the most important contribution of the RBV (Barney et al., 2001). It has been assumed that knowledge has the greatest ability of all resources to serve as a source of sustainable competitive advantage (McEvily and Chakravarthy, 2002; Nonaka, 2007), in part because when it is well managed it can be a great source of inimitability. In addition, knowledge permits firms to predict more accurately the nature and commercial potential of changes in the environment and the appropriateness of strategic and tactical actions (Cohen and Levinthal, 1990). Therefore, among other reasons, companies will manage knowledge to generate inventions that are patentable.

The knowledge necessary to execute organizational routines tends to be tacit in nature (Polanyi, 1966; Winter, 1987) because, although the knowledge involved in each of the tasks in a specific routine can be explicit, the routines as a whole may be unknown to the majority of the participants and, therefore, it will be tacit. Knowledge tacitness has been one of the most discussed concepts in the managerial literature on innovation development (Polanyi, 1966; Winter, 1987; Nonaka, 1994; Zander and Kogut, 1995). Given the difficulty of covering all the knowledge tacitness aspects, Subramaniam and Venkatraman (2001), based on Zander and Kogut (1995), consider whether knowledge tacitness includes knowledge codifiability, observability and simplicity. These knowledge dimensions create temporal and spatial distance, decreasing the likelihood of successful imitation (King, 2007). In relation to the extent to which companies manage knowledge to generate inventions that are patentable, we propose that while knowledge codifiability will positively influence patenting choice, knowledge observability and simplicity will negatively influence the patenting activities of organizations. Arguments supporting this idea are developed next.

Knowledge codifiability captures the degree to which knowledge can be encoded, even if an individual operator does not have the capacity to understand it (Winter, 1987). That is, it considers the extent to which the knowledge could be articulated in documents or software (Zander and Kogut, 1995).

Uncodified knowledge is implicitly acquired and cannot be fully articulated (Gopalakrishnan and Bierly, 2001). It is related to know-how and based on experience (Nonaka, 1994). It is difficult to pass this kind of knowledge on to others outside the practising community because the terminology and basic principles associated with it are not easily understood. The transfer of uncodified knowledge often requires informal communication methods and face-to-face contact (Zander and Kogut, 1995), making it very difficult to obtain from another organization. Daft (1983) examines whether one of the conditions that make a resource impossible to imitate is when it arises from a combination of particular abilities, knowledge and organizational learning, and thus exhibits causal ambiguity.

Codified knowledge is easy to transmit and rival companies can thus appropriate this kind of knowledge via simple market transaction, unless it is protected by patents (Grant, 1996). The patent system is, therefore, more effective when protecting this type of knowledge (González-Álvarez and Nieto-Antolín, 2007). In addition, codified knowledge is easier to patent because, by definition, it is easily reducible to information and therefore easy to describe. Because appropriability is expected to fall systematically as the degree of codification increases, the higher the degree of knowledge codification, the higher the disposition to patent for the firm. Thus, we can propose our second hypothesis.

H2: There is a positive relationship between knowledge codifiability and the number of inventions patented by a firm.

The second aspect of knowledge in relation to inventions is based on its observability. The possibility that knowledge can be observed makes reference to the degree to which the underlying necessary knowledge is revealed by its use (Winter, 1987). That is, knowledge observability establishes the degree to which knowledge can be identified without having personal previous experience, and the degree to which it is obvious for a generality of users (Subramaniam and Venkatraman, 2001). Unobservable knowledge hinders knowledge transfer, aggregation and appropriation. In relation to inventions, when knowledge is unobservable, companies will have to develop their own ideas to be able to obtain new products. However, if knowledge is observable, all companies will have the same ability to launch similar products. Based on the idea that the generation of knowledge together with the novelty of the launched product are the dimensions that distinguish innovation from imitation, it is reasonable to believe that unobservable knowledge will motivate companies to generate ideas internally and give rise to inventions that are patentable. That is, prototypes obtained from observable knowledge will never be patentable. The reason is that if we get something based on observable knowledge (obvious for a generality of users) there will be nothing to patent. Thus:

H3: There is a negative relationship between knowledge observability and the number of inventions patented by a firm.

The last aspect of knowledge in relation to inventions is based on its complexity. Pringle (1951) defines knowledge complexity as the number of parameters needed to define a system. It can also be defined in terms of the level of interdependence inherent in the subcomponents of a piece of knowledge (Winter, 1987; Zander and Kogut, 1995). Gopalakrishnan and Damanpour (1994) define the complexity of an innovation using three characteristics: difficulty, intellectual sophistication, and originality. Therefore, to develop inventions that are patentable, companies need to use some degree of complex (or less simple) knowledge. That is, companies need to base their patentable ideas on some original and sophisticated knowledge. The reason is that unoriginal knowledge cannot be patented because it is known to the rest of the market. These statements lead us to propose our fourth hypothesis.

H4: There is a negative relationship between simplicity and the number of inventions patented by a firm.

2.3. Combining R&D and knowledge to determine patenting choice

The previous arguments lead us to assume an interesting effect regarding the interactions between the three types of knowledge and R&D. That is, different combinations of types of knowledge and R&D expenditure can be analysed to better understand why there are different patenting propensities among firms.

Starting with the first knowledge type, that is, knowledge codifiability, it is easy to understand that if codified knowledge positively influences patenting choice, its combination with R&D expenditure will increase the propensity of a firm to patent. That is, companies that have invested in R&D will increase their incentive to patent their results if they are based on codified knowledge. The reason is that these inventions based on codified knowledge will be easy to imitate and companies will want to guarantee the appropriability of the return of the inventions through patent protection (Teece, 1986). Thus, our fifth hypothesis follows.

H5: Knowledge codifiability moderates the relationship between R&D expenditure and the number of inventions patented by a firm. Knowledge codifiability increases the positive relationship that R&D has with the inventions patented by a firm.

On the side of knowledge observability, given that observable knowledge cannot be patented, this type of knowledge will reduce the possibilities of patenting the R&D efforts made by a company. That is, even when companies invest in R&D, if their results are based on observable knowledge, there will be nothing to patent. For that reason, we propose that knowledge observability harms the relationship between R&D expenditure and patents. Thus, our sixth hypothesis follows.

H6: Knowledge observability moderates the relationship between R&D expenditure and the number of inventions patented by a firm. Knowledge observability reduces the positive relationship that R&D has with the inventions patented by a firm.

Finally, even if companies are investing a lot of money in their R&D department, when the outputs of such R&D efforts are unoriginal ideas or simple knowledge, these outputs will not be patentable. Thus, our seventh hypothesis follows.

H7: Knowledge simplicity moderates the relationship between R&D expenditure and the number of inventions patented by a firm. Knowledge simplicity reduces the positive relationship that R&D has with the inventions patented by a firm.

3. Methods

3.1. Sample

To examine the extent to which firms patent their inventions, we require a sample of firms involved in these kinds of activities. We therefore begin with a sample including Spanish firms from innovative industries, based on information provided by the National Statistical Institute of Spain.[2] We use the SABI database (the most comprehensive database of company information in Spain) to identify all companies in these industries. There were a total of 2942 firms with more than 10 workers in our target sectors. This minimum number of employees guarantees the possibility of knowledge sharing and knowledge creation (Nonaka, 1994).

Between March and November 2006, data for the study's independent and control variables were collected. In January 2008, data for the dependent variable were collected,

[2] The National Statistical Institute (INE) of Spain identifies the five industries with the most "innovative" firms as: NACE 24, Chemical companies; NACE 32, Radio, TV, and communications equipment; NACE 33, Medical, precision, and optical instruments; NACE 34, Manufacture of motor vehicles, trailers, and semi trailers; and NACE 35, Manufacture of other transport equipment.

which reduced the problem of reverse causality encountered in many cross-sectional studies. A time lag between independent and dependent variables is also important because the patenting effects of knowledge and R&D take time to materialize.

To collect data for the independent variables, the 2942 firms were contacted by telephone, and, shortly thereafter, all firms interviewed were sent an email survey. Because the unit of analysis adopted in this study was the department where the innovation activity of the company is carried out, we spoke to the R&D manager. If the firm did not have an R&D manager, we instead spoke to the CEO. In total, 2765 firms responded to our phone calls (response rate of 94%). During the interview, we first ensured that the firm indeed belongs to one of the target sectors as specified in the database and that they had more than 10 employees. Those firms with less than 10 employees (19), which do not belong to our target sectors (539), or which are duplicated or without real activity (443), are excluded from our sample. We asked the remaining 1764 firms if we could send them our questionnaire. In total, 402 firms responded to this questionnaire and of those, 394 are considered valid. This corresponds to a response rate of 22.3% of the firms in our target population. An analysis of respondents and non-respondents, via mean difference analysis, shows no significant differences in industry membership, number of employees, or revenue. To collect data for the dependent variable we used the European Patent Office database, which contains more than 60 million patent documents from around the world.

3.2. Variable measures

We take several steps to ensure data validity and reliability for the measures used in the questionnaire. First, we pre-tested all measures in 25 interviews with R&D managers and asked them to closely review 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.

Dependent variable. Our dependent variable is the number of inventions patented by the firm. It is measured by the number of patents subscribed by each firm on the European Patent Office database. This number ranges from 0 to 455. However, after conducting an outliers analysis, we eliminate eight firms. For the 394 valid firms, the number of patents subscribed by companies ranges from 0 to 54. We then convert this number into a seven-point Likert scale (the same used in the questionnaire). This measure has been validated by a question from the questionnaire in which we ask each firm if they patented their inventions. The correlation between these two measures is 0.707 ($p < 0.01$), suggesting large convergent validity (Cohen and Cohen, 1983).

Independent variables. Internal R&D expenditure is measured as an average percentage of the sales turnover of the company for the past five years. We measure knowledge codifiability, observability and simplicity using the Subramaniam and Venkatraman (2001) scale. The questions appear in a seven-point scale consisting of six items. The first three items measure knowledge codifiability ($\alpha = 0.91$); the next two items measure knowledge observability ($\alpha = 0.68$) and the last item measures knowledge simplicity. It has to be mentioned that while the original authors found a unidimensional construct that they called "tacit knowledge", we find three independent dimensions. This result could be seen as a limitation in that we do not find the same result as the authors of the scale; however, it is also a contribution if we take into account that we are able to relate each of the dimensions with patenting choice.

Control variables. We control for organizational size, age, external R&D expenditure, the radicalness of the inventions developed and the company's industry. The size, age, R&D

expenditure and the radicalness data are obtained from the questionnaire, while we take the industry data from the SABI database. The size variable is measured in terms of the number of employees. Because of its dispersion, the variable is log transformed. Industry effects are captured by dummy variables for the firms' main sector as indicated by their industry code (NACE code) taken from the sample frame. Dummy variables were created for industries 24, 32, 33, 34 and 35. We divided industry 24 into pharmaceutical and non-pharmaceutical because of the large differences that we found between them. We measured inventions' radicalness based on the Subramanian and Youndt (2005) scale.

4. Results

Table 1 provides means, standard deviations and correlations for all quantitative variables. Skewness and kurtosis statistics fall well within the boundaries for normality, allowing parametric tests of significance. To ensure that multicollinearity was not an issue, value inflation factors were computed (not reported because of space limitations). None of them exceeded 2, indicating no multicollinearity.

Insert Table 1 about here

The hypotheses were tested using hierarchical regression analysis because an interaction effect only exists if the interaction term gives a significant contribution over and above the direct effects of the independent variable (Wiklund and Shepherd, 2003). The results are displayed in Table 2.

Insert Table 2 about here

The base model (control variables only) explains a statistically significant share of the variance in patenting choice (adjusted $R^2 = 0.14$, $p < 0.001$). Taking into account the effects of each control variable, firm size and age positively influence patenting choice. Furthermore, consistent with the literature (Mansfield et al., 1981) pertaining to the pharmaceutical and the radio, TV and communication equipment industries, patenting choice is positively related to higher levels of patenting activity. The main effects model makes a significant contribution over and above the base model ($^\wedge R^2 = 0.06$, $p < 0.001$). The positive and significant effects of internal R&D expenditure and knowledge codifiability on patenting choice support hypotheses 1 and 2, respectively. Hypothesis 3 is supported by the negative and significant effect of knowledge observability on patenting choice. However, hypothesis 4 is not supported.

The interaction terms make different contributions. The second interaction term, which relates R&D with knowledge observability, makes a significant contribution over and above the main effects ($^\wedge R^2 = 0.01$, $p < 0.1$) and supports hypothesis 6. To determine the nature of this interaction, we plot the effect of knowledge observability against the dependent variable for values of R&D set at the mean and one standard deviation above and below the mean, as suggested by Cohen and Cohen (1983). The plot indicates that for high levels of knowledge observability, the relationship between internal R&D expenditure and patenting choice is almost constant. However, when knowledge is unobservable, companies will tend to patent while their internal R&D expenditure increases (see Figure 1a).

Insert Figure 1a about here

The third interaction, which relates R&D with knowledge simplicity, makes a significant contribution over and above the main effects ($\Delta R^2 = 0.02$, $p < 0.05$) and gives support to hypothesis 7. To determine the nature of this interaction, we plot the effect of knowledge simplicity on the dependent variable for values of R&D set at the mean and one standard deviation above and below the mean, as suggested by Cohen and Cohen (1983). The plot indicates that firms tend to patent a little less when internal R&D expenditure increases and knowledge is very simple. On the contrary, we find that companies increase their patenting activity if knowledge is complex and their R&D expenditure increases (see Figure 1b).

Insert Figure 1b about here

The insignificant effect of the interaction between R&D and knowledge simplicity does not give support to hypothesis 5.

5. Conclusions

"In an economy where the only certainty is uncertainty, the one sure source of lasting competitive advantage is knowledge" (Nonaka, 2007, p. 162). In this sense, this paper explains that companies may face such uncertainties by patenting inventions through the appropriate use of their resources, knowledge and money (internal R&D expenditure).

There is a consensus in the literature confirming that internal R&D expenditure positively influences patents and that patents are a good driver of higher levels of performance (Somaya et al., 2007). Based on the characteristics of VRIO resources (Barney, 1991), on previous literature and on general intuition, we have taken for granted that patenting leads to higher levels of performance. On the contrary, given that not all R&D-intensive companies patent their inventions, we have looked for an explanation of the causes that could make companies increase or reduce their patenting decisions. Among the large number of reasons given in the literature for enhancing and harming patenting (González-Álvarez and Nieto-Antolín, 2007), we have focused our analysis on the combination of internal R&D expenditure and types of knowledge.

Having found that internal R&D has a positive impact on the number of inventions patented by a firm is important because it helps both researchers and practitioners confirm that investing money in R&D has the benefit of obtaining a higher number of inventions to patent, and by extension, higher levels of performance and value (Nerkar and Shane, 2007; Somaya et al., 2007). It is also interesting to point out that external R&D expenditure does not impact on patenting propensity. This is because external R&D is used more to obtain imitations than innovations (Bierly and Chakrabarti, 1996).

However, our findings about the relationship between the types of knowledge and patenting choice lead us to a very interesting point. In general, we have proposed that inventions that are patentable should be based on codified, unobservable and complex knowledge. Taking into account the positive relation found between codified knowledge and patenting, we can conclude that, consistent with the literature, imitable knowledge will be patented while non-imitable knowledge (uncodified) will be the base for causal ambiguity and then, companies will have no need to patent (Mansfield et al., 1981; Daft, 1983; Reed and DeFillippi, 1990; Barney, 1991; Zander and Kogut, 1995). Furthermore, this finding confirms that a good way of guaranteeing the appropriability of the returns of inventions based on codified knowledge is by patenting them (González-Álvarez and Nieto-Antolín, 2007). The negative relationship between observable knowledge and patenting is unsurprising when we consider that observable or known knowledge cannot be patented (there is nothing new to protect). Taking these two findings as a whole, we can conclude that companies patent those new ideas (based on unobservable knowledge) that can be imitated (based on codified knowledge). This is interesting because it helps us understand why knowledge must be thoroughly analysed. That is, knowledge must be separated into its various types to be understandable. This idea of separating types of knowledge makes an interesting contribution beyond Subramanian and Venkatraman's (2001) finding. That is, while they analysed knowledge tacitness as a unique construct that did not permit the analysis of each of its dimensions independently, we have been able to find out that one of the dimensions of knowledge tacitness (codifiability) positively influences patenting choice, while the other two are negatively related to our dependent variable.

Finally, we find interesting the negative moderator role of both knowledge observability and simplicity and R&D on the propensity to patent inventions. That is, we found that for high levels of knowledge observability and simplicity, the relationship between internal R&D expenditure and the patenting choice is highly stable. Even more, when combining very simple knowledge with R&D expenditure, companies tend to patent less. Maybe, because given the simplicity of such knowledge, companies do not want to disclose the knowledge used to their competitors. These findings suggest that companies cannot protect any R&D effort if the output is observable and simple knowledge. The reason is that, as we have already explained, simple and unoriginal knowledge does not give rise to inventions that are patentable. However, when knowledge is unobservable (new for other competitors) and/or complex, companies will tend to patent while their internal R&D expenditure increases. That is, companies tend to patent their original and complex ideas obtained by investments in

R&D. This is because, once those companies have something to patent (an original and new idea), they want to secure the appropriability of the returns of their investments on R&D.

This study has certain limitations that future research should aim to overcome. First, because our intention was to look at the proclivity to patent inventions, we focused on five industries traditionally involved in innovative activity. While we believe that this is an appropriate approach given our research interest, care must be taken in generalizing our findings to other industries. In addition, our data were collected from Spanish firms only, which limits their generalizability to other cultural contexts. Second, we used the industry as a control variable, obtaining similar findings to those of other studies (Mansfield et al., 1981). That is, we found that traditional patenting industries such as pharmaceuticals or medical, precision, and optical instruments do influence the patenting propensity of firms. However, other contextual factors such as dynamism should be taken into account in future research.

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Figure 1a. Interaction between R&D and knowledge observability

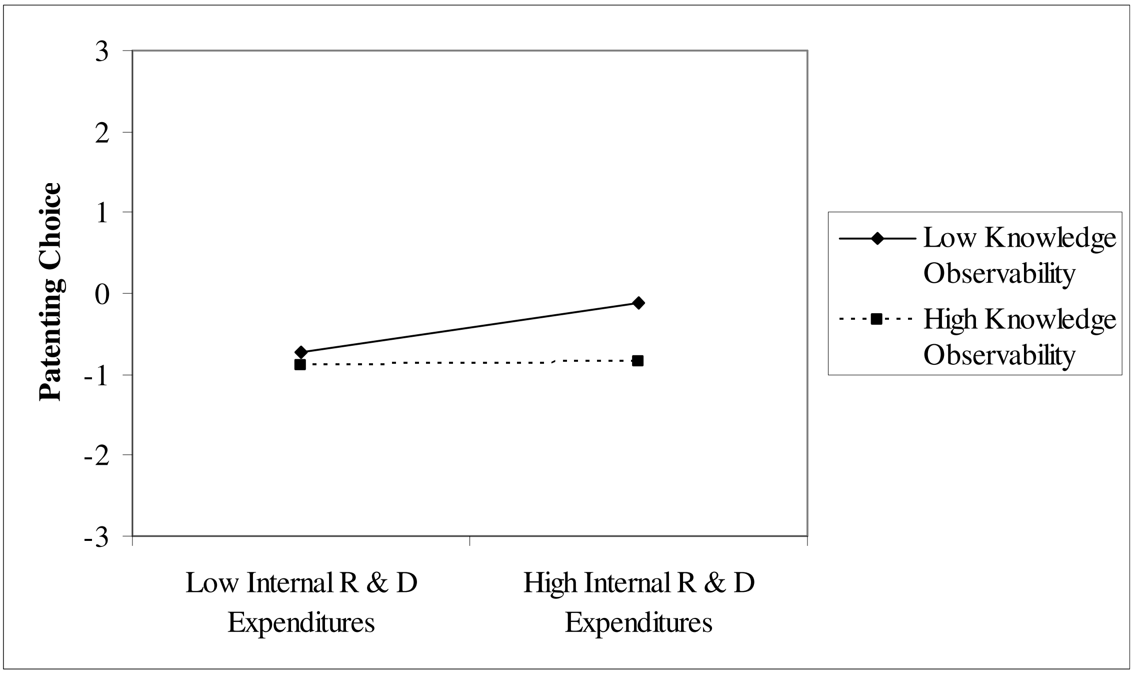

Figure 1b. Interaction between R&D and knowledge simplicity

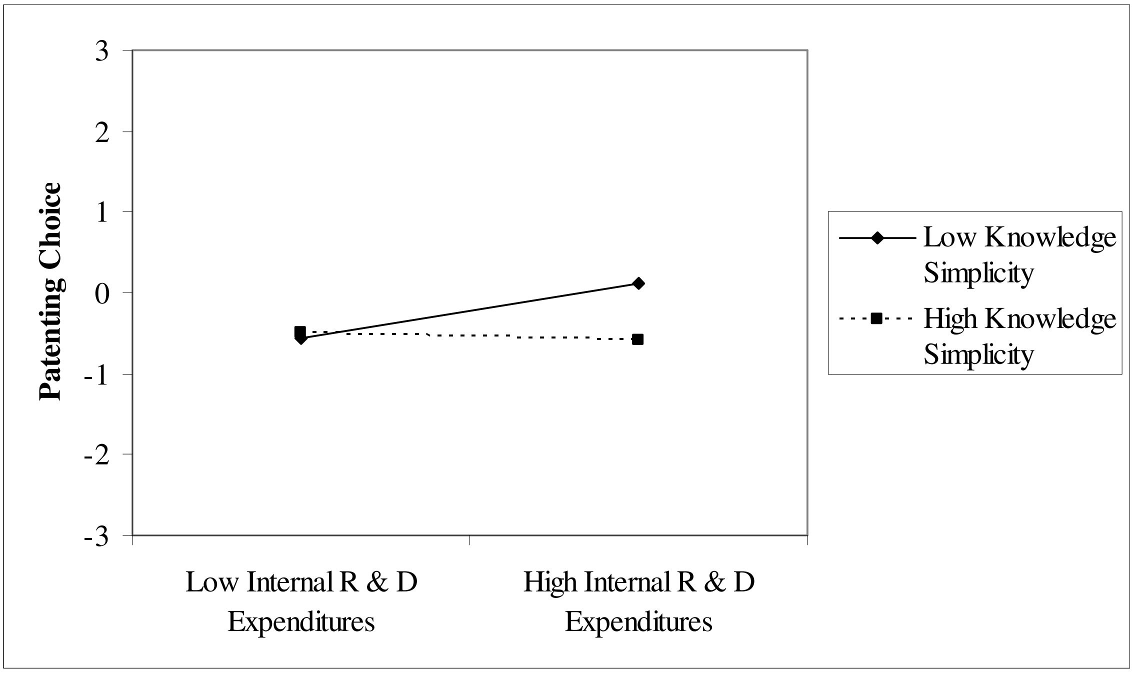

Table 1. Means, standard deviations and correlations for quantitative variables

Variables	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12
1. Patents	2.13	1.75	1											
2. Codifiability	4.59	1.34	0.07	1										
3. Observability	3.63	1.35	–0.15(**)	0.40(**)	1									
4. Simplicity	3.70	1.66	–0.13(**)	0.33(**)	0.44(**)	1								
5. Internal R&D	9.77	14.48	0.11(*)	–0.01	–0.11(*)	–0.136(**)	1							
6. External R&D	2.52	6.89	0.01	–0.03	0.016	–0.001	0.285(**)	1						
7. Firm Size	32.09	23.44	0.18(**)	–0.01	–0.03	0.017	–0.074	–0.053	1					
8. Firm Age	3.98	1.35	0.36(**)	–0.03	–0.12(*)	–0.024	–0.150(**)	–0.063	0.33(**)	1				
9. Industry 244	0.07	0.25	0.15(**)	–0.01	–0.01	–0.019	0.082	0.185(**)	0.01	0.15(**)	1			
10. Industry 32	0.13	0.33	0.06	–0.03	–0.07	–0.050	0.160(**)	0.023	–0.16(**)	–0.06	–0.10(*)	1		
11. Industry 33	0.10	0.30	–0.02	–0.08	–0.03	–0.047	0.117(*)	0.041	–0.11(*)	–0.13(**)	–0.09	–0.13(*)	1	
12. Industry 34	0.20	0.40	0.03	0.01	0.08	0.075	–0.131(**)	–0.061	–0.00	0.19(**)	–0.13(**)	–0.19(**)	–0.17(**)	1
13. Industry 35	0.13	0.34	–0.04	–0.02	0.07	–0.039	–0.060	–0.027	0.05	–0.05	–0.10(*)	–0.15(**)	–0.13(*)	–0.19(**)

+ p < .10 * p < .05 **p < .01 *** < .001 (n = 394)

Table 2. Independent and contingency models of R&D, knowledge and patents

Dependent variables	Base model		Independent model		Contingent model 1		Contingent model 2		Contingent model 3	
	Coefficient	*t-statistic*	Coefficient	*t-statistic*	Coefficient	*t-statistic*	Coefficient	*t-statistic*	Coefficient	*t-statistic*
Control variables										
Firm size	0.42***	6.32								
Firm age	0.01+	1.94								
External R&D	0.01	0.25								
Industry 244[a]	0.89*	2.48								
Industry 32[a]	0.66*	2.43								
Industry 33[a]	0.44	1.48								
Industry 34[a]	0.12	0.53								
Industry 35[a]	0.07	0.26								
Radicalness	–0.05	–0.80								
Main effect variables: Internal R&D expenditure and types of knowledge										
Internal R&D			0.02*	2.48						
Codifiability			0.25***	3.59						
Observability			–0.18*	–2.24						
Simplicity			–0.09	–1.63						
Interactions: Internal R&D × types of knowledge										
Codifiability × R&D					–0.01	–1.43				
Observability × R&D							–0.01+	–1.76		
Complexity × R&D									–0.01*	–2.47
Model										
R^2	0.16		0.22		0.23		0.23		0.24	
Adjusted R^2	0.14***		0.19***		0.20***		0.20***		0.21***	
F-statistic		8.31		8.26		7.84		7.932		8.21
Change in R^2			0.06***		0.01		0.01+		0.02*	
Change in F				6.97		2.06		3.099		6.11

Standardized regression coefficients are displayed in the table.

[a]Dummy for industries; + p < .10 * p < .05 **p < .01 *** < .001 (n = 394)