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THE ROLE OF INTELLECTUAL CAPITAL MANAGEMENT ON INNOVATION PROCESS: DOES ONE SIZE FIT ALL?

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Abstract

Intellectual Capital Management (ICM) research has focused predominantly on demonstrating the link between ICM and innovative performance from a general, context-free perspective. This paper analyzes deeper implications of ICM showing the inadequacy of this one-size-fits-all approach, and introduces a more realistic view of the role of ICM on innovation process. We propose an analytical framework where differences in ICM strategies are explained by differences in the environment faced by firms and characterized by disparate levels of threats posed by potential imitators. Although legal protection of intellectual property rights has been traditionally the center of attention on this topic, the firm's strategy might be far more complex involving alternative ICM activities guided by the incentives of the environment. Using panel data for Spanish SMEs over the 5-year period between 2008 and 2012, we provide evidence consistent with this approach. Empirical analysis shows that certain ICM strategies are profitable in specific environments, but might be very unattractive in other contexts where other strategies prove to be more efficient. These findings contribute to the development of a more nuanced interpretation of the role played by ICM on the innovation process. Implications for management and policy are discussed.

Keywords: intellectual capital management; R&D; appropriability regime; innovation process

Resumen

La investigación sobre la Gestión del Capital Intelectual (ICM) se ha centrado en demostrar el vínculo entre el ICM y el desempeño innovador desde una perspectiva general, independientemente del contexto de la empresa. Este trabajo analiza las implicaciones de la ICM que muestran que una explicación general es insuficiencia. Proponemos un marco analítico donde las diferencias en las estrategias de ICM se explican por las diferencias en el entorno de las empresas, que se caracterizan por niveles dispares de las amenazas que plantean los potenciales imitadores de la innovación. Aunque la protección legal de los derechos de propiedad intelectual ha sido tradicionalmente el centro de atención en este tema, la estrategia de la empresa podría ser mucho más compleja, involucrando actividades alternativas encausadas por los incentivos específicos de cada entorno. Utilizando datos de panel para PYMES españolas en el período entre 2008 y 2012, se aportan pruebas consistentes con este enfoque. El análisis empírico muestra que ciertas estrategias ICM son rentables en entornos específicos, pero podrían ser al mismo tiempo muy poco atractivo en otros contextos en los que otras estrategias han demostrado ser más eficientes. Estos resultados contribuyen al desarrollo de una interpretación más matizada del papel desempeñado por la ICM en el proceso de innovación. Se discuten las implicaciones para la gestión empresarial y la política.

Palabras clave: gestión del capital intelectual; I+D; régimen de apropiabilidad; proceso de innovación

I. Introduction

Although there is a broad consensus about the importance of Intellectual Capital Management (ICM) as a source of value creation in today's economies, recent research suggests that the literature has focused predominantly on demonstrating the link between ICM and innovative performance from a general, context-free perspective (Mouritsen, 2006; Guthrie et al., 2012; Dumay and Garanina, 2013). As these authors state, this perspective is rooted on the mistaken believe that ICM will yield necessarily greater profits, regardless of the context where the empirical analysis takes places.

This paper analyzes deeper implications of ICM showing the inadequacy of this one-size-fits-all approach, and introduces a more realistic view of the role played by ~~of~~ ICM on innovation processes. We propose an analytical framework where the differences in ICM strategies followed by firms in order to profit from innovative activities are explained by differences in the environments they face and characterized by disparate levels of threats posed by potential imitators. Although legal protection of intellectual property rights has been traditionally the center of attention on this topic, the firm's strategy might be far more complex involving alternative ICM activities guided by the incentives of the environment. Under this approach some profitable ICM strategies in specific environments (e.g. patenting) might be, in contrast, very unattractive in other contexts where other strategies prove to be significantly more efficient (e.g. developing productive capabilities or market linkages). It is in this sense that we offer a context-dependent analysis of ICM rather than the one-size-fits-all approach prevalent in the literature.

A first step to advance towards a better understanding of the role of ICM on the innovation process is to go beyond the idea that for any innovator "the more knowledge the better". It is not difficult to find this type of approach in recent ICM research, posing context-free hypotheses like "the greater the human capital, the higher the innovative capability", or "intellectual capital enhances firm's performance"; or "the number of knowledge management practices is positively correlated with innovation propensity"; or "organizational capital is one of the main sources for firm innovation" (see, for example, Subramaniam and Youndt, 2005; Delgado-Verde, et al., 2011; Mangiarotti, 2012; Ling, 2013).

An important source of confusion comes from the fact that the innovation plan of a firm is often seen simply as an "invention plan" (typically, but not exclusively, an R&D plan); for example, a plan to develop a new product or process. This emphasis in the invention plan is evident in innovation policy prescriptions, generally linked to R&D activities. However, success in innovation cannot be assured if firms focus solely on inventive activities: an "appropriation plan" is also needed in order to profit from innovative activities. The simple argument that "the more knowledge the better" might be (although not necessarily) more appropriate for ICM relative to the invention plan, because an invention is more about creating applied knowledge and might be independent of the context of the firm. For example, a scientific plan for developing a new drug might be regarded as completely independent of the market structure in the pharmaceutical industry but, as we will argue, this is not clearly the case of the appropriation plan of a pharmaceutical company trying to commercialize this new drug. This paper focuses on the often overlooked, non-trivial role of ICM management in the appropriation strategy of the innovative firm.

Schumpeter (1950) and Arrow (1962) introduced the "appropriability problem" in the theoretical discussion of innovation, explaining that certain degree of monopoly might be

desirable to foster innovation. This theoretical problem has been typically used to justify the introduction of intellectual property rights to guarantee the appropriation of benefits from innovations. However, it is evident that legal protection of intellectual property rights are not a perfect strategy in certain contexts. Teece's (1986) seminal work, *Profiting from technological innovation*, showed that the appropriation strategy of innovators might be quite complex, involving managerial decisions conditioned by the environment. In particular, innovators' strategy must be shaped by what he called the "appropriability regime". This regime refers to the environmental factors, different from firm and market structure, that govern an innovator's ability to capture the profits generated by an innovation. According to Teece (1986), the most important dimensions of such a regime, are the nature of the technology and the efficacy of legal mechanisms of protection.

In this paper we integrate Teece's approach with the ICM literature to develop a non-trivial explanation of the role of ICM strategy in firms' innovation plans. In order to analyze typical responses of firms -in terms of ICM strategies- related to specific environments, we follow the sectoral taxonomy proposed by Castellacci (2008), that introduces differences in appropriability regimes, highlighting the relevance of different forms of intellectual property protection (patents, trademarks, or copyright) within each sector. Two sectors of activity, intimately related but with significant differences in their appropriability regimes, are used in our empirical analysis: hardware and software industries. The former relies significantly more on intellectual property protection than the later. Using panel data for Spanish SMEs over the 5-year period between 2008 and 2012, we show that certain ICM strategies are profitable in specific environments, but might be unattractive in other contexts where other strategies prevail. These findings contribute to the development of a more precise description of the role of ICM on the innovation process.

The rest of this paper is structured as follows. In the next section, a critique of the current state of ICM research is discussed, highlighting the fact that most of this work is rooted on the mistaken believe that ICM will yield necessarily greater profits, regardless the context where the empirical analysis takes places. Section III presents the use of Tecee's approach to explain the differentiated role of ICM, affecting innovation process not only through its role on the "invention plan", but also through the strategy followed by the firm to effectively appropriate the benefits generated by those inventions. Section IV discusses the approprability regime concept, emphasizing the way it might induce firms to adopt different ICM strategies. The research design and methods are explained in Section V. Section VI presents the results of the empirical analysis. Finally, we provide a discussion of the managerial and policy implications of such results in Section VII.

II. Intellectual capital and innovation: overcoming context-free theorizing

The concept of intellectual capital (IC), or intangible assets, is relatively new in the economic literature. It refers to those non-physical assets with three core characteristics: they are a source of probable future economic benefits, have no physical embodiment and, to some extent, may be retained and managed by companies (OCDE, 2011).

Although in the past the concept of intangible asset was primarily related to R&D and intellectual property rights (such as patents and trademarks), the extension of innovative activities to other areas beyond the purely technological ones has led to an expansion of this concept. Nowadays it is widely accepted that IC consists of three interrelated bodies of

knowledge: capabilities and skills of the members of the team; structured/codified knowledge owned by the firm (such as production processes, internal procedures, results of R&D activities, or intellectual property protection); and the set of relations established with other agents or organizations outside the firm. These three bodies of knowledge are usually called human capital, structural (or organizational) capital and relational capital, respectively (Cañibano et al., 2002).

The specialized literature has highlighted the effect of IC on the innovation process. Some authors have emphasized that organizations that develop and exploit effectively their IC have a competitive advantage (Steward, 1997). Becerra et al. (2008) state that an effective ICM can avoid unauthorized knowledge transfers, which is one of the major risks faced by innovative firms. Along the same lines, other recent studies have found a positive relationship between IC management and innovation (Henry, 2013; Kremp and Mairesse, 2009; Mangiarotti, 2012). Marvel and Lumpkin (2007) studied the role of experience, education and prior knowledge on innovation outcomes, and De Winne and Sels (2010) show that human capital (of managers and employees) and human resource management are important determinants of innovation in start-ups. There is a vast literature on the effect of R&D activities and patents on innovation performance, but we can also find studies on the effect of other kind of structured knowledge owned by the firm. As Huchzermeier and Loch (2001) pointed out, there are different sources of uncertainty in R&D activities (market payoffs, project budgets, product performance, market requirements, and project schedules), and management team's ability to adapt processes and procedures is key to improve risk management in R&D projects. Finally, there are several studies analyzing the relative impact of R&D collaborations and participation in networks on innovation performance (Ahuja, 2000; Reagans and Zuckerman, 2001; Belderbos, Carree and Lokshin, 2004; Czarnitzki and Ebersberger, 2007; Un, Cuervo and Asakawa, 2010).

The existing literature on intangibles has been primarily devoted to emphasize the impact of IC on firm performance in an ostensive/general way and also to design new methods to measure IC. These two main concerns of research practices corresponds to what Guthrie et al. (2012) denominate, respectively, the first and second stage of research on IC, focused on "revealing" the importance of intellectual capital to create competitive advantages, and on the design of indicators to measure and report IC within the firm. In both stages, the empirical evidence is insufficient or inconclusive, although there is a broad consensus on the importance of intangible assets as a source of value creation (Dumay and Garanina 2013, 12). As discussed in Dumay (2012), IC research has not reached the point where it can be stated that managing IC leads to greater profitability because of the inability to make causal links between IC and value creation.

This paper is ascribed to what Guthrie et al. (2012) calls the "third stage" of IC research. This new stage, just in its infancy, attempts to provide deeper managerial implications, avoiding the general and somehow tautological perspective that simply postulates that ICM boosts innovative performance across the board. We sustain that ICM is part of the business strategy to profit from innovative activities and this strategy is clearly conditioned by the firm's context. Our analysis focuses on differentiating between IC strategies of innovative firms in several contexts and rationalizing them as differences in business strategies to appropriate the benefits of their innovation activity. In this sense, our contribution to the literature is to unpack previous discussion on links between ICM and innovation, analyzing the role of ICM in a context-dependent strategy. This enables us to transcend the simple argument that "the more knowledge the better" and introduce the

analysis of ICM into high-level debates about profitability of specific IC strategies, organization and market structure, and public policy.

III. Intellectual capital, what for?

As stated before, much of the specialized literature has focused on demonstrating the link between ICM and innovative performance in a very general, context-free perspective. In fact, context-free theorizing has been very popular in management and accounting research (Llewelyn, 2003). However, little attention has been paid to the specific role played by each element of ICM in the strategy of the innovative firm, where the context conditions the complementarity or substitutability among them.

We follow the approach of Teece (1986), assuming that innovative firms are solving a problem: How to profit from their innovations? The contribution of Teece (1986) has to do with the different strategies that a firm can choose to guarantee the appropriation of the rents generated by innovations, conditioned by the characteristics of the knowledge embedded in the potential innovation (tacitness, complexity, observability), the legal instruments to protect innovations (patents, copyrights, designs, etc.), and the complementary activities or capabilities available to the innovator (such as marketing, competitive manufacturing, after-sales support, etc.). We argue that in order to understand the role of ICM in innovative activities, we need to be able to see how it fits in this different «appropriation strategies».

Elaborating on the argument of Teece (1986), there are at least to types of activities needed to profit from innovations:

- *Inventive activities*, to produce (or acquire) the "core knowledge" embedded in a potential innovation
- *Appropriation activities,* to profit from the creation of this core knowledge

It is obvious that not all firms engage in inventive activities (e.g. not all firms try to develop new products). And we've learnt from Teece that a successful innovation cannot be assured if the firms focus solely on inventive activities, given the need for managing and developing complementary assets in order to profit from innovation activities.

We propose to classify the role of the different ICM activities regarding their relation with these two types of activities. While certain ICM activities will be directly related with the innovation process, through their role in shaping and executing activities specifically aimed to the development of the core knowledge embedded in potential innovations (as context-free theorizing research has tried to prove), other activities might have a more complex, context-dependent relation with innovation process, e.g. providing services that might improve the ability of the innovative firm to appropriate the profits from its innovations in different specific contexts.

There are very good reasons to expect that ICM might be context-dependent, since the threats and opportunities for innovative firms might not be the same everywhere and the strategy of the firm must discriminate among ICM activities. For example, developing structural capital in the form of legal protection of intellectual property might be a good strategy for certain types of codified knowledge. However, this kind of strategy if far from perfect in other contexts, where priority should be given to protecting other types of knowledge and ensuring the profitability of R&D. Take, for instance, the case of tacit

knowledge flowing with the mobility of workers. In this case the management of human capital in the company might be essential to guarantee the appropriation of profits from R&D (Hurmelinna and Puumalainen, 2007; Hurmelinna et al., 2007; Casper and Whitley, 2004). Relational capital might also affect the ability of firms to appropriate the rents of innovation. As Henttonen et al. (2015) observe, collaboration with other partners for R&D activities might generate risks of spreading knowledge and misappropriation of the generated value. This risk can be managed by the firm using different strategies, alongside the mechanisms of protection of intellectual property: lead-time innovation, continuous incremental innovations, cost reduction of innovations, etc. (Pérez-Cano, 2013).

We consider that ICM activities must coordinate the firm strategy to profit from the creation of new knowledge, depending on the context of the firm. For example, in an "ideal" (but not necessarily desirable) context where legal framework offers perfect intellectual property protection, inventive activities might be sufficient for the innovative firm, since the new knowledge can be sold or licensed. In this sense, this innovative firm might not need to develop manufacturing capabilities, market linkages, or other type of complementary assets to profit from innovations. As we move away from this ideal case, the threat posed by imitators forces the innovative firm to develop more complex strategies. We assume that ICM strategy is a mixed combination of the following activities:

- Management of the development of the «core knowledge» embedded in a potential new product invention
- Intellectual property protection
- Management of production processes and organizational procedures
- Management of commercialization

While the first one is clearly an *Inventive activity*, the three remaining activities are what we denominate *Appropriation activities.* The attractiveness of each possible combination of these four activities will depend on the context faced by the firm, and ~~on~~ the nature of the innovation.

IV. ICM and appropriablity regimes

It was Schumpeter (1950) and Arrow (1962) who introduced the "appropriability problem" in the theoretical discussion of innovation, linking the profitability of innovation with the-market structure, in the sense that certain degree of monopoly might be desirable to foster innovation. This theoretical problem was conceptually tackled with the introduction of an ideal patent guaranteeing the appropriation of the benefits generated by innovations. However, as it is well known, legal protection of intellectual property fails to be efficient in certain contexts. As Teece (1986) argues, the appropriation strategy of innovators is far more complex, involving important managerial decisions conditioned by the environment.

As we stated before, the innovative firm tries not only to solve the problem of how to develop a new product (or process), but also to find a way to profit from this innovation. The strategy to successfully commercialize an innovation will be strongly conditioned by the environment of the firm. Teece (1986) illustrated how the concept of "appropriability regimes" is useful to understand the different types of environments or contexts faced by innovative firms.

The appropriability regime is a theoretical construction assessing the threats for innovative firms posed by potential imitators. This regime can move within a range that goes from "tight" to "weak", where the former indicates a regime where imitation is difficult (because of the legal framework or the complexity of the knowledge involved in the innovation), while the latter is a situation where it is easy for competitors to copy innovations.

Even though there might be different possible approaches to characterize differences in appropriability regimes within the economy, an important amount of literature has focused on sector-specific regimes (Breschi et al., 2000; Marsili and Verspagen, 2002; Malerba, 2002; Van de Poel, 2003; Dosi et al., 2006). More recently, Castellacci (2008) proposed a new sectoral taxonomy that highlights the relevance of different forms of intellectual property protection (patents, trademarks, or copyright) within each sector. For example, sectors like Electronics or Machinery rely substantially more on patents than sectors like Software or Engineering. These differences induce different needs from the perspective of ICM: where intellectual property protection is not a profitable strategy (as might be the case of these latter sectors of activity) other types of ICM must emerge to accomplish the goals of innovative firms. In Figure 1, we draw this possibility of differentiated profitability of ICM strategies as a function of the approprability regime.

V. Questions and research design

In this paper we posit that ICM activities cannot be studied through context-free theorizing, since this type of activities have an organic relation with the specific context faced by the firm. In this sense, and contrary to the tradition of literature relating ICM and innovation, we propose that not all ICM activities are necessarily desirable in all contexts, given the fact that some of them will have little effect on the general strategy of the innovative firm under certain conditions. To challenge this view we ask: does the appropiability regime faced by the firm influence the impact of ICM on innovation activities? And, if this is the case, is it possible to find clear patterns for ICM responses from companies, which can be explained by differences in appropiability regimes?

Most ~~of~~ analyses relating ICM with innovation processes use "output variables" such as innovation performance or sales. In this paper, we have chosen a different strategy studying the role of ICM on innovation process through its impact on other variable related also with IC activities: R&D expenditure. There are at least two good reasons for this choice.

Firstly, the advantage of using input variables is that they differ from output variables in the sense that they reflect an active attitude towards the attainment of innovations, and are not directly mixed with demand conditions for innovation, as is the case of variables such as innovation performance (Arqué-Castells, 2013). In this sense, most analyses involving performance measures might be using incorrectly specified models, since the explanation of innovation performance might require, besides the input variables, other measures representing demand conditions that are usually omitted in such models.

Secondly, based on Teece (1986), recent studies have highlighted the relevance of complementary knowledge and capabilities affecting the profitability of R&D investment, but the study of ICM as a complementary intangible asset in innovation process has been overlooked in empirical analysis. As we will argue, some IC activities are expected to have an intimate (maybe trivial) relation with the profitability of R&D investment since they are

directly connected with the development of the core knowledge embedded in potential innovations (e.g., R&D outsourcing, collaboration for R&D projects, acquisition of external knowledge such as patents, licenses or other technical knowledge, etc.). But there are other IC activities that are not related with this core knowledge, and therefore their role in innovation process (if any) is not straightforward and might show how innovation processes depend on other types of knowledge and capabilities, such as manufacturing capacities, managerial capabilities, marketing activities, and so on.

As ~~we~~ stated before, from an innovation perspective we might split the firm's activities in two different groups: *Inventive* and *Appropriation* activities, that is to say, activities to produce the core-knowledge embedded in innovations and activities to appropriate from the benefits of such innovations respectively. From an empirical point of view, when analyzing ICM as a determinant of private R&D investment, we must be aware of the distinction between these two kinds of activities. On the one hand, the relation of inventive activities with R&D profitability will be somehow trivial: inventive activities are clearly complementary to R&D activities, because R&D is one of them; so this relation might ~~be~~ just relate to the scale of the inventive plan of the firm. On the other hand, appropriation activities might be related (but not necessarily) with R&D profitability because they might be a part of the strategy of the firm to profit from R&D activities though the commercialization of R&D results.

The basic approach to R&D investment from a micro-level perspective is well developed (Howe and McFetridge, 1976; David, Hall and Toole, 2000). The starting point is the assumption that the firm sorts the existing R&D projects hierarchically according to their expected returns, in order to start investing in those considered more profitable. The marginal profit of R&D activities can be represented as a function involving marginal returns (MR) and marginal costs (MC), as presented in the following system:

$$F_i = MR_i(R_i, \boldsymbol{I}_i, \boldsymbol{X}_i, \boldsymbol{Z}_i) - MC_i(R_i, \boldsymbol{I}_i, \boldsymbol{X}_i, \boldsymbol{Z}_i), \quad for\ i = 1, \dots, n \tag{1}$$

where R_i is a scalar measure of R&D projects for *i-th* firm–as it is usual in conventional analysis, each project is implicitly taken as being finely divisible for expositional convenience. The vector $\boldsymbol{I}_i$ contains measures for inventive activities; vector $\boldsymbol{X}_i$ captures appropriation activities; $\boldsymbol{Z}_i$ are other factors possibly related with the profitability of R&D activities, such as technological opportunities, state of demand, institutional factors, technology policy, conditions and expectations impacting on internal and external cost of funds, etc. (see David, Hall and Toole, 2000).

A competitive equilibrium requires that $F_i = 0$, for all *i*. Regarding R_i, the "shift factors", $\boldsymbol{I}_i$, $\boldsymbol{X}_i$, and $\boldsymbol{Z}_i$, are assumed to displace de marginal profit function. Figure 2 illustrates this case, assuming that $F: \mathbb{R}^2 \to \mathbb{R}$. A shift in the use of input *X* from *X'* to *X''* generates new incentives to invest in R&D. The result is an increase of R&D activities of *R''*-*R'*.

Assuming that the output of R&D activities is a function with strictly decreasing returns of scale for each input, and a maximizing profit behavior, then we can interpret the relation between R&D activities and other inputs as a function[1]:

$$R_i = R_i(\boldsymbol{I}_i, \boldsymbol{X}_i, \boldsymbol{Z}_i), for\ i = 1, \dots, n \tag{2}$$

[1] By the implicit function theorem, these functions will exist if $\partial F/\partial R \neq 0$. It is easy to show that decreasing returns of scale guarantee that $\partial F/\partial R < 0$, since $\partial MR/\partial R < 0$, and $\partial MC/\partial R > 0$. It would be possible to obtain the relation between R and the other input variables using this theorem, but as far as we know there are no reasonable assumptions surrounding the sign for each $\partial F/\partial X_i$. These are exactly the relations estimated by the model proposed in this paper.

The specialized literature usually uses a linear function for equation (2) to establish the relation between R&D and other relevant factors (taking observed values, or their logarithmic transformation), generally using regression or panel data analysis. We will also follow this traditional approach in this study.

We propose a semi-log model, where the dependent variable, called RDown, is the natural logarithm of R&D expenditure financed with the own funds of the firm (i.e., excluding funds from other private or public organizations). This variable will be explained by other variables divided in two groups: inventive activities and appropriation activities. Given the fact that also our dependent variable is an "inventive activity", its relation with other activities of this type is somehow direct, showing the scale of this plan, its openness to other sources of knowledge and, as we will see, the substitutability of sources for R&D funds. The explanation provided by appropriation activities (divided in three subgroups: productive capabilities, commercialization and intellectual property) show the non-trivial relation of the activities to appropriate profits with R&D effort. All variables are presented in Table 1. Given our aim to integrate Teece's approach with ICM literature, Table 1 presents the variables used in the analysis from both perspectives.

The strategy of this paper to answer our research questions is to test the relation of appropriation activities with R&D profitability under different appropriability regimes, following the sectoral taxonomy proposed in Castellacci (2008). In order to simplify the exposition of the results, we shall focus on two sectors of activity: Software and Hardware. The first is classified as having a weak appropriability regime where patent protection is not a typical strategy, as opposed to the second where patenting appears to be a profitable strategy. In this sense, our study might be seen as a case study, where empirical evidence is intended to show the plausibility of the relation between the environment of the firm and the IC strategy. The justification for the choice of these two sectors is that they appear to be based on very different strategies regarding intellectual property protection; therefore ~~and~~ we expect to find not only confirmation in these two sectors (i.e., showing that patenting is a profitable strategy in Hardware but not in Software), but also to prove that this difference induces another strategy in Software. A strategy that incorporates other activities and capabilities to overcome the appropriation problem faced by innovative software firms.

To test these relations, we use of the Spanish Panel of Technological Innovation (PITEC) –a CIS-type survey–, selecting a sample of Spanish SMEs over the 5-year period between 2008 and 2012, for different sectors of activity. Given the fact that the aim of the study is to analyze the role of certain inputs in the profitability of R&D devoted to the generation of new products, the sample only includes firms declaring innovations and R&D activities in at least one year during the period considered, excluding those firms that are engaged exclusively in process innovations. In order to solve potential endogeneity problems with the variables included in the model, all models are estimated using instrumental variables regression for panel data (generalized two-stage least squares method), besides the conventional panel analysis and pooled models to test the robustness of our results.

The relationship between IC and R&D as a fundamental part of corporate innovation activities, has been established through the role that the various components of intangible assets have as part of the development of the "core knowledge" of innovative companies, the use of legal mechanisms to protect intellectual property, or as part of the complementary assets (production capabilities and marketing) that allow these firms a better appropriation of the returns from R&D.

VI. Results

Table 2 shows the averages of the variables used in each industry analyzed and a two-sample mean-comparison test. Significant differences appear in many of the variables used.

In the set of variables associated with the generation of core knowledge, significant differences are observed in the proportion of workers with higher education (education), R&D financed by external funds (RDout) and cooperation agreements with competitors for innovation (Coopcomp). In all cases, the values reached in Software firms exceed the corresponding values in Hardware firms. The remaining variables have slightly different values in the two sectors, but the differences are not significant. Given the assignment of these variables to the different components of IC, it can be concluded that companies in the software industry have a higher level of human, relational and structural capital than firms in the hardware sector.

The average values in the block of instruments related with the protection of intellectual property are substantial and significantly higher in the hardware sector when it comes to the use of patents or designs, while the values relating to the use of trademarks and copyright are higher in the software sector and only significant in the latter case. Each sector thus forms the composition of its structural capital in a different way. Therefore, the use of the various elements of structural capital related to the protection of intellectual property protection is different between companies in the two sectors analyzed.

Among the complementary assets related to production capabilities, an important difference can be observed in the values reached by the variable production capacity (Prod_cap) in each sector, to the point that the coefficient corresponding to hardware firms is five time larger than in software firms. Following Teece, the larger production capacity and, in consequence, the higher size of hardware companies is a complementary asset that can be used to ensure the appropriation of the returns to innovation. Intersectoral differences in the remaining variables considered part of complementary production assets are not significant.

Regarding the complementary assets related to commercialization, where we find especially variables linked to relational capital of the firm, hardware firms have higher values in many of the indicators, but these differences become significant only in the international presence in non-EU markets (Int_market) and in the aesthetic changes in product design (Incom1).

In sum, we observe that companies in the Hardware sector have a greater supply of complementary assets (production capabilities and commercialization) and make greater use of the instruments of protection of intellectual property (patents and designs). However, this does not necessarily imply that the strategic value of these assets - in terms of facilitating the appropriation of the returns on R&D - is also higher.

This last point is analyzed using econometric analysis. Table 3 presents the main results of the estimated models for both sectors. We have to underline that this table is interesting not only because it identifies the variables that best explain the behavior of the dependent variable, but also because those that are not relevant reflect differences in the use of mechanisms of appropriation of the rents of R&D activities.

The information on the relevance of different strategies to protect intellectual property shows that patents are significantly profitable in the case of hardware sector but not in the

software sector. That is, the use of patents by hardware firms makes a difference in terms of R&D performance.

The production complementary assets that better explains the effort in R&D is, in both sectors, the production capacity. However, important differences between the coefficients in each sector are observed. The higher coefficient in Software sector indicate that not only the size (in terms of production capacity) is relevant to explain R&D, because it makes it more profitable, but also that this relationship is much more decisive in software firms. That is, increments in the productive capacity of Software companies result in significant increases in their financial efforts in R&D. According to our theoretical approach, this indicates that an increase in production capacity is associated with an improvement in the ability to appropriate returns from these R&D activities.

The sign of the coefficient of the square of productive capacity indicates the possibility of diminishing returns from the growth of this capacity from the point of view of R&D efforts.

None of the variables related with commercialization complementary assets are significant in the hardware sector. In the case of Software, activities aimed at introducing innovations in the market (Marketing) and cooperation with suppliers (Coopsup) are positive and significant. These results indicate that in the Software sector the greater active marketing efforts have a positive differential effect on performance and, consequently, in R&D effort.

In terms of IC, our results reflect, first the existence of a positive relationship between many of the variables of IC and R&D, because of the positive effect of these elements on the ability to appropriate the returns from R&D activities. Second, that companies develop different strategies to benefit from their R&D, depending on their specific circumstances. For the hardware sector, the use of instruments of protection of intellectual property such as patents, has a positive and significant impact on the performance of R&D, while in the case of software companies it is the availability of complementary production and marketing assets that increases the capacity of appropriation.

Thus, the importance of structural capital (particularly patents) and human capital management (training) to explain investment in R&D in hardware sector is unquestionable, while in the Software industry relational capital management becomes more relevant (marketing, Coopcos, Coopknow).

A summary of these results is presented schematically in Figure 3, replicating the idea expressed in Figure 1.

VII. Concluding Remarks

The aim of this research was to answer the following two questions: Does the appropiability regime faced by the firm influence the impact of ICM on innovation activities? And, if this is the case, is it possible to find clear patterns for ICM responses from companies which can be explained by differences in appropiability regimes? Regarding the first question, evidence is consistent with the fact that there is a differentiated impact of ICM activities across sectors. In the Hardware sector, where patenting is profitable, in terms of R&D the size and marketing activities are not as relevant as in the case of the Software industry.

Indeed, the analysis has shown that, as noted in the taxonomy proposed by Castellacci (2008), appropriability is an element of sectoral differentiation in the sense that different economic activities involve different strategies on legal protection of IC. Since the elements of IC include instruments such as patents, licenses, etc. it can be argued that the capital structure between different sectors is due to the way companies try to appropriate the rents of innovation.

Regarding the second question, our empirical results might be rationalized through the existence of an appropriation strategy whereby firms try to profit from their R&D activities making use of a more diverse ICM beyond the intellectual property protection, either developing bigger productive capabilities or stronger connections with the market.

Our analysis also reveals that companies follow different strategies to pursue the benefits from innovation, even though there are sectors that have a greater supply of complementary assets. We have shown that the hardware sector, for which the appropriability regime is stronger, has higher levels of complementary assets both in terms of production and marketing, but the strategic importance of IC management with respect to the software sector is significantly lower.

This paper has contributed to improving our understanding of the role of IC, and its different elements, on innovative activity. The results confirm that IC management generates positive results through its positive effect on appropriation capabilities. Moreover, this work has contributed towards what the "third phase" of IC literature (Guthrie et al., 2012), which seeks to explain the causal relationship between IC and strategic management.

From a public policy perspective, contemporary thinking on innovation policy tends to focus on the generic promotion of the creation of the core knowledge embedded in potential new products, and on the strengthening of intellectual property protection. But patents (and other legal instruments), while offering considerable protection to some products, do not guarantee complete appropriability of some innovations especially in certain sectors. And, as Teece (1986) showed, profiting from innovations may depend not only on the legal protection offered by intellectual property rights, but also on the availability of other complementary assets and capabilities. In this sense, innovation policy become more closely aligned with the strategic analysis of markets and industries, considering alternative choices for public policy. Along these lines, Peneder (2008) suggests that the quantity of the subsidy must depend on the specific appropriability conditions faced by the firm, in the sense that firms that can rely more on intellectual property protection should receive less compensation. Although the implications of this paper to innovation policy might not be straight forward, our results are consistent with Peneder's (2008) conjecture about the key role of appropriability conditions in fostering innovation and the role of public policy in this field.

In this sense, we might need to reinterpret what is meant with the idea of encouraging R&D, in order to include broader measures to support firm's capabilities to transform new knowledge in a profitable business plan, besides the typical policies supporting the creation of the new knowledge embedded in innovation and the strengthening intellectual property protection.

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Figures

Figure 1

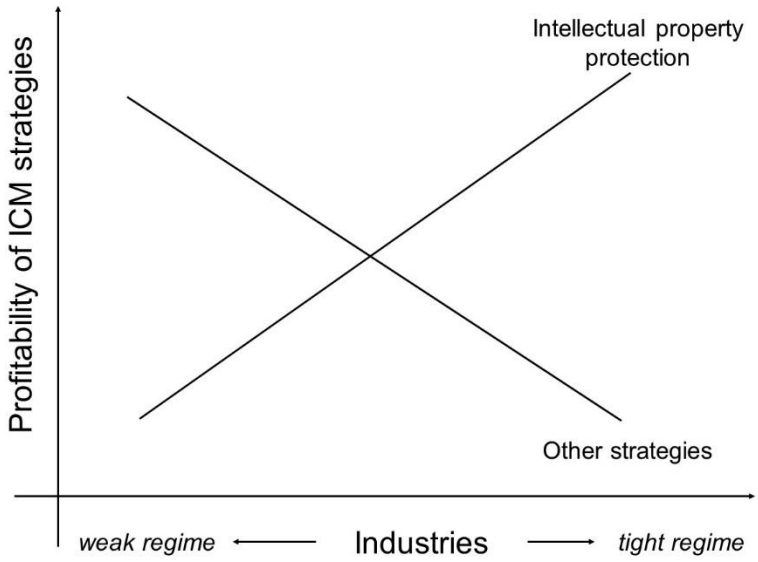


Figure 2

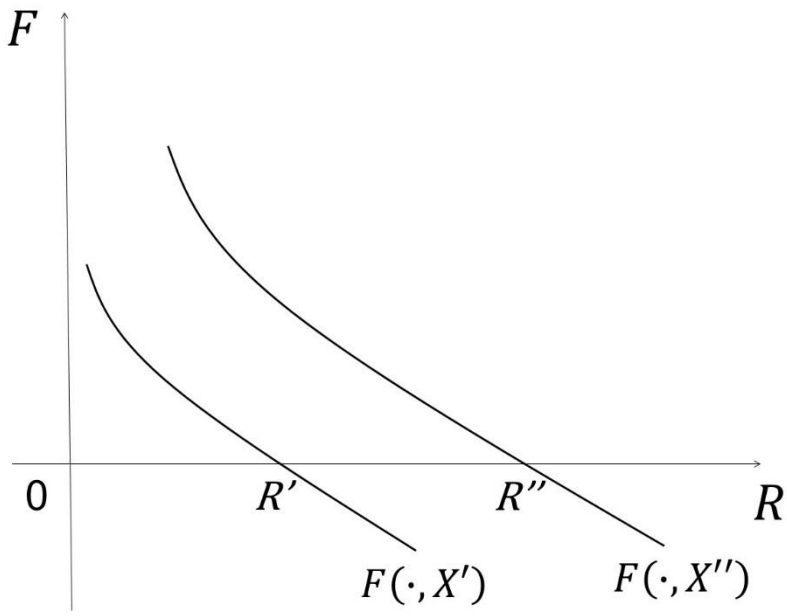
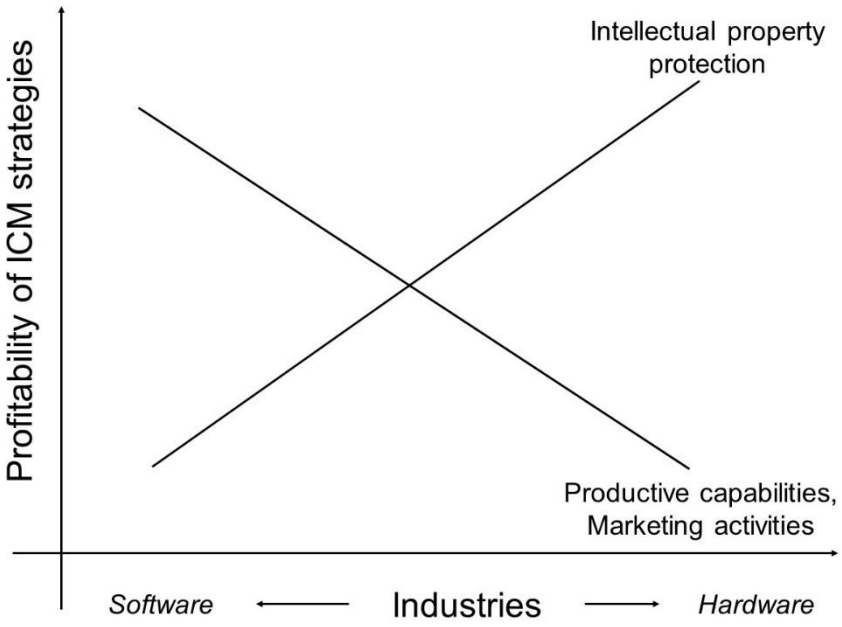


Figure 3


Profitability of ICM strategies
Intellectual property protection
Productive capabilities, Marketing activities
Software
Industries
Hardware

Tables

Table 1

Type		Human Capital		Structural Capital		Relational Capital	
Innovation activities		**Education**	Percentage of employees with higher education	**RDown**	In-house R&D expenditure, in euros, financed with own funds (natural logarithm)	**Coopsup**	Co-operation with suppliers (dummy)
		Training	Staff training expenditure, specifically aimed at the development of innovations (natural logarithm)	**RDout**	Internal R&D, in euros, financed by other org. (natural logarithm)	**Coopcomp**	Co-operation with competitors (dummy)
				RDext	External R&D expenditure, in euros (natural logarithm)	**Coopknow**	Co-operating with universities, research institutes, or consultants (dummy)
Appropriation activities	Intellectual property			**Patent**	Patent application (dummy)		
				Design	Design registration (dummy)		
				Trademark	Trademarks registration (dummy)		
				Copyright	Copyright registration (dummy)		
	Productive capabilities		**Prod_cap**	Market share of the firm (productive capacity)			
				Innproc	Process innovation (dummy)	**Innorg2**	New methods of organising external relations (dummy)
				Innorg1	New practices for organising procedures and responsibilities		
	Commercialization			**Incom1**	Changes to the aesthetic design of the product (dummy)	**Marketing**	Expenditure, in euros, on activities for market introduction of innovations, including market research and launch advertising (natural logarithm)
						Coopcos	Co-operation with customers (dummy)
						Incom2	New methods for product placement (marketing, pricing) (dummy)
						Int_market	Sales in Non-EU contries (dummy)

Table 2

Variables	Hardware	Software	t-stat	
Productive capabilities				
Prod_cap	0,230	0,027	6,30	**
Innproc	0,413	0,354	1,08	
Innorg1	0,500	0,450	0,90	
Innorg2	0,238	0,210	0,60	
Commercialization				
Marketing	3,412	2,818	1,10	
Incom1	0,302	0,205	1,89	†
Incom2	0,365	0,371	-0,11	
Int_market	0,762	0,424	7,15	**
Coopcos	0,190	0,210	-0,44	
Intellectual property				
Patent	0,175	0,061	2,69	**
Design	0,119	0,009	3,07	**
Trademark	0,167	0,188	-0,51	
Copyright	0,000	0,013	-19,52	**
Inventive activities				
Rdown	10,146	9,883	0,47	
RDout	3,068	4,872	-3,14	**
RDext	4,087	3,142	1,56	
Training	1,789	1,394	1,01	
Education	38,564	64,900	-9,59	**
Coopsup	0,175	0,109	1,55	
Coopcomp	0,079	0,188	-3,61	**
Coopknow	0,254	0,332	-1,61	

Note: The symbols (**), (*) and (†) stand for 99%, 95% and 90% confidence, respectively.

Table 3

Explanatory variables	Hardware						Software					
	Pooled model		Random effects		Instrumental variables		Pooled model		Random effects		Instrumental variables	
	Coef.	*P>t*	*Coef.*	*P>t*	*Coef.*	*P>t*	*Coef.*	*P>t*	*Coef.*	*P>t*	*Coef.*	*P>t*
Productive capabilities												
Prod_cap	3,62	0,000	2,77	0,000	2,90	0,000	17,65	0,000	15,23	0,000	14,62	0,000
Prod_cap (sq.)	-1,86	0,000	-1,28	0,005	-1,33	0,004	-24,77	0,000	-20,59	0,001	-19,36	0,002
Innproc	0,07	0,668	0,19	0,261	-0,44	0,194	0,15	0,406	0,40	0,042	-0,16	0,676
Innorg1	0,30	0,074	0,19	0,320	0,32	0,111	0,02	0,921	0,11	0,642	0,20	0,411
Innorg2	-0,41	0,025	-0,30	0,118	-0,33	0,085	-0,21	0,348	-0,21	0,371	-0,19	0,431
Linkage to market												
Marketing	0,02	0,141	0,00	0,935	0,00	0,764	0,03	0,160	0,03	0,047	0,03	0,045
Incom1	-0,10	0,547	0,00	0,983	-0,02	0,912	0,41	0,068	0,18	0,441	0,22	0,366
Incom2	-0,21	0,207	-0,24	0,175	-0,12	0,535	-0,40	0,062	-0,32	0,158	-0,30	0,196
Int_market	-0,21	0,223	-0,16	0,458	-0,14	0,506	0,15	0,397	0,22	0,300	0,22	0,296
Coopcos	0,13	0,507	0,07	0,726	0,09	0,669	0,62	0,019	0,44	0,115	0,50	0,077
Intellectual property protection												
Patent	0,46	0,011	0,41	0,034	0,38	0,052	-0,04	0,894	0,01	0,971	-0,06	0,872
Design	0,15	0,472	0,17	0,466	0,14	0,540	-0,25	0,524	-0,06	0,883	-0,05	0,896
Trademark	-0,10	0,526	-0,16	0,369	-0,07	0,683	0,02	0,917	-0,18	0,357	-0,13	0,499
Copyright	-0,91	0,133	-0,37	0,519	-0,20	0,736	0,59	0,160	0,51	0,270	0,60	0,203
Innovation activities												
RDout	-0,01	0,426	-0,01	0,382	-0,01	0,501	-0,09	0,000	-0,10	0,000	-0,09	0,000
RDext	0,04	0,008	0,04	0,008	0,04	0,009	0,00	0,984	-0,01	0,753	-0,01	0,640
Training	0,04	0,038	0,04	0,045	0,04	0,048	-0,03	0,226	-0,03	0,252	-0,02	0,463
Education	0,00	0,807	0,00	0,623	0,00	0,778	0,00	0,908	0,00	0,862	0,00	0,935
Coopsup	-0,08	0,719	0,16	0,469	0,14	0,512	0,20	0,461	0,17	0,589	0,21	0,516
Coopcomp	0,02	0,931	-0,02	0,924	0,03	0,916	0,22	0,371	0,17	0,502	0,15	0,553
Coopknow	0,25	0,202	-0,01	0,974	0,06	0,784	0,62	0,008	0,79	0,002	0,76	0,003
Const.	11,72	0,000	11,86	0,000	12,13	0,000	11,59	0,000	11,55	0,000	11,82	0,000
Num. Of firms	-		95		95		-		148		148	
Num. of observations	475		475		475		740		740		740	
R-squared	0,274		0,2599		0,2411		0,142		0,1336		0,1328	