Gonzalez, N.& Nieto, M.(2007): Appropriability of innovation results: an empirical study in Spanish manufacturing firms¨, Technovation : International Journal of Technological Innovation , Entrepreneurship and Technology Management, vol.27, nº5 (280-295)

APPROPRIABILITY OF INNOVATION RESULTS: AN EMPIRICAL STUDY IN SPANISH MANUFACTURING FIRMS

Nuria González-Álvarez[1]

Departamento de Dirección y Economía de la Empresa

Universidad de León

Campus de Vegazana s/n

24071 León-Spain

Tel. +34 987 29 17 14

Fax. +34 987 29 17 50

e-mail: ddenga@unileon.es

Mariano Nieto-Antolín

Departamento de Dirección y Economía de la Empresa

Universidad de León

Campus de Vegazana s/n

24071 León-Spain

Tel. +34 987 29 18 76

Fax. +34 987 29 17 50

e-mail: ddemna@unileon.es

[1] Corresponding author

Abstract

This study is intended to analyse several mechanisms available to companies in order to appropriate the results of their innovative activities. These mechanisms include patents, industrial secret, cost and time of imitation and continuous innovation. Specifically, this paper focuses on studying the factors that determine the choice of one appropriation method over another. To this end, we propose a specific model of analysis, which includes various hypotheses to be tested in a sample of 258 Spanish manufacturing companies. The results confirm that companies that mostly use explicit knowledge chose the patenting system as a defence mechanism, while those companies in which tacit type knowledge predominates tend to opt for industrial secret. We could also prove that larger companies tend to choose the patenting system as a protection mechanism. Finally, the hypothesis that companies that use high-commitment human resources practices use continuous innovation or technological leadership as a protection mechanism could be also tested.

Keywords:

Appropriability, knowledge protection, patents, Spain

1. Introduction

The resource based view (RBV) has become the dominant paradigm in strategic management research (Peteraf, 1993). According to this perspective, variations in the performance of companies that compete within a single industry can be explained on the basis of the differences in their provision of resources (Barney, 1986a, 1986b, 1991; Peteraf, 1993; Wernerfelt, 1984). Traditionally, it has been thought that companies that have valuable, rare, non-substitutable and non-imitable resources will be able to achieve and maintain an advantageous position with respect to their competitors (Barney, 1991: 56). Of these four characteristics, inimitability is the most important (Hoopes, Madsen and Walker, 2003: 890) and is the most important contribution of the resource based view (Barney, 2001: 45).

Similarly, maintenance of competitive superiority over time depends on the ability of a company to protect its innovations from imitation by its rivals. In order to do this, innovative companies have various alternatives available to them, as we can see from the studies by Scherer et al. (1959), Mansfield (1986a), Teece (1987), Levin et al. (1987), Dosi (1988), Geroski (1995), Harabi (1995), Cohen et al. (2000), Arundel (2001) and Cohen et al. (2002). These alternatives include patents, industrial secrets, lead time advantages, imitation cost and time and the use of complementary resources.

In this regard, this study shall attempt to analyse the main relationships between the aforementioned protective mechanisms, the characteristics of the technologies developed within a company and other characteristics specific to organisations, such as size and the human resources system. In short, an attempt shall be made to analyse which factors related to knowledge attributes and the characteristics of companies in

general determine the selection of one protection mechanism or another. With this aim in mind, the article is organised as follows. The next section establishes the theoretical framework of the problem on the basis of the analysis of various protection mechanisms and their relationship to the specific characteristics of the company and its knowledge, including a set of hypotheses to be tested. After that, we describe the sample used and the empirical methodology followed. Subsequently, we present our findings; after that, we ground the main conclusions drawn from this work within the previous literature in the Conclusions section at the same time we suggest some managerial implications. In that section we also point out the main limitations of the study and we suggest some directions for future research.

2. Protection Mechanisms

The appropriation of results of the innovative activity is very important for innovative companies since it enables them to enjoy the profits generated by their innovations. The ability of firms to appropriate at least some of the value created by their innovations is essential if there is to be incentive to innovate (Cohen et al., 2002). This importance was recognised by Arrow (1962) who said that companies are only interested in developing innovations if there is a high probability beforehand that they will be able to appropriate all or part of the profits generated by that innovations. Appropriability is identified as a strategic success factor for organizations than produce R&D results for proprietary use (Brockhoff, 2003) and establishing an effective appropriability regime can facilitate firms to take profit from innovations (Hurmelinna, et al., 2005) . Since appropriability is difficult to measure directly, many researchers have been trying to investigate it indirectly and qualitatively by examining the effectiveness of various means (Harabi, 1995: 990). The most important of these means

are patents, industrial secret, imitation cost and time and continuous innovation. These categories are considered in the following sections.

Patents

The patent system, by establishing ownership rights in the results of the innovation process, legally protects innovators against imitators. In this way, the company that owns the patent enjoys a temporary monopoly during which the investment can generate return. In addition to protection against imitation, patents offer other advantages for the companies that develop them. As Blind et al. (2006) point out the traditional motive to patent is the protection of own inventions from imitation. The strategic motive, which is in the forefront of most investigations, is to block competitors. Besides these two central motives, the number of further imaginable strategic motives is considerably larger. Among others, the fact that they represent an objective measure of performance of R&D employees (Levin et al., 1987:798, Harabi, 1995:989, Cohen et al., 2002:1358; Blind et al. 2006:657), they improve the position of companies in negotiations with other companies (Levin et al., 1987:798; Harabi, 1995:989; Cohen et al., 2002:1358; Blind et al. 2006:657), they increase the company's reputation (Cohen et al., 2002:1358; Blind et al. 2006:657) and they allow companies to gain access to certain foreign markets where access requires companies to have license contracts with domestic companies, for which purpose they need to have developed patents (Levin et al., 1987:798; Harabi, 1995:990; Blind et al. 2006:657). For example, in several key industries, including semiconductor, biotechnology, computer, software and the internet, the patent system is creating a patent thicket, an overlapping set of patents rights requiring that those seeking to commercialize new technology obtain

licenses from multiple patentees (Shapiro, 2001). Cross-licenses are the preferred means by which large companies clear blocking patent positions amongst themselves. In that sense, Intel has entered into a number of broad cross-licenses with other major industry participants, such as IBM, under which most of each company´s vast patent portfolio is licensed to the other. In the same way, Hewlett-Packard and Xerox recently announced a cross-license that settled their outstanding patent disputes (Shapiro, 2001).

In those industries, patents are used not only to protect innovation but are often adopted as part of a firm´s strategic plan. In other words, many firms file many different patents relating the same sector in order to discourage competitors form investing in research and development in that sector. A firm´s successful execution of the player depends in part on the bargaining power that comes with possession of a larger patent portfolio (Cohen et al., 2002). Patents become weapons in mutually reinforcing, noncooperative strategic interactions where firms feel increasingly compelled to patent either because the need to protect themselves from suits or use patents as bargaining chips in negotiations (Cohen et al., 2000; Hall and Ziedonis, 2001; Granstrand, 2002). Therefore, firms use patents in more subtle and sophisticated ways than simply as a legal barrier to deter rivals (Arora, 1997:392). Even, in cases where the companies are not sure about the concrete use of their innovation they may decide to keep their options open for the future and may ask for patent protection (Takalo and Kanniainen, 2000)[2].

However, the preference for patents is called into question by the empirical evidence based on innovation survey in the United States (Levin et al., 1987; Rausch,

[2] Takalo and Kanniainen (2000) consulted Mr. Ilka Rahnasto, a legal counsel for Intellectual Property Rights Management of Nokia Group. He indicated that patents are often left temporarily unused when they arise as distinct from the normal activity of a company, or in other cases when there is considerable uncertainty about future technology or market.

1995; Cohen et al., 1998), Europe (Arundel et al., 1995; Harabi, 1995; Arundel, 2001; Galende, 2006) and Australia (McLennan, 1995). These surveys consistently show that for most manufacturing firms patents are less effective than alternatives such as lead time, secrecy and complementary sales and service effort. The single exception is Japan, where firms give a higher rating to patents for product innovations, although secrecy is more valuable for process innovations (Cohen et al., 1998).

Levin et al. (1987) point out a range of reasons why in the majority of industries patents are not used as mechanisms to protect against imitators. In addition to the fact that it is often not easy to demonstrate the novelty of the innovation and the high costs involved in obtaining and defending it (Kingston, 2001:410) and that imitators can legally copy around the patented technology, there are situations in which information included in the patent limits its effectiveness since it can reveal important information on the technology used by the company (Arundel, 2001:612; Cohen et al., 2002:1362; Thumm, 2005: 1411). By patenting, the patent holder discloses information about its innovation to competitors. Information disclosure has social value in reducing duplication (Takalo and Kanniainen, 2000: 1106). So, there is a trade-off between the disclosure of detailed information by the inventor against the insurance of a limited monopoly awarded by the state (Scherer and Ross, 1990: 623). The importance of disclosure as a reason not to patent has been established in both theoretical models of patent behaviour (Horstmann et al., 1985; Scotchmer and Green, 1990; Harter, 1993) and in survey-based research (Arundel and Kabla, 1998; Cohen et al., 1998). Moreover, from the point of view of the economic system, recent studies have found that too much patenting can potentially deter innovation (Heller and Eisenberg, 1998; Hall and Ziedonis, 2001, Thumm, 2005). Strong patents rights could build up barriers to follow-

up research and thus hinder technological advance. With cumulative innovation and multiple blocking patents, stronger patents rights can have the perverse effect of stifling, not encouraging, innovation (Shapiro, 2001). In the same way, the so called 'tragedy of the anti-commons' (Heller and Eisenberg, 1998) poses a serious threat. It describes a situation, where it might be that the necessary knowledge to conduct further research is covered by a large number of patents held by many different firms. Transaction costs become too high to collect all the relevant information for further research. The anti-commons could be one reason why the patents system can impede the combination of new ideas and inventions by raising transaction costs for follow-on innovation and by providing an opportunity for rent seeking (Thumm, 2005: 1411).

Industrial secret

Industrial secret consists of keeping the information secret preventing any essential element of that knowledge from spilling over outside the firm. Trade secrets cover a wide range of confidential information from technical secrets such as formulae, know-how, and processes, to information about a firm´s customers, employees, sales strategies, etc.. Trade secrets therefore depend on the imposition, sometimes unilaterally, of personal obligations on others, either by means of the law of confidentiality, or the law of contract. The nature of this contract, which may be implicit or explicit, can give one party (say the employer) rights, whilst the other party (say the employee) may experience restrictions (Hall, 1992: 138). As opposed to other forms of intellectual property, the protection of trade secrets is, in large part, accomplished through mangers rather than legal licensing procedures. Thus, it is important that mangers understand what a trade secret is and what the present legal environment

suggests for their rights and responsibilities in protecting such secrets (Maurer and Zugelder, 2000: 156). The main problem with this method is that in practice the secret only provides effective protection if innovations cannot be easily observed and replicated using reverse engineering processes, as occurs in the case of process innovations (Von Hippel, 1988; Arundel, 2001). So, protection though industrial secret can be adequate provided that the innovation is not rapid cancelled by inverse engineering processes once it has been commercialised (Galende, 2006).

Cost and time for imitation

On the other hand, companies can use imitation cost and time to protect their innovations from their competitors. This mechanism refers to the fact that the imitator will have to reproduce the whole of the innovative process, devoting much time, great investment and many resources to it (Pavitt, 1987: 186). This method is related to the complexity of the technology and the learning effect. The learning effect refers to the fact that the manufacturing time of a product becomes progressively shorter the larger the number of units produced. In this way, labour costs per unit and therefore total product cost are reduced. The learning effect has been observed in most industries for decades (Hirschmann, 1964; Abernathy and Wayne, 1974). Those companies that have reduce their costs via the learning effect will have advantages over their potential imitators since these will not be able to benefit from the advantages associated with this effect when attempting to imitate it. For this reason, potential imitators may be dissuaded from copying innovations from companies that benefit from the learning effect.

Lead time or continuous innovation

This mechanism is based on the advantage gained by a firm when it is able to develop an innovation before its rivals. This strategy consists of innovating more quickly than rivals so that when a competitor manages to imitate a company's innovation, it has already released another one onto the market. If the innovator continues to accumulate knowledge and innovates constantly over time, he will be able to maintain a position of technological leadership over his potential imitators and also to achieve a stronger market position, acquire a significant market share and extend an exclusive co-operation network with his technological partners, suppliers, distributors and customers. The issue raised in the literature is whether a firm can sustain that edge in the long run (Makadok, 1998). Innovative firms can damper the incentives to imitation with dissuasive measures, such as threatening potential imitators with reprisal or investing in reputation and creating an image of quality and reliability (Grant, 1996). Similarly, constant incremental improvement of innovations is one of the means that a firm can use to retain its lead time (Malerba and Torrisi, 1992; Torrisi, 1998).

3. Specific Analysis and Hypothesis Method

When making a decision on which protection method to select, companies can take into account various factors such as the institutional framework (Kortum and Lerner, 1999; Granstrand, 2000; Hall and Ziedonis, 2001; Pitkethly, 2001; Cohen et al., 2002; Hurmelinna et al., 2005), the legal system in their country (Ordover, 1991; Kortum and Lerner, 1999; Shapiro, 2001; Cohen et al., 2002; Graham et al., 2002; Hurmelinna et al., 2005), the structure of the industry in which they compete (Scherer et al., 1959; Mansfield et al., 1981; Mansfield, 1986; Levin et al., 1987; Scherer and Ross, 1990; Arora, 1997; Grindley and Teece, 1997; Arundel and Kabla, 1998; Cohen et al., 2000; Arundel, 2001; Cohen et al., 2002; Graham et al., 2002; Hertzfeld et al., 2006),

the dimensions of the technological knowledge they use (Arora, 1997; Pitkethly, 2001; Nieto and Pérez Cano, 2004; Durack, 2004; Hurmelinna et al., 2005; Hertfeld et al, 2006) and other characteristics specific to the companies as the firm´s own innovation strategies (Levin et al., 1987; Arundel and Kabla, 1998; Cohen et al., 2000; Arundel, 2001; Cohen et al., 2002, Galende, 2006), the size (Cohen et al., 2000; Arundel, 2001; Brouwer and Kleinkenecht, 1999; Hall y Ziedonis, 2001; Kingston, 2001) or the organizational resources (Maurer and Zugelder, 2000; Hurmelinna et al., 2005; Galende, 2006; Hertfeld et al., 2006). In this study, we analyse two types of factors. On the one hand, the characteristics of the knowledge developed by the company which have been traditionally linked with the concept of appropriability (Nelson and Winter, 1982; Zander and Kogut, 1995) and which in recent years have become particularly relevant (Arora, 1997; Pitkethly, 2001; Nieto and Pérez Cano, 2004; Durack, 2004; Hurmelinna, Kylaheiko and Jauhiainen, 2005). On the other hand, we will study other characteristics specific to companies such as the size and the human resources policy. As it has been mentioned above, the knowledge attributes and the size are ones of the firm's most traditional factors linked to innovation protection and they have been analysed in all types of international studies. However, there are not studies about Spanish firms that test the influence of both factors on the appropriation mechanism's choice. Moreover, there are other resources, which are intangible and hence more difficult to identify and evaluate, but which can have an impact on how the results are appropriated (Galende, 2006). Among these intangible resources, we chose human resources because their importance has been highlight in previous studies (Maurer and Zugelder, 2000; Casper and Whitley, 2004; Hurmelinna et al., 2005). As Maurer and Zugelder (2000: 166) suggest, beyond its numerous implications for management practice, the knowledge

protection presents a variety of issues for future study by both organizational and human resource (HR) scholars.

Figure 1 presents the model of analysis proposed in this study. The aim is to test the influence of the characteristics of the knowledge and technology developed by the company (complexity, codification and specificity) and other characteristics of the company (size and human resources) on how the innovative results are appropriated. The following proposition contains the general objective of this study:

H: The mechanisms used for appropriating the results of innovative activity depend on the specific characteristics of the technology and the company.

This initial proposition can be divided into several more specific hypotheses that consider the specific relationship that exists between the different characteristics of the technology of the company and the different protective mechanisms. Each of these relationships is described below and a hypothesis associated to each one is proposed.

INSERT FIGURE 1

Both the evolutionist approach (Nelson and Winter, 1982) and the resources based view (Barney, 1991) have stressed that technologies emerging from the innovation process do not possess the features of 'information' as suggested by certain neoclassical views (Arrow, 1962). Those technologies are built on the basis of knowledge, learning and experience whereby the company accumulates knowledge that gradually becomes routine (Nelson and Winter, 1982). The knowledge necessary to execute organisational routines tends to be tacit in nature (Polanyi, 1962; Itami, 1987; Winter, 1987) since, although the knowledge involved in each of the tasks in a specific routine can be explicit, the routine as a whole may be unknown to the majority of the participants and, therefore, it will be tacit (Winter, 1987). The tacitness of knowledge is

a subject that has been widely studied in literature since the seminal work of Polanyi (1962). Furthermore, other attributes related to technological knowledge have also been identified, such as complexity (Rogers, 1962; Winter, 1987; Reed and DeFillipi, 1990; Zander and Kogut, 1995), the level at which knowledge can be taught (Winter, 1987, Zander and Kogut, 1995) and observed (Rogers, 1992; Winter, 1987; Zander and Kogut, 1995), specificity (Reed and DeFillipi, 1990; Galunic and Rodan, 1998) and the level of dependence of other knowledge (Winter, 1987; Garud and Nayyar, 1994; Zander and Kogut, 1995).

In this study, we have chosen three of these attributes: codification, complexity and specificity. This choice is motivated by two factors. Firstly, these attributes are among those most commonly analysed in previous research. Secondly, they were proposed by Reed and DeFillipi (1990) in a study that analyses the characteristics of firm competencies, including knowledge, and the barriers to imitation, and in which special emphasis is stressed on the concept of appropriability.

Codification of knowledge refers to the fact that knowledge may be converted into information using formulas, diagrams, numbers or words. On this basis, two types of knowledge are defined: explicit and tacit (Polanyi, 1962; Nonaka and Takeuchi, 1995; Grant, 1996; Spender, 1996). The main component of explicit or codified knowledge is information and its transmission is therefore not difficult. Rival companies can thus appropriate this kind of knowledge via simple market transactions, unless it is protected by patents (Grant, 1996). The patent system is therefore more effective when protecting this type of knowledge (Pitkethly, 2001). Explicit knowledge is easier to patent because, by definition, it is easily reducible to information and therefore easy to describe. Well articulated knowledge can lead to stronger and better

defined patents (Arora, 1997:393). Appropriability is expected to fall systematically as the degree of codification increases (Saviotti, 1998).Thus, the higher the degree of codification of an item of knowledge, the more efficient the legal means of protecting it (Nieto and Pérez-Cano, 2004; Hurmelinna et al, 2005). This idea is reflected in the following hypothesis:

H1: Companies that use mostly explicit knowledge tend to choose the patent system as a protection mechanism.

On the other hand, tacit knowledge is knowledge that cannot easily be reduced to information and it therefore cannot be codified, as it resides essentially in the minds of individual people (Polanyi, 1962). It is therefore easier to keep within the company since its tacit nature, which hampers its identification and evaluation by external agents, makes it difficult to imitate (Teece, Pisano and Shuen, 1997: 526). Knowledge based on inductive and empiricist procedure is often difficult to protect through patents (Arora, 1997). This in not only because such knowledge is often difficult to codify but also because patent claims on such knowledge would have to be narrow to be valid. If so, patents would disclose a great deal of useful information to potential imitators. The logical course of action would be to patent the clearly articulated aspects of the technology and to keep secret the rest (Arora, 1997: 393). While some companies rely on patents or other legal means (e.g. explicit contracts), others rely more on the ways to embed tacit knowledge deep into the organizational structure (Hurmelinna et al. 2005,). Therefore, protecting tacit knowledge, which is impossible to patent as it cannot be reduced to information, requires the use of industrial secret as a defence mechanism (Nieto and Pérez-Cano, 2004). This last idea enables us to propose the following hypothesis:

H2: Companies that use mostly tacit knowledge tend to choose industrial secret as a protection mechanism.

Moreover, the complexity of technological knowledge can be defined in terms of the level of interdependence inherent in the subcomponents of a piece of knowledge (Simon, 1962; Winter, 1987; Kauffman, 1993; Zander y Kogut, 1995; Sorenson et al.,, 2006). Intuitively one supposes that the more simple the technology, the easier it is to identify and transfer (Reed and DeFillipi, 1990). On the other hand, the more complex the technology, the greater the effort required of the imitators and the greater the time and number of resources necessary to identify it, copy it and apply it (Kogut y Zander, 1995). Complex knowledge resists diffusion even within the social circles in which it originated (Sorenson et al., 2006: 994). So, complex knowledge is generally slow to transfer, and thus easier to protect using mechanisms controlled by the firm, since complexity hinders imitation (Nieto and Pérez-Cano, 2004: 121). Patents are relatively unimportant compared to alternative appropriation methods in sectors that produce complex products that are costly to copy, or where high investment costs and expertise levels create entry barriers that limit competition from new entrants, such as in aerospace (Arundel and Kabla, 1998:129). It would therefore be useful for companies that use complex technologies to use imitation cost and time as their method of appropriation since complex technology is, by definition, costly to imitate, in terms of both time and resources. The following hypothesis reflects this idea:

H3: Companies that use mostly complex knowledge or technologies tend to choose imitation cost and time as their protection mechanism.

Furthermore, knowledge or technology is specific when it only has one specific use and can only be used by a specific user without loss of productive value

(Williamson, 1990). This means that this type of knowledge is idiosyncratic to the organisation and it is therefore advisable to keep it secret in order to avoid competitor action. While specific knowledge is valuable to the firm, it is often hard for individuals to sell on market (Casper and Whitley, 2006). That is, even if competitors do discover the secret, the very specificity of the knowledge prevents its use, thus guaranteeing the appropriation of the profits generated by the said knowledge. The following hypothesis reflects this idea:

H4: Companies that use mainly specific knowledge or technology tend to choose industrial secret as a protection mechanism.

On the other hand, in addition to the characteristics of the company's technology, other characteristics of the same could be determinant when choosing the most suitable protection mechanism. Firstly, the size of the company is a company-specific characteristic that is often used in previous studies (Arundel and Kabla, 1998; Cohen et al., 2000; Arundel, 2001; Brouwer and Kleinkenecht, 2001; Hall y Ziedonis, 2001; Kingston, 2001). These studies show empirically that larger companies tend to prefer the patenting system since this makes it easier for them to introduce themselves into other countries via licence contracts with companies that operate in the said countries and, in this way, they can also control the technological evolution in their country of origin. Furthermore, the high costs involved in obtaining and defending a patent can only be born by large companies. According to Arundel (2001:613) incremental and accumulative innovation tends to occur in small companies and their protection via patents presents serious difficulties. In addition to patent application costs, which could be a greater barrier to small than larger firms, small firms could find it exceedingly difficult to protect their patents from infringement, which would increase

the relative value to them of secrecy compared to patents. Another possibility is that many small firms, with the exception of those that are pursuing a high-technology strategy, could be less likely than large firms to develop patentable innovations. Instead, many of their innovations could be based on minor incremental improvements that are not worth patenting (Arundel, 2001:613). Brouwer and Kleinknecht (1999) found that small firms are less likely to use the patent system, although when it is used they tend to have, in relative terms, a greater number of patents than larger firms. Therefore, the appropriation of innovations via patents should be more marked in larger firms as the following hypothesis suggests:

H5: Larger companies tend to choose the patenting system as a protection mechanism.

Finally, the human capital of a company plays an essential role in innovative processes and may affect a firm´s chances of appropriating its intangibles and profiting from them (Hurmelinna et al., 2005). If there is a group of suitably qualified scientists and technicians who are motivated and have experience in innovative activity in a company, it is easier for the said company to generate ongoing innovations over time (Galende, 2006). Managers of firms attempting to develop radical innovations are face with the need to attract and motive expert staff to work on complex problems. They often employ performance-based incentives schemes and employee ownership plans to induce employees to commit to solve organizational problems (Casper and Whitley, 2004). In this sense, high-commitment or high-involvement human resources practices help to create a work force which is motivated and highly committed to the organisation's aims. These practices include, among other things, worker participation, a concern for their training and selection processes. In contrast to more traditional practices which seek to control workers so that they reflect specific previously defined

performance levels (Walton, 1985), management of high-commitment staff is intended to improve the worker's skills and increase his motivation. There are various studies in literature that relate the said practices to workers leaving their jobs (Arthur, 1994; Huselid, 1995; Guthrie, 2001), to productivity (Ichniowski, Shaw and Prennushi, 1997; MacDuffie, 1995; Huselid, 1995), to financial profits (Delery and Doty, 1996), to survival (Welbourne and Andrews, 1996), to the value of the company (Huselid, 1995; Huselid and Becker, 1997) and to organisational performance (Delaney and Huselid, 1996; Bae and Lawler, 2000).

If the company uses this type of human resources practices, its employees will be qualified and will be more motivated for ongoing innovation, which means that the company will be able to maintain its position of technological leadership with respect to its competitors and better appropriate the profits of its innovative activity, as the following hypothesis sustains:

H6: Companies that have better human resources than those of their competitors tend to choose ongoing innovation as a protection mechanism.

Figure 2 provides a synthesis of all the hypotheses proposed.

INSERT FIGURE 2 HERE

4. Methodology

4.1. Sample

In order to obtain data that will enable us to compare the proposed hypotheses, we chose a population of companies from the 2001 edition of the directory *Duns 50.000 de principales empresas españolas (50,000 main Spanish companies)*. The selection and information collection process was as follows. First of all, the sample was limited

exclusively to manufacturing companies (with SIC code between 20 and 39) of medium or large size (with turnover of more than 20 million Euros in 1999). With these two criteria, the intention was to guarantee that the companies being studied had developed a certain number of complex technologies which could possibly present problems for the total knowledge by its competitors. There were 1967 companies that met both these criteria simultaneously.

Second, as the information provided by the above-mentioned directory was insufficient for the needs of our research, we sent a questionnaire to each of the 1967 firms. The format and content of the questionnaire were initially developed from a thorough literature review and pretested using doctoral students, faculty and business executives. In particular, a group of six business executives participated in a pretest phase by completing an advanced version of the questionnaire and by offering criticisms and suggestions for improving it.

The questionnaire was directed at the chief executive (CEO), considered to be the person most qualified to respond to the questions and with easiest access to the information required. Thus, during the data collection period of the first semester of 2002, 253 valid questionnaires were received, representing a sample error of ±5,80% and a confidence level of 95%. Most of the sample firms were in the range of 101 and 250 employees and approximately 52 percent of the firms had sales for more than 40 million of euros. In order to test if the sample was statistically representative of the population, we carried out several χ^2 tests. The results showed that the sample was representative of the population for activity sectors (χ^2=31,345; p=0,068), sales (χ^2=8,304; p=0,081) and number of employees (χ^2=10,556; p=0,061).

4. 2. Variable Measures

With reference to the measurement of the variables included in the study, we mostly used subjective measures, provided by the responses given by the directors to a series of indicators that were considered in the questionnaire. Appendix A includes the indicators used for measuring each variable implied in the research. As it can be seen, the appropriation mechanisms were measured using ordinal scales that went from 1 (the company does not use them) to 7 (the company always uses them) using one indicator for each of the mechanisms following previous studies (Levin et al., 1987; Harabi, 1995; Hurmelinna et al., 2005; Galende, 2006). In the same way, the characteristics of the technology were also measured through ordinal scales using three indicators to compute the complexity of the knowledge, extracted and modified from the studies of Zander and Kogut (1995) and Simonin, (1999), five to assess its codification, taken from the studies of Zander and Kogut (1995), Simonin (1999), King and Zeithaml (2001) and Schulz and Lobe (2001) and four for the specificity attribute, some of them extracted from Simonin (1999) and some were self elaborated. The average sales obtained by the company in the last three years was used as the size indicator for the companies following previous studies (Arundel and Kabla, 1998; Cohen, Nelson and Walsh, 2000; Galende, 2006). The use of the average sales for these three years helped to mitigate the effects of possible extraordinary results. Finally, as a measure of high commitment HR practices, twenty seven indicators, taken from recent publications dealing with the subject, were used (Cutcher-Gershenfeld, 1991; Arthur, 1992; 1994; Kochan and Osterman, 1994; Huselid, 1995; MacDuffie, 1995; Delaney and Huselid, 1996; Delery and Doty, 1996; Bae and Lawler, 2000).

In order to get unbiased estimators, we selected some control variables considered to be related to some of the variables in the study. In this way, we could

prove that depending on the sector in which the company operates, the protection mechanism it uses will be different. Therefore, companies that operate in certain sectors, such as the pharmaceutical sector, could be more accustomed to using patents as a protection mechanism against imitation. The percentage of innovations that are patented should vary by sector because of differences in the value of patents as a means of appropriating investments in innovation (Levin et al., 1987; Arundel et al., 1995; Harabi, 1995, Thumm, 2004). For this reason, 17 dummy variables were included in the model representing the 18 different sectors to which the companies in the sample belonged, according to the classification provided by the SIC codes at the two digit level. The number of sectors to which the companies in the sample belonged was smaller than in the initial population, going from 20 to 18, since it was not possible to get a response from companies that belonged to sectors 21 and 25 according to the SIC classification.

In order to assess the reliability of the scales proposed for the case of characteristics of technology and human resources practices, we calculated the Cronbach alpha coefficient for each of these variables. The values obtained are listed in Appendix 1. These coefficients shows us that all variables have been measured reliably (the alpha coefficient is higher than 0.70) except in the case of technology specificity. Therefore, since we do not have a reliable measure for this last variable, we should not use it in subsequent analyses, which means that hypothesis H_4 regarding the effect of specificity of technological knowledge on the use of industrial secret as an appropriation mechanism cannot be tested.

5. Results

Using the data obtained, we have first carried out an exploratory study in order to get an initial idea of how and to what extent Spanish companies protect their innovations. Figure 3 shows the average level of use of the four appropriation mechanisms proposed in this research, valued on a scale of 1 (the company does not use this mechanism) to 7 (the company always uses this mechanism).

INSERT FIGURE 3 HERE

Continuous innovation that enables companies to keep their competitors behind is the mechanism most commonly used by the sample companies, with a point's score of 5.58. This result coincides with the results of previous studies which also test the importance of this method empirically (Shaw, 1986; Levin et al., 1987; Levin, 1988; Harabi, 1995; Arundel, 2001; Cohen et al., 2002; West and Iansiti, 2003). The second most commonly used mechanism is imitation cost and time with mean use of 5.12. This result is consistent with the study carried out by Brouwer and Kleinknecht (1999) which recognises the importance of this mechanism as a method for appropriating the results of innovative activity carried out by companies. Industrial secret is the third most frequently used mechanism, with a score of 5.04. The studies of Brouwer and Kleinknecht (1999), Arundel (2001) and Cohen et al. (2002) underline the greater use of industrial secret as opposed to patents as a protection mechanism. The last place is occupied by patents, with a score of 4.79. This indicates that this method is the least used by Spanish manufacturing companies, confirming the results obtained in the research of Harabi (1995) and Brouwer and Kleinknecht (1999). In this sense, patents are increasingly perceived in many industrial sectors as being a rather ineffectual means of appropriating economic benefits from appropriation (Hanel, 2006).

We have also studied the relationship between the size of the company and the sector to which it belongs with the chosen protection method. Table 1 shows, according to the size of the company, the average score obtained for each of the protection methods studied. Here we can appreciate that as the size of the company increases, the use of the patent system increases, especially for the last two size intervals considered. The relationship between firm size and the use of patents has been considered in some previous studies (Brouwer and Kleinknecht, 1999; Kingston, 2001; Arundel, 2001), the results obtained being similar to those found in those studies.

INSERT TABLE 1 HERE

According to the sector of activity, Table 2 shows the average score given to each mechanism by industrial sectors. We can see a certain tendency to using the patenting system in the chemical and electronic sectors, while this system is used little in the textile and timber sectors. These results coincide with the findings of previous studies (Levin et al., 1987; Harabi, 1995; Brouwer and Kleinknecht, 1999, Arundel and Kabla, 1998) in which the effectiveness of the patents in sectors such as chemicals and pharmaceuticals is highlighted.

INSERT TABLE 2 HERE

In order to summarise the data obtained for both the characteristics of the technology, disregarding specificity, and for high-commitment human resources policies, two factorial analyses were carried out, one on the indicators used to measure the codification and complexity of technology variables and another on the questions related to the human resources variable. Both analyses were carried out following the principal components method and in order to obtain more easily interpretable results, we applied a factor rotation using the varimax method with Kaiser normalisation.

Table 3 shows the matrix of rotated components, the communalities, the initial eigenvalues, and the percentage of variance accounted for each component used for the case of characteristics of the technology. As can be seen, the analysis resulted in two factors, each of which grouped the indicators corresponding to one attribute of knowledge. Once the factors corresponding to the characteristics of the technology were detected, the factor scores of all the firms were noted for each factor.

INSERT TABLE 3 HERE

In the same way, Table 4 shows the matrix of rotated components, the communalities, the initial eigenvalues, and the percentage of variance accounted for each component for the factorial analysis carried out on the indicators relative to high commitment HR practices. Based on this matrix, the following conclusions become available:

1. In the case of the first factor, it is easy to observe the significance of those indicators that refer to the degree of motivation of employees, to the amount of information shared by them and to the existence of an atmosphere of high cooperation and trust inside the firm. Thus, such variables would seem to imply the existence of a good climate in the firm, as employees are motivated and the environment is favourable. For these reasons, this factor was named CLIMATE.
2. The items referred to employee training plans carried out by the company and to concern about safety at work are outstanding in connection with the second factor. This would seem to indicate that the company takes care of the staff, especially as far as training is concerned. Therefore, this factor was named TRAINING.

INSERT TABLE 4 HERE

3. The third factor pay attention to items such as the ones referring to the existence of mechanisms and processes intended to increase the motivation of employees and to the existence of problem-solving groups and mechanisms that support new ideas (quality circles and suggestion systems). So, this factor seems to imply the existence of mechanisms that enhance innovation and creativity. Therefore, this factor was named INNOVATION SUPPORT.
4. The fourth factor is represented by the indicators referring to the reward policies used by the company and to results-based performance appraisal. It could refer to the existence of a pay system especially based on results. For this reason, the factor has been named RESULTS-BASED COMPENSATION.
5. The fifth factor is only formed by items that refer to the selection processes applied by the company and is therefore named SELECTION.
6. In the case of factor number 6 it is easy to observe that significant items are those that refer to the existence of different wages for the same task and behaviour-based performance appraisal. It could refer to the existence of a pay system especially based on behaviour, which justifies a variety of salaries for the same job. Therefore, this factor has been named BEHAVIOUR-BASED COMPENSATION.
7. Finally, the seventh and last factor is formed by the indicators that refer to a broad design of jobs, i.e. that the jobs in the firm include a great variety of tasks and there is rotation of such jobs. This factor has been named JOB DESIGN.

Once we have completed the reduction of data referring to the indicators that measured the high commitment HR practices used by the company, the factor scores of all the firms were noted for each factor. Subsequently, following Bae y Lawler (2000) and Guthrie (2004) we construct an index measure for high involvement human resource practices based on the factor scores noted for each firm. In that way, we create a new variable, that is, high involvement human resource practices that adopted seven possible values. In order to distinguish whether a firm uses or not a particular factor of practices we compare each firm factor score to the average score of the same factor corresponding to the 258 firms of the sample. Since the average of each factor is 0 because they are resulted from a factor analysis, the new variable takes value 0 when the firm has not any factor score greater than 0 that means that the firm uses the high involvement practices in a less intensive way than the average of the firms. In the opposite side, the variable takes value 7 when the firm presents seven factor scores greater that 0. This indicates that that company uses the human resource practices related to each factor in a more intensive way that the average of the firms. So, a high score on the human practices measure indicates relatively intensive use and investment in high involvement human resource practices. On the other hand, lower scores on this measure indicate less intensive use of high involvement human resource practices.

The use of a single high involvement human resource practices index is supported by arguments made by Becker and Huselid (1998) who agree with the extant practice in the empirical literature that an index derived form prior empirical work is the more appropriate measure of the HRM since a single index reflects the notion of a single HRM system as a strategic asset.

Finally, in order to explain the determining factors of the proposed protection methods, we carried out a multiple regression analysis. In total, four regressions were carried out, in each of which one appropriation mechanism was used as a dependent variable. Table 5 shows the results.

INSERT TABLE 5 HERE

This first regression analysis took the use of patents as the dependent variable and codification of knowledge and firm size as independent variables. It also used the industrial sector to which each company belonged as a control variable. The results indicate that the independent variables explain 13% of variance of the dependent variable. Furthermore, both the coefficient related to codification of knowledge and that corresponding to the size of the company were significant and positive. So, hypotheses H_1 and H_5 can not be rejected. That means that firms that use explicit type knowledge tend to use the patenting system as the mechanism to protect their innovations, which coincides with the results obtained by Nieto and Pérez-Cano (2004). Moreover, larger companies use the patenting system more often than smaller firms, which also coincides with the results obtained in studies by Brouwer and Kleinknecht (1999) and Arundel (2001).

The dependent variable in the second regression analysis was the use of industrial secret as a mechanism for appropriation and codification of knowledge, specificity of the same and development of process innovations were the independent variables. As we can see, these independent variables explain more than 15% of the variance of the dependent variable. The coefficient associated with the codification of knowledge variable was significantly different from 0 and negative. Thus, hypothesis H_2 can not be rejected. In this way, companies that use tacit knowledge choose

industrial secret as a mechanism to protect them against their competitors, a fact that is also reflected in some previous studies (Nieto and Pérez-Cano, 2004).

The third regression analysis carried out includes the use of imitation cost and time as a protection mechanism as a variable to be explained, and complexity of technological knowledge as an explanatory variable, with a view to test hypothesis H_3. Given that the coefficient turned out to be positive and significantly different from 0, the said hypothesis can not be rejected.

Finally, a regression analysis was carried out in which the use of continuous innovation as a protection method was used as a dependent variable and high-commitment human resources practices were used as an independent variable. The coefficient associated to these practices is positive and statistically different from 0. Thus, hypothesis H_6 can not be rejected.

6. Conclusions

This study has analysed the influence of several factors (characteristics of knowledge, size and human resources policy) on the different mechanisms used by companies in order to protect their technological innovations from imitation by their competitors. As Arundel suggests (2001:614), the aim is to analyse the factors, besides size, that affect the choice of the different mechanisms of appropriation. With this aim in mind, a specific analysis model is proposed which includes several hypotheses to be tested. In order to contrast these hypotheses, we use a sample of 253 Spanish firms.

First of all, a descriptive analysis was carried out in order to have an initial approximation of the protection methods used by Spanish companies. In this way, it became clear that the method most commonly used by Spanish manufacturing companies is continuous innovation, which enables them to keep a position of

technological leadership with respect to their rivals. This result is similar to the results obtained in previous studies (Levin et. al., 1987; Harabi, 1995; Arundel, 2001; Cohen et al., 2002; West and Iansiti, 2003). The second most commonly used protection mechanism in Spanish companies was complexity of technology, which reflects that found in the study carried out by Brouwer and Kleinknecht (1999) in which the importance of this mechanism as a method of appropriating the profits of innovative activity carried out by companies is recognised. The third most commonly chosen mechanism for appropriation in Spanish companies is industrial secret. In this sense, the studies by Brouwer and Kleinknecht (1999), Arundel (2001) and Cohen et al. (2002) underline the greater use of industrial secret as opposed to patents as a protection mechanism. The patenting system is the last position, which shows that it is the least used mechanism in Spanish manufacturing companies, which also confirms the results obtained in the studies by Harabi (1995) and Brouwer and Kleinknecht (1999).

Later, in order to test the proposed hypotheses, four regression analyses were carried out, each of which took one of the proposed appropriation mechanisms as a dependent variable. In this way, it was possible to check how companies who use explicit type knowledge chose the patenting system as a defence mechanism, while those companies in which tacit type knowledge predominates tend to opt for industrial secret. These results are logical from an intuitive point of view since when knowledge is tacit, it remains in the mind of individuals and in the relationships established between them, and it is easier to keep it in secret inside the company. Furthermore, even if tacit knowledge goes beyond the bounds of the organisation, it will be difficult for competitors to duplicate it exactly due to its tacit nature. In the same way, it can be seen that the companies with most complex knowledge benefit from the cost and time that

duplicating this knowledge requires. These results are similar to those found in the study by Nieto and Pérez-Cano (2004).

It can also be seen that larger companies tend to choose the patenting system as a protection mechanism. In the same way, we have also been able to prove the hypothesis that companies that use high-commitment human resources practices use continuous innovation or technological leadership as a protection mechanism as this enables them to always remain one step ahead of their competitors in the development of innovations. This is the most novel result of this study since there are no previous studies that analyse this relationship. However, it results logical from an intuitive point of view because since high-commitment human resources policies promote the commitment and involvement of employees in the objectives of the company, they can motivate firm employees to the ongoing development of innovations.

The most important contribution of this study to business is that it provides practical suggestions concerning appropriability. Unlike other transactions among firms, there are many critical interrelated factors that affect the choice of protection mechanisms. In that sense, this study goes into some of these crucial factors.

Specifically, from our findings we might advance several suggestions to help managers to protect their innovations against their competitors. On the one hand, this study deals with the attributes of firm´s technology. Identifying such attributes will enable the firm to choose the most effective appropriation method to protect its innovations. Moreover, we found that larger firms tend to choose patenting system more often than smaller firms. This can also help managers in their appropriation mechanisms´choice. Finally, this study highlights the role that human resource practices play in protecting innovations. If a manager uses high involvement human resource

policies to manage people, he should choose continuous innovation as protection mechanism. Moreover, our results are relevant for governments involved in designing and implementing innovation policies. Since continuous innovation is the most effective mean of capturing and protecting competitive advantages of innovations for Spanish firms, and therefore a crucial factor for the long term success of firms and industries, it is necessary for government to take all possible measures to speed up the whole innovation process.

One of the main limitations of this study is that it has not considered the possession and use of the complementary resources of innovations developed by the company as a protection mechanism like in previous studies (Teece, 1987, 1988; Cohen et al. 2002; Nieto and Pérez-Cano, 2004; Galende, 2006). Although at the beginning the intention was also to study the factors that determine the choice of this mechanism and for this reason it was included in the questionnaire sent to the companies, its analysis was not possible due to the small number of responses obtained for this mechanism. Another significant limitation lies in the fact of having considered the information at a company level and not at an innovation level since, depending on the characteristics of the innovation developed companies could choose one protection mechanism or another.

Finally, future research that could be derived from this work include going deeper into the different relationships found in this work, particularly that which exists between the high-commitment human resources policies and continuous innovation as a method of appropriation.

Acknowledgements

This study was carried out with the financial support obtained from the Fundación Banco Herrero (Research Aids 2005) for the research project Protecting innovations: appropriation mechanisms and determining factors.

Biographies of the authors

Nuria González-Álvarez is an Associate Professor of Strategic Management at the University of Leon, Spain. She holds a Ph.D. in Management from the same university. Her research interests concerns innovation and inter and intra-firm competencies transfer and imitation and she has published in several journals such us International Journal of Technology Management and Industrial Management and Data System.

Mariano Nieto is a Professor of Strategic Management at the University of Leon, Spain. His most recent research is on knowledge management and innovation and he has contributed to publications in periodicals such as Technological Forecasting and Social Change, International Journal of Technology Management and Technovation.

References

Arrow, K., 1962. Economic welfare and the allocation of resources for invention, in: Nelson, R. R. (Ed), The Rate and Direction of Inventive Activity, Princenton University Press, Princenton, New York, 609-625.

Abernathy, W. J., Wayne, K., 1974. Limits of the learning curve. Harvard Business Review 52, 109-119.

Arora, A., 1997. Patents, licensing, and market structure in the chemical industry. Research Policy 26, 391-403.

Arthur, J., 1992. The link between business strategy and industrial relations systems in American steel minimills. Industrial and Labor Relations Review. 45, 488-506.

Arthur, J., 1994. Effects of human resource systems on manufacturing performance and turnover, Academy of Management Journal. 37, 670-687.

Arundel, A., 2001. The relative effectiveness of patents and secrecy for appropriation, Research Policy 30, 611-624.

Arundel, A., Kabla, I., 1998. What percentage of innovative activity is patented?, Research Policy 27, 127-141.

Arundel, A., van de Paal, G., Soete, L., 1995. Innovation strategies of europe´s largest industrial firms: results of the PACE Survey for information sources, public research, protection of innovations and government programmes. Directorate General XIII, European Commission, EIMS Publication 23.

Bae, J., Lawler, J.J., 2000. Organizational and HRM strategies in Korea: impact on firm performance in an emerging economy. Academy of Management Journal 43, 502-517.

Barney, J. B. 1986b. Organizational culture: can it be a source of sustained competitive advantage?. Academy of Management Review 11, 656-665.

Barney, J. B., 1986a. Strategic factor markets: expectations, luck and business strategy. Management Science 32: 1231-1241.

Barney, J. B., 1991. Firm resources and sustained competitive advantage. Journal of Management 17, 99-120.

Barney, J. B., 2001. Is the resource-based view a useful perspective for strategic management research? Yes. Academy of Management Review 26, 41-56.

Becker, B., Huselid, M., 1998. High Performance Work Systems and Firm Performance: A Synthesis of Research and Managerial Implications, Research in Personnel and Human Resources Management, JAI Press, Greenwich, 53-101.

Blind, K, Edler, J., Frietsch, R., Schmoch, U., 2006. Motives to patent: empirical evidence from Germany. Research Policy 35, 655-672.

Brockhoff, K. 2003. Exploring strategic R&D success factors. Technology Analysis & Strategic Management 15 (3), 333-348.

Brouwer, E., Kleinknecht, A., 1999. Innovative output, and a firm propensity to patent. An exploration of CIS micro data. Research Policy. 28, 615-624.

Casper, S., Whitley, R. 2004. Managing competences in entrepreneurial technology firms: a comparative institutional analysis of Germany, Sweden and the UK. Research Policy 33, 89-106.

Cohen, W. M., Goto, A., Nagata, A., Nelson, R. R., Walsh, J. P., 2002. R&D spillovers, patents and the incentives to innovate in Japan and the United States. Research Policy 31, 1349-1367.

Cohen, W. M., Nelson, R. R., Walsh, J. P., 1998. Appropriability conditions and why firms patent and why they do not in the American manufacturing sector. Carnegie Mellon University, Pittsburgh, Mimeo.

Cohen, W. M., Nelson, R. R., Walsh, J.P., 2000. Protecting their intellectual assets: appropriability conditions and why US manufacturing firms patent (or not). NBER Working Paper no. 7552

Cutcher-Gershenfeld, J.C., 1991. The impact on economic performance of a transformation in workplace relations. Industrial and Labour Relations Review 44, 241-260.

Delaney, J.T., Huselid, M.A., 1996. The impact of human resource management practices on perceptions of organizational performance. Academy of Management Journal 39, 949-969.

Delery, J.E., Doty, D. H., 1996. Modes of theorizing in strategic human resource management: tests of universalistic, contingency and configurational performance predictions. Academy of Management Journal 39, 802-835.

Dosi, G., 1988. Sources, procedures, and microeconomic effects of innovation, Journal of Economic Literature 26, September, 1120-1171.

Duns & Bradstreet España, 2001. Duns 50.000 Principales Empresas Españolas. Madrid.

Durack, K. T., 2004. Tacit knowledge in patent applications: observations on the value of models to early US Patent Office practice and potential implications for the 21st century. World Patent Information 26, 131-136.

Galende, J. 2006. The appropriation of the results of innovative activity. International Journal of Technology Management 35 1/2/3/4, pp. 107-135.

Galunic, D. C., Rodan, S., 1998. Resource combinations in the firm: knowledge structures and the potencial for schumpeterian innovation. Strategic Management Journal 19, 1193-1201.

Garud, R., and Nayyar, P., 1994. Transformative capacity: continual structuring by intertemporal technology transfer. Strategic Management Journal 15, 365-385.

Geroski, P. A., 1995. What do we know about entry?. International Journal of Industrial Organization 13, 412-440.

Graham, S. J., Hall, B. H., Harhoff, D., Mowery, D. C., 2002. Post-issue patent "quality control": a comparative study of US patent re-examinations and European patent oppositions. Available at http://repositores.cdlib.org/cgi/viewcontent.cgi?article =1046&context=iber/econ.

Granstrand, O., 1999. The economics and management of intellectual property. Edward Elgar, Cheltenham.

Grant, R. M., 1996. Toward a knowledge-based theory of the firm. Strategic Management Journal, Winter Special Issue 17, 109-122.

Grant, R., 1996. Toward a knowledge-based theory of the firm, Strategic Management Journal 17 (Winter Special Issue), 109-122.

Grindley, P. C., Teece, D. J., 1997. Managing intellectual capital: licensing and cross-licensing in semiconductors and electronics. California Management Review 39, 8-41.

Guthrie, J.P., 2001. High involvement work practices, turnover and productivity: evidence from New Zeland. Academy of Management Journal 44, 180-191.

Hall, B., Ziedonis, R. M., 2001. The patent paradox revisited: an empirical study of patenting in the US semiconductor industry, 1979-1995. RAND Journal of Economic 32, 101-128.

Hall, R., 1992. The strategic analysis of intangible resources. Strategic Management Journal 13, 135-144.

Hanel, P. 2006. Intellectual property rights business management practices: a survey of the literature. Technovation, in press.

Harabi, N., 1995. Appropriability of technical innovations: an empirical analysis. Research Policy 24(2), 981-992.

Harter, J. F. R., 1993. The propensity to patent with differentiated products. Southern Economic Journal 61, 195-200.

Heller, M. A., Eisenberg, R. S., 1998. Can patents deter innovations?. Science 280, 671-698.

Hertzfeld, H. R., Link, A. N., Vonortas, N. S., 2006. Intellectual property protection mechanisms in research partnerships. Research Policy 35, 825-838.

Hirshmann, W. B., 1964. Profit from the learning curve. Harvard Business Review 42, 116-130.

Hoopes, D. G., Madsen, T. L., Walker, G., 2003. Why is there a resource-based view? Toward a theory of competitive heterogeneity. Strategic Management Journal. 24 (Special Issue), 889-902.

Horstmann, I., MacDonald, G. M., Slivinski, A., 1985. Patents as information transfer mechanisms: to patent or (maybe) not to patent. Journal of Political Economy 93, 837-858.

Hurmelinna, P., Kylaheiko, K., Jauhiainen, T., 2005. The Janus face of the appropriability regime in the protection of innovations: theoretical re-appraisal and empirical analysis. Technovation, in press.

Huselid, M. A., 1995. The impact of human resource management practices on turnover, productivity, and corporate financial performance. Academy of Management Journal 38, 635-670.

Huselid, M.A., Becker, B. E., 1997. The impact of high performance work systems, implementation effectiveness, and alignment with strategy on shareholder wealth, Unpublished paper, Rutgers University, New Brunswick, NJ

Ichiniowski, C., Shaw, K., Prennushi, G., 1997. The effects of human resource management policies on productivity: a study of steel finishing lines. American Economic Review 87, 291-313.

Itami, H., 1987. Mobilizing invisible asset, Harvard University Press, Cambridge, MA.

Kauffman, S. A., 1993. The origins of order. Oxford University, New York.

Kingston, W., 2001. Innovation needs patents reform. Research Policy 30, 403-423.

Kochan, T.A., Osterman, P., 1994. The mutual gains enterprise, Harvard Business School Press, Boston, MA

Kortum, S., Lerner, J., 1999. What is behind the recent surge in patenting?. Research Policy 28, 1-22.

Levin, R. C., Klevorick, A. K., Nelson, R. S., Winter, S. G., 1987. Appropiating the returns from industrial research and development. Brooking Papers on Economic Activity 3, 783-820.

Levin, R., 1988. Appropiability, R&D spending, and technological performance, American Economic Review 78 (2), 424-428.

MacDuffie, J. P., 1995. Human resource bundles and manufacturing: performance: Organizational logic and flexible production systems in the world auto industry. Industrial and Labour Relations Review 48, 197-221.

Makadok, R., 1998. Can first-mover and early-mover advantages be sustained in an industry with low barriers to entry/imitation?. Strategic Management Journal 19, 683-696.

Malerba, F., Torrisi, S., 1992. Internal capabilities and external networks in innovative activities: evidence from the software industry. Economics of Innovation and New Technology. 2,49-71

Mansfield, E., 1986. Patents and innovations: An empirical study. Management Science 32 (2), 173-181.

Mansfield, E., Schwartz, M., Wagner, S., 1981. Imitation costs and patents: an empirical study. The Economic Journal 91, 907-918.

Maurer, S. D., Zugelder, M. T., 2000. Trade secret management in high technology: a legal review and research agenda. The Journal of High Technology Management Research 11, 155-174.

McLennan, W., 1995. Innovation in Australian manufacturing 1994. Australian Bureau of Statistics, Canberra, catalogue no. 8116.0.

Nelson, R. R., Winter, S. G., 1982. An Evolutionary Theory of Economic Change, Harvard University Press, Cambridge, MA

Nieto, M., Pérez-Cano, C., 2004. The influence of knowledge attributes on innovation protection mechanisms. Knowledge and Process Management 11(2), 117-126

Nonaka, I., Takeuchi, N., 1995. The knowledge-creating company, Oxford University Press, New York.

Ordover, J. A., 1991. A patent system for both diffusion and exclusion. Journal of Economic Perspectives 5, 43-60.

Pavitt, K., 1987. The objectives of technology policy. Science and Public Policy 14 (4), 182-188.

Peteraf, M. A., 1993. The cornerstones of competitive advantage: a resource based-view, Strategic Management Journal. 14, 179-191.

Pitkethly, R. H., 2001. Intellectual property strategy in Japanese and UK companies: patent licensing decisions and learning opportunities. Research Policy 30, 425-442.

Polanyi, M., 1962. Personal knowledge: towards a post-critical philosophy, Chicago University Press, Chicago, IL.

Rauch, L., 1995. Estimates from the manufacturer´s innovations survey pilot. National Science Foundation, Washington, DC., April, Mimeo.

Reed, R., Defillipi, R., 1990. Causal ambiguity, barriers to imitation and sustainable competitive advantage. Academy of Management Review 15, 88-102.

Rogers, E., 1962. The diffusion of innovations, Free Press, New York.

Saviotti, P. P., 1998. On the dynamics of appropriability, of tacit and of codified knowledge. Research Policy 26, 843-856.

Scherer, F. M., Ross, D. (Hrsg.), 1990. Industrial market structure and economic performance, 3rd ed. Geneva, Dallas.

Scotchmer, S., Green, J., 1990. Novelty and disclosure in patent law. RAND Journal of Economics 21, 131-146.

Shapiro, C., 2001. Navigating the patent thicket: cross licenses, patent pools and standard-setting. Available at http://haas.Berkeley.edu/shapiro/thicket.pdf.

Shaw, B. 1986. Appropriation and transfer of innovation benefit in the U. K. medical equipment industry. Technovation 4, 45-65.

Simon, H. A., 1962. The architecture of complexity. Proceedings of the American Philosophical Association 106, 467-482.

Sorenson, O., Rivkin, J. W., Fleming, L., 2006. Complexity, networks and knowledge flow. Research Policy 35, 994-1017.

Spender, J. C., 1996. Making knowledge the basis of the dynamic theory of the firm. Strategic Management Journal 17, 45-62.

Takalo, T., Kanniainen, V., 2000. Do patents slow down technological progress? Real options in research, patenting, and market introduction. International Journal of Industrial Organization 18, 1105-1127.

Teece, D., 1987. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy, in: Teece, D. (Ed.), The Competitive Challenge. Ballinger Publishing, Cambridge, MA, pp. 185-219.

Teece, D., Pisano, G., y Shuen, A., 1997. Dynamic capabilities and strategic management. Strategic Management Journal 18, 509-533.

Thumm, N., 2004. Strategic patenting in biotechnology. Technology Analysis & Strategic Management. 16 (4), 529-538.

Thumm, N., 2005. Patents for genetic inventions: a tool to promote technological advance or a limitation for upstream inventions?. Technovation 25, 1410-1417.

Torrisi, S., 1998. An international study of the software industry, Edward Elgar, Cheltenham, U. K.

Von Hippel, E., 1988. The Sources of Innovation, Oxford University Press, New York.

Walton, R., 1985. From control to commitment in the Workplace, Harvard Business Review 73(2), 77-84.

Welbourne, T.M., Andrews, A.O., 1996. Predicting the performance of initial public offerings: should human resource management be in the equation?. Academy of Management Journal 39, 891-919.

Wernerfelt, B., 1984. A resource-based view of the firm, Strategic Management Journal 5, 171-180.

West, J., and Iansiti, M., 2003. Experience, experimentation, and the accumulation of knowledge: the evolution of R&D in the semiconductor industry. Research Policy 32, 809-825.

Williamson, O. E., 1990. Comparative economic organization. The analysis of discrete structural alternatives. Working paper presented at the Law and Economics Workshop, University of Michigan, 26 April.

Winter, S. G., 1987. Knowledge and competence as strategic assets, in: Teece, D. (Ed.), The Competitive Challenge. Ballinger Publishing, Cambridge, MA, pp. 159-183.

Zander, U., Kogut, B., 1995. Knowledge and the speed of transfer and imitation of organizational capabilities: an empirical test. Organization Science 6, 76-92.

Appendix A

Measures of the variables used in the research

Appropriation mechanisms

Patents/Industrial Secret/Imitation Cost and Time /Continuous Innovation.

Tacitness of technological knowledge (5 items; α=0.74)

Our company has procedures manuals which describe all its processes and tasks/All the knowledge possessed by our company is contained in a manual or software/After business meetings, exhaustive reports are systematically produced regarding all the matters discussed/All the activities of our company can be performed successfully by following a manual/It would be easy for the staff of our company to produce a useful manual describing all the knowledge they possess.

Complexity of technological knowledge (3 items; α=0.79)

The resources, knowledge and skills possessed in our company are the combination of many technologies, routines, individuals and independent resources/Production of our products requires many resources, much knowledge and a great deal of skills/Production of our products requires different resources, knowledge and skills in each case.

Specificity of technological knowledge (4 items; α=0.48)

The resources, skills and knowledge of our company can only be used in the tasks for which they were designed/Our Company has made significant investments in assets or resources that will be useful to carry out specific activities/The majority of the tasks carried out in our company require staff with specific skills/Our assets or resources could only be sold to companies belonging to the same sector.

Size

Average sales obtained by the company in the last three years.

Human resources policies (27 items; α=0.90)

Our firm works hard to find the adequate people for each job/Our firm devotes quite a lot of time to staff selection processes/Our firm only selects employees having the necessary qualifications for the job/Our selection processes take into account the problem solution skills of each candidate/Our firm applies exhaustive processes to personnel training/Some training activities in our firm are addressed to employees that require technical skills/Some training activities in our firm are addressed to employees that need certain skills required for the solution of problems/Our employees assimilate the specific training we give them/In our firm, employee compensation is based on their skills/Our firm applies compensation systems based on individual performance/Our firms grants incentives based on group productivity/Salaries paid by our firm are high if compared with those paid by our competitors/Within the same level of work there is a wide range of salaries/The performance of our employees is assessed according to results/The performance of our employees is assessed according to their behaviour/Jobs in our firm require a great variety of skills and capabilities/The rate of rotation of jobs in our firm is high/Employees are allowed a certain degree of autonomy at work/Our employees take the performance of their task as a personal challenge/Our employees are highly motivated/Our firm has available mechanisms and procedures planned for an increase of employee motivation/Our employees share information/In our firm, there are groups of people whose task is to help solving problems/Quality circles intended to evaluate new ideas are used in our firm/Our employees have available some mechanisms -such as mail-boxes for suggestions- allowing them to contribute new ideas and development/A high cooperation and confidence climate is existing in our firm/Our firm is careful about conditions and safety at work.

Figure 1. Theoretical model

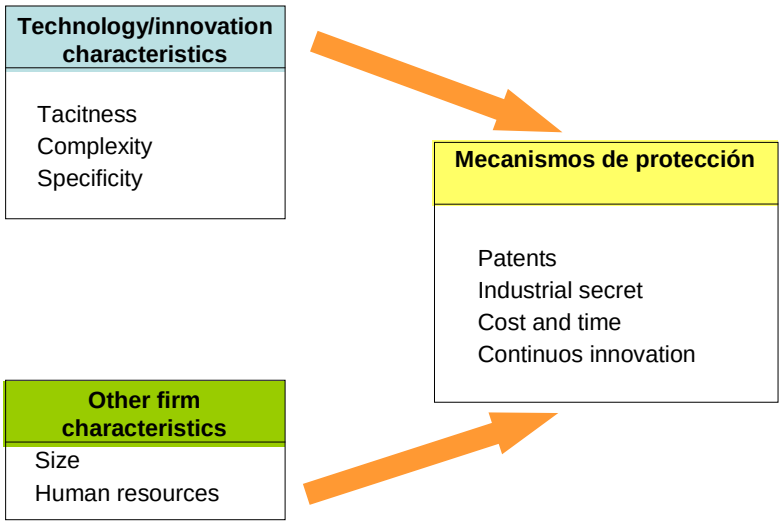

Figure 2. Hypotheses proposed

		Protection mechanism			
		Patents	Industrial Secret	Cost and time	Continuos innovation
Determining factors	Tacitness	+	-		
	Complexity			+	
	Specificity		+		
	Size	+			
	Human Resources				+

Figure 3. Degree of use of protection mechanisms

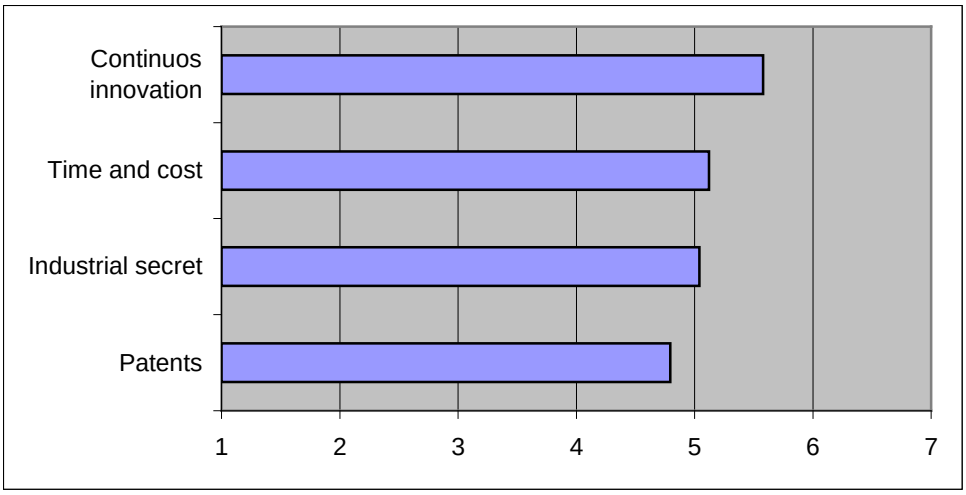

Table 1. Degree of use of protection mechanisms by size

Sales (mill €)	Number of firms	Patents	Secret	Cost and time	Continuos innovation
20-30	65	4.77	4.74	5.25	5.63
30.01-40	42	4.80	5.14	5.19	5.68
40.01-60	50	4.46	4.62	4.80	5.38
60.01-100	36	5.08	5.19	5.25	5.64
>100	60	4.91	5.55	5.13	5.58
Total	253	4.79	5.04	5.12	5.58

Table 2. Degree of use of protection mechanisms by sector activity

SIC	Activity sector	Number of firms	Patents	Secret	Cost and time	Continuos innovation
20	Food and Kindred Products	42	4.88	5.05	5.19	5.86
22	Textile Mill Products	9	5.11	5.89	5.22	6.00
23	Apparel and Other Textile Products	2	1.00	5.00	1.00	4.50
24	Lumber and Wood Products	2	2.50	3.00	4.00	3.00
26	Paper and Allied Products	5	3.80	4.20	4.80	5.20
27	Printing and Publishing	9	4.22	5.22	4.22	6.22
28	Chemicals and Allied Products	37	5.40	5.54	5.40	5.70
29	Petroleum and Coal Products	1	4.00	4.00	5.00	6.00
30	Rubber/Misc. Plastic Products	12	5.66	5.58	5.75	5.25
31	Leather and Leather Products	2	2.00	4.50	5.50	5.00
32	Stone. Clay. Glass and Concrete Products	21	3.90	4.62	4.80	4.76
33	Primary Metal Industries	10	3.80	5.30	4.70	4.90
34	Fabricated Metal Products	15	4.80	5.00	5.13	5.46
35	Industrial and Commercial Machinery and Computer Equip	26	4.81	4.57	4.65	5.65
36	Electrical Equipment and Components	21	5.47	4.95	5.47	5.90
37	Transportation Equipment	28	4.78	4.92	5.25	5.57
38	Measurement Analyzing. Control Instr and Related Prod.	6	5.17	5.17	6.17	6.17
39	Misc. Manufacturing Industries	5	1.58	1.48	0.83	0.71
	Total	253	4.79	5.04	5.12	5.58

Table 3. Factorial analysis. Knowledge attributes

ÍTEM[3]	COMPONENTS		COMUNALITIES
	1	2	
TAC1	**0.669**	-0.181	0.480
TAC2	**0.842**	-0.094	0.718
TAC3	**0.652**	-0.237	0.482
TAC4	**0.783**	0.099	0.623
TAC5	**0.714**	0.178	0.542
COM1	-0.022	**0.752**	0.567
COM2	-0.093	**0.850**	0.732
COM3	-0.016	**0.816**	0.666
% of variance	35.09	25.00	
Eigenvalue	2.81	2.00	

[3] These indicators are those that were used to measure knowledge tactiness and complexity. They are shown in appendix 1.

Table 4. Factorial Analysis. Human resource practices

ITEM[4]	COMPONENTS							COM
	1	2	3	4	5	6	7	
SEL1	0.153	0.472	-0.040	0.233	**0.626**	0.160	-0.052	0.72
SEL2	0.116	0.500	-0.040	0.167	**0.575**	0.218	-0.001	0.67
SEL3	0.170	0.170	-0.009	0.101	**0.744**	-0.030	-0.082	0.63
SEL4	0.068	0.046	0.110	0.199	**0.795**	0.072	0.128	0.71
TRN1	0.178	**0.705**	0.257	0.204	0.207	-0.018	0.142	0.70
TRN2	0.183	**0.701**	0.324	0.053	0.278	0.005	0.186	0.74
TRN3	0.240	**0.608**	0.409	0.121	0.145	0.010	0.111	0.64
TRN4	0.365	**0.598**	-0.114	0.244	-0.058	-0.040	-0.054	0.57
COMP1	0.101	0.048	0.154	**0.695**	0.303	0.071	-0.108	0.63
COMP2	0.033	0.122	-0.016	**0.818**	0.180	0.078	0.040	0.72
COMP3	0.271	0.030	0.161	**0.649**	0.018	0.008	0.092	0.53
COMP4	0.216	0.165	0.385	0.157	0.087	0.091	-0.427	0.45
COMP5	0.108	-0.118	0.013	0.102	0.071	**0.766**	0.094	0.64
APPR1	0.189	0.268	0.028	**0.683**	0.102	0.231	0.075	0.64
APPR2	0.124	0.123	0.205	0.148	0.084	**0.741**	0.053	0.65
JDSN1	0.118	0.178	0.110	0.196	0.330	0.086	**0.616**	0.59
JDSN2	0.135	0.045	0.054	0.011	-0.119	0.129	**0.739**	0.60
MOTI1	**0.736**	0.035	0.000	0.072	0.140	0.259	0.231	0.69
MOTI2	**0.806**	0.178	0.120	0.248	0.166	0.140	0.073	0.81
MOTI3	**0.738**	0.346	0.180	0.176	0.103	0.072	-0.153	0.77
MOTI4	**0.503**	0.247	**0.501**	0.302	0.067	0.089	0.023	0.70
OTHS1	**0.661**	0.214	0.333	0.086	0.184	-0.109	0.225	0.70
OTHS2	0.190	-0.005	**0.761**	0.020	0.112	-0.017	-0.005	0.63
OTHS3	0.129	0.210	**0.780**	0.140	-0.072	0.135	-0.009	0.71
OTHS4	0.043	0.380	**0.652**	-0.051	-0.056	0.140	0.150	0.62
OTHS5	**0.631**	0.334	0.386	0.111	0.028	0.054	-0.094	0.68
OTHS6	0.136	**0.622**	0.223	0.000	0.209	-0.031	-0.084	0.51
% of variance	31.86	8.82	6.74	5.30	5.06	4.10	3.40	
Eigenvalue	8.60	2.40	1.82	1.43	1.37	1.11	0.92	

[4] These indicators are those that were used to measure human resource practices. They are shown in appendix 1.

Table 5. Regression analysis. Protection mechanisms.

	Patents	Industrial secret	Cost and time	Continuos innovation
Constant	4.800***	4.955***	5.774***	5.457***
Knowledge characteristics				
Tacitness	0.311***	-0.219*	0.444***	
Complexity				
Size				
Sales	0.001**			
Human resources				
High involvement human resource practices				0.268***
Industrial sector				
		(S.23) -3.980***	(S.23) -	(S.23) –1.757*
		(S.31) -2.758*	4.768***	(S.24) -3.322***
			(S.27) -1.811**	(S.30) -1.189*
			(S.33) -1.145*	(S.32) -1.483*
			(S.35) -1.219*	(S.33) -1.360*
				(S.37) -0.980*
R^2	0.126	0.152	0.253	0.236
Adjusted R^2	0.054	0.086	0.195	0.171
F-value	1.758**	2.209***	4.365***	3.647***

*** p < 0.01; ** p < 0.05; * p < 0.10

Nuria González-Álvarez

Mariano Nieto-Antolín