# Managing external knowledge flows: The moderating role of absorptive capacity

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ABSTRACT

In this paper, we argue that those firms with higher levels of absorptive capacity can manage external knowledge flows more efficiently, and stimulate innovative outcomes. We test this contention with a sample of 2265 Spanish firms, drawn from the Community Innovation Surveys (CIS) for 2000 and 2002, produced by the Spanish National Statistics Institute (INE). We find that absorptive capacity is indeed an important source of competitive advantage, especially in sectors characterized by turbulent knowledge and strong intellectual property rights protection. The implications for management practice and policy are also discussed.

> "Ninety-nine percent of everything exciting that happens will happen outside your own research labs"
> Tom McKillop, CEO of Astra Zeneca.

## 1. Introduction

The recognition of the importance of external knowledge flows is an important phenomenon seen in the organization of the innovation process within corporations, over the last two decades (Rigby and Zook, 2002). Firms are gradually abandoning the idea that the generation of new knowledge is mostly an internal process (Arora et al., 2001; Gans and Stern, 2003). In some industries, the boundaries between the organization's knowledge stock and external knowledge stock are blurred (Teece, 1998).

Cohen and Levinthal's seminal contribution highlights the fact that firms cannot benefit from external knowledge flows merely by being exposed to them (Cohen and Levinthal, 1989, 1990). Instead, firms must develop the ability to recognize the value of new external knowledge, and then assimilate and utilize such knowledge for commercial ends; they must develop "absorptive capacity". Given the increasingly significant role played by external knowledge flows in recent years, absorptive capacity has gradually become a key driver of a firm's competitive advantage (Cockburn and Henderson, 1998). A firm's absorptive capacity depends on its existing stock of knowledge, much of which is embedded in its products, processes and people. Thus, a firm's knowledge base plays both the role of innovation and absorption (Cohen and Levinthal, 1989).

This paper attempts to isolate empirically the impact of absorptive capacity on innovation performance. The focus is on how such an influence moderates the degree to which external knowledge flows affect innovation output. Specifically, this research is centered on involuntary knowledge flows, arising when part of the knowledge generated by an organization spills over its boundaries and becomes available to other organizations (Nelson, 1959; Arrow, 1962). We posit that, while the innovation role of a firm's knowledge base does not necessarily depend on the amount of external knowledge, its absorption role only comes into play if external knowledge flows are available. Thus, a plausible means of isolating the impact of absorptive capacity on innovation performance is to look at the moderating role played by this factor. As a further step, we explore how some key contingencies, in the external knowledge environment, influence the relationship between absorptive capacity, involuntary knowledge flows and innovation performance. In particular, we focus on two types of contingencies: the degree of turbulence; and the strength of intellectual property rights (IPR) protection. We argue that the role of absorptive capacity is more pronounced in environments characterized by a high degree of turbulence and tight IPR protection. Thus, we expect that the absorption role played by a firm's knowledge base is relatively more important under such circumstances.

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To perform our empirical analysis, we employ a sample of 2265 Spanish firms, drawn from the Community Innovation Surveys (CIS) for 2000 and 2002, administered by the Spanish National Statistics Institute. We find evidence that a firm's knowledge base positively moderates the impact of involuntary knowledge flows on innovation performance; this behavior confirms the importance of the role played by absorption. Our data also suggest that the impact of absorptive capacity depends on the nature of the external knowledge environment, and that absorptive capacity becomes more relevant in sectors characterized by high turbulence and tight IPR protection. Our findings remain qualitatively unchanged after we control carefully for sample selection and for the potential correlation between external knowledge flows and other variables like, for instance: absorptive capacity, innovation performance; and the level of IPR protection.

Our paper contributes to the empirical literature on absorptive capacity and its impact on different innovation outcomes. Cohen and Levinthal (1989) argue that the desire to assimilate external knowledge creates a positive incentive to invest in R&D. They find indirect evidence of the relationship between innovation performance and absorptive capacity by showing that external knowledge flows encourage investment in R&D. Gambardella (1992), after performing several case studies for large US drug manufacturers, concludes that firms with better in-house scientific research programs exploit outside scientific information more efficiently. Focusing on collaborative linkages in the biotechnology industry, Arora and Gambardella (1994) find that a firm's absorptive capacity plays a crucial role in explaining the number of alliances established by each firm. Cockburn and Henderson (1998) show that the ability to maintain close ties with the scientific community is a key factor in driving a firm's ability to recognize and use upstream research and findings. Moreover, connectedness is significantly correlated with performance, in drug discovery. More recently, Cassiman and Veugelers (2006) show that the reliance on more basic R&D, which might proxy a firm's absorptive capacity, is a contextual variable positively affecting the complementarity between internal and external innovation activities.

Summarizing, most of the existing empirical research is focused on how absorptive capacity directly affects several dependent variables like, for instance: performance, innovation, R&D alliances, and technology sourcing. However, this approach does not allow us to disentangle the innovation role from the absorption role of a firm's knowledge base. For instance, consider R&D investment. Greater R&D investment is correlated with both absorptive capacity and innovation ability; and in turn, both capabilities affect innovation performance. Instead, by focusing on the moderating role of absorptive capacity we are able to separate these two channels more convincingly. Hayton and Zahra (2005) also attempt to separate the main effect (innovation) of a firm's knowledge base, from its moderating effect (absorption). Our paper extends their findings to a larger set of firms, across two different time spans and, most importantly, focuses on involuntary external knowledge flows rather than on acquisitions and joint ventures. A problem that arises when considering acquisitions and joint ventures is that they are typically decision variables for a firm and thus might be subject to some endogeneity concerns; this is not the case for involuntary external knowledge flows. In addition, we explore the role of absorptive capacity in environments characterized by high turbulence and tough IPR protection, which – to the best of our knowledge – has not been addressed empirically before.

The remainder of the paper is organized as follows. Section 2 develops the theoretical underpinnings, drawing on the related literature on involuntary knowledge flows and absorptive capacity. In Section 3, we conduct the empirical analysis. The paper ends with some final remarks and a discussion of policy as well as managerial implications.

## 2. Background theory: innovation, external knowledge flows and absorptive capacity

Innovation is a complex activity in which new knowledge is applied for commercial ends. New knowledge is generated through a cumulative process in which knowledge is added, deleted, transformed, modified or simply reinterpreted. Part of this knowledge reaches the firm from external sources (Cassiman and Veugelers, 2002), which are recognized as a pivotal element in the success of a firm's innovation activity (Rosenberg, 1982). Inward looking firms have been accused of suffering from the so-called "Not invented here" syndrome (Katz and Allen, 1982). However, the importance of knowledge generated outside a firm's boundaries has increased dramatically over the last few years (see the opening quotation).

The greater availability of external knowledge does not imply that firms can now rely simply on outside knowledge flows. In fact, mere exposure to external knowledge is not sufficient to internalize it successfully. As discussed in the introduction, Cohen and Levinthal (1990) highlight the key role played by "absorptive capacity". Absorptive capacity is defined as the ability to recognize the value of external knowledge, assimilate it, and apply it to commercial ends.

Involuntary external knowledge flows constitute a prototypical example of external knowledge sources that a firm can potentially exploit to enhance innovation performance.[1] The concept was pioneered by Nelson (1959) and Arrow (1962) who characterized knowledge as having the features of a durable public good. The knowledge produced by an innovator is easily "borrowed" by another party that has no intention of compensating the former. Several authors have documented the importance of external knowledge flows as an aid to strategic decision-making at the firm level (Jaffe, 1986; Cohen and Levinthal, 1989; Cassiman and Veugelers, 2002). The external knowledge base available to a firm depends among other factors on: the density of firms clustered in a given geographical area; sector of activity; social ties; nature of the knowledge; and the level of IPR (Jaffe et al., 1993; Teece, 1986; Saxenian, 1994). Some authors stress the localized nature of knowledge flows, because ideas circulate easily from one firm to another, as a result of geographical and social proximity (Saxenian, 1994; Audretsch and Feldman, 1996; Fosfuri et al., 2001). Others, instead, question the common presumption of a close relationship between functional, relational and geographical proximity, and argue that there is no reason why such a learning process should be limited territorially (Amin and Cohendet, 2004; Giuliani and Bell, 2005).

Whether or not knowledge flows are localized geographically, firms exposed to the same amount of external knowledge flows might not derive equal benefits, because they differ in their ability to identify and exploit such flows (Beaudry and Breschi, 2003; Giuliani and Bell, 2005). Thus, both the amount and effect of external knowledge flows are unequally distributed across the population of firms. In other words, absorptive capacity can be a source of a firm's competitive advantage.

A firm's absorptive capacity depends on its existing knowledge stock, much of which is embedded in its products, processes and people. Thus, a firm's knowledge base plays both the role of inno-

[1] Involuntary external knowledge flows are sometimes referred as knowledge spillovers. For instance, Cassiman and Veugelers (2002) argue that knowledge spillovers might play a dual role. Incoming knowledge spillovers might be beneficial, whereas outgoing knowledge spillovers might benefit competitors and thereby reduce a firm's competitive advantage in innovation.

vation and that of absorption (Cohen and Levinthal, 1989). Put differently, the drivers of absorptive capacity are highly correlated with the inputs from the innovation process as well as a firm's innovation ability, and it is not easy to estimate their individual effect on innovation performance. For instance, R&D employees, without any publications in scientific journals, may ignore the existence of such specialized journals where a great deal of publicly available knowledge can be sourced. On the other hand, the fact that these scientists have never managed to publish might also be a warning of low quality inputs into the innovation process that highlights the inability to innovate.

We adopt the following approach in order to address these subtleties. We posit that absorptive capacity has an impact on innovation performance only when there are external knowledge flows that can be identified, integrated and, thereafter, exploited. Put differently, a firm that lives in a vacuum would not derive any benefit from absorptive capacity. By contrast, innovation capabilities, *per se*, do generate innovation outcomes irrespective of the presence of external knowledge flows. Hence, the way to isolate the role of absorptive capacity is by studying its *moderating* effect on the impact of external knowledge flows on innovation performance. Firms with greater absorptive capacity benefit more from the presence of external knowledge flows. As mentioned before, many of the drivers of innovation performance are also drivers of a firm's absorptive capacity. Thus, it would be difficult to isolate the impact of absorptive capacity on innovation performance, if one had posited a direct effect. In such a case, the only available option is to impose ex-ante a different set of proxies that explain absorptive capacity. We believe that absorption and innovation are so intertwined that it would be meaningless to proceed down this path.

Note that the literature suggests two separate roles played by absorptive capacity with respect to external knowledge (Cohen and Levinthal, 1989; Arora and Gambardella, 1994; Zahra and George, 2002). First, absorptive capacity helps the firm to identify more available knowledge flows. In other words, the amount of external knowledge that the firm perceives is an increasing function of its absorptive capacity. Second, for a given quantity of identified external knowledge flows, the degree by which the firm derives benefits also depends on its absorptive capacity. The former effect is what other scholars refer to as: ability to identify, ability to evaluate; or potential absorptive capacity; the latter effect is labeled typically as: ability to use; ability to exploit; or realized absorptive capacity. Overall, we can conclude that heterogeneity in the level of absorptive capacity translates into differences in the benefits from otherwise similar stocks of external knowledge both because the firm can identify more of them and because it can exploit them more efficiently.

**H1.** *A firm's absorptive capacity moderates positively the impact of involuntary external knowledge flows on innovation performance.*

The relationship between absorptive capacity, external knowledge flows and innovation performance depends crucially on some key contingencies in the external knowledge environment, thus, making absorptive capacity a more or a less critical, strategic dimension. We focus here on two contingencies: the degree of turbulence and the level of legal appropriability. We argue below that the role of absorptive capacity is more pronounced in environments characterized by high degree of turbulence and tough IPR protection. We expect the absorption role of a firm's knowledge base to be relatively more important in such environments, thus making it easier for us to isolate its impact empirically. This effect further validates our moderating approach to measure the importance of a firm's absorptive capacity.

### 2.1. *Turbulent knowledge environments*

Although outside knowledge is critical to the innovation process in general, it becomes even more important in the context of changing knowledge environments (Ilinitch et al., 1996). Firms competing in such environments need to reconfigure their knowledge bases if they want to survive (Barnett and Sorenson, 2002). A key difference between stable and turbulent knowledge environments depends on the relative importance of explorative and exploitative learning processes (March, 1991). Exploration implies search, discovery, experimentation, risk taking and innovation; while exploitation implies refinement, implementation, efficiency of production and selection (Levinthal and March, 1993). In stable knowledge environments, firms place a strong emphasis on exploiting knowledge, since the knowledge domain that they wish to utilize is closely related to their current knowledge base. On the contrary, in turbulent knowledge environments, firms are more active in exploration since the relevant knowledge might be far removed from their existing knowledge stock (Van den Bosch et al., 1999).

The role played by outside knowledge is rather different across these two activities. While local search processes that characterize exploitation might not need external feedback, exploration activity more heavily relies on outside knowledge for idea generating, fundamental understanding of the phenomena, basic knowledge and market response (Rosenkopf and Nerkar, 2001). Hence, in turbulent knowledge environments, the emphasis is on monitoring external knowledge development and an inward looking attitude would be penalized strongly. In turn, this behavior implies that absorptive capacity plays a more important role in turbulent knowledge environments. Because a great deal of the relevant knowledge required for innovation activity is found outside a firm's boundaries, external knowledge flows become more important; and the ability to benefit from these flows plays a crucial role in securing competitive advantage.

**H2.** *In turbulent knowledge environments, the moderating role of absorptive capacity becomes relatively more important.*

### 2.2. *The degree of legal appropriability*

Another important characteristic of the knowledge environment is the strength of the appropriability regime. Appropriability refers to the firm's ability to protect the advantages of (and benefit from) new products or processes (Teece, 1986). Appropriability depends, among other things, on the levels of legal protection for IPR. Under a strong protection regime, firms patent their intellectual property to protect revenue streams arising from innovations. Imitation is more difficult and valid patents constitute an important source of a firm's sustainable competitive advantage.

One of the patent system's principal tasks is related to the disclosure of information that can be socially and efficiently used by other players. If the protection regime is strong, firms tend to patent extensively, thereby contributing to generate comprehensive and accessible sources of high-quality scientific and technological information (Granstrand, 1999).[2] However, patenting is a risky strategy when the protection regime is weak. Indeed, a patent may provide enabling information for other firms and yet offer little guarantee to the innovating firm that holds the patent. This implies, first, that firms have fewer incentives to undertake costly and complex innovative projects which could then generate knowledge flows.

[2] For instance, Arora et al. (2008) show empirically that a firm's propensity to patent and the patent premium (i.e. the extra profit that a patent confers to an innovation) are positively correlated.

Second, firms will develop mechanisms to protect their innovation by reducing the amount of information disclosed. Cohen et al. (2000) find, after an extensive survey of manufacturing firms, that secrecy is the preferred mode of protecting both product and process innovations. Thus, the amount and quality of external knowledge flows is greater in environments characterized by strong legal appropriability.

In addition, under a tight protection regime, firms can only use outside information if they are able to transform and modify it in such a way that the new knowledge does not infringe the patented knowledge, for instance, by inventing around the patent. This knowledge transformation capability is a critical component of a firm's absorptive capacity. By contrast, under a regime of weak IPR protection, imitation is widespread. Imitating firms do not need to transform the knowledge but can use it as it is. Thus, the exploitation of external knowledge flows does not require the firm to undertake the complex and demanding task of knowledge transformation (Zahra and George, 2002). While competitive firms must keep innovating so as to stay ahead of rivals, absorptive capacity has less impact when IPR protection is weak (Spence, 1984).

**H3.** *In environments with strong IPR protection, the moderating role of absorptive capacity becomes relatively more important.*

## 3. Empirical analysis

### 3.1. Data

The dataset used in this study is assembled from the Community Innovation Survey conducted in Spain, in 2000, and administered by the Spanish National Statistics Institute (INE), together with a fully comparable survey conducted by the same Institute in 2002 (*Encuesta de Innovación Tecnológica*, *EIT*). The survey collects detailed information about innovation activities for Spanish firms belonging to all sectors of the economy. The database for each year is composed of a stratified sample, according to the number of employees and sector. In particular, the number of employees is divided into three intervals (from 10 to 49; from 50 to 249; and more than 250). INE only sent the questionnaire to firms with more than 10 employees. Firms are assigned to 55 different 2-digit sectors (grouped in 10 broad 1-digit sectors), following a Spanish classification named CNAE that is equivalent to the 2-digit SIC classification. Questionnaires were sent to the CEOs. The response rate was very good (92%). This is not surprising given that Spanish firms have a legal obligation to fill in questionnaires originating from INE. The final database, after removing observations with missing values, is a panel of about 4000 firms that have answered the questionnaire in both periods. Some diagnostic checks are performed to ensure that the sample does not suffer any serious selection bias.[3] Slightly more than 55% of the firms in our sample indicate that they have spent a positive amount of resources on innovation activities. We think that this subject is irrelevant for those firms that have not devoted resources to innovation activities. However, as discussed later, we also estimate a Heckman's two-stage selection model, using the full sample, in order to prevent a possible sample selection bias.

### 3.2. Variable definition

#### 3.2.1. Innovation performance.

We look at two different measures of innovation performance. *NewProd* is the percentage of total annual sales (for the year 2002) that comprises new or substantially improved products introduced over the period 2000–2002. The natural log is used to compensate for skewness.[4] *Innov* is a dummy that equals 1 if the firm has introduced a product or a process innovation during the period 2000–2002 and 0 otherwise.

#### 3.2.2. External knowledge flows

In the questionnaire, firms rate the importance of different information sources as a catalyst for innovation, on a four-point scale from 1 (high) to 4 (not at all). We focus on 7 sources: suppliers, clients, competitors, universities, other research institutions, specialized journals and meetings.[5] We build an index (*ExtKnow_flows*) by computing the principal component of the variables that capture the role of the aforementioned sources of external knowledge.[6]

#### 3.2.3. Absorptive capacity

The literature proposes several different measures of absorptive capacity, and no single one is superior to all others, under all circumstances. Cohen and Levinthal (1989, 1990) use R&D intensity, although the process of building absorptive capacity is inherently cumulative.[7] Veugelers (1997) and Cassiman and Veugelers (2002), among others, use the fact that the firm has a fully staffed R&D department to capture such cumulativeness. Finally, since absorptive capacity is related to the ability of individuals in the organization to assimilate, then process and transform external knowledge flows; scholars also use measures of a firm's human capital. For instance, as such a measure, Mowery and Oxley (1995) and Keller (1996) employ investment in scientific and technical training and the number of scientists and engineers. Similarly, Veugelers (1997) uses the number of doctorates within the R&D department. Following the different suggestions in the literature, we operationalize our measure of absorptive capacity by constructing an indicator, *AbsCap*, which is the principal component of: (1) the internal R&D expenses (*Internal_R&D*); (2) a dummy which is equal to 1 if the firm has a fully staffed R&D department (*Permanent_R&D*); (3) a dummy that is equal to 1 if the firm provides training for its R&D personnel (*Training*); and (4) the ratio of scientists and researchers to total employees (*R&D_Skills*).

#### 3.2.4. Inputs of the innovation process

We try and control as much as possible for other possible drivers for innovation performance. As we discussed before, a firm's knowledge base plays the role of both innovation and absorption. Thus, for inputs of the innovation process, we use exactly the same variables that enter in our measure of absorptive capacity, that is, *Internal_R&D*, *Permanent_R&D*, *Training*, and *R&D_Skills*. In order to capture empirically the moderating role of absorptive capacity, we cross our indicator of a firm's absorptive capacity with our measure of external knowledge flows (*AbsCap* × *ExtKnow_Flows*). In addition, we also control for a direct effect of external knowledge flows on innovation performance.

[3] Specifically, we have checked that the records we removed for missing values were not different in some observable dimensions from the sample we finally used.

[4] To avoid dropping observations with zero values we define the transformed variable as log(1 + NewProd). Although not reported, we also conduct estimations using Pakes (1985) correction. Results remain unchanged qualitatively.

[5] Cassiman and Veugelers (2002), in their study of R&D cooperation and spillovers, discuss the virtues of a measure of knowledge spillovers based on the importance of different information sources for innovation vis-à-vis alternative measures proposed in the literature.

[6] As a robustness check, we also use, in unreported estimations (available upon request), a measure based on the normalized sum of the 7 variables, capturing the aforementioned sources of external knowledge. Results remain unchanged in qualitative terms.

[7] Nesta and Saviotti (2005) show that the successful integration of external and internal knowledge occurs when firms base their research activities on distinctive competencies developed across time.

*3.2.5. Turbulent knowledge sectors*

Turbulent knowledge environments are those where the underlying knowledge base is subject to a process of continuous evolution and change. By identifying the degree of knowledge turbulence at the sector level, we attempt to address the fact that some industries may experience greater technological ferment which, in turn, may drive both the importance of absorptive capacity and the opportunities to benefit from external knowledge flows. We reflect the "turbulent nature" of a sector by employing a variable that is the difference between the sector growth rate, in sales of new or improved products, and the average growth rate computed across all available sectors (*Turbulent*).

In order to contrast H2, we construct a three-term interaction variable (*Turbulent* × *AbsCap* × *ExtKnow_Flows*). Also, so as to test correctly for the existence of a positive moderating role played by absorptive capacity in turbulent sectors, we incorporate the two-term interaction variables (*AbsCap* × *ExtKnow_Flows*, *Turbulent* × *ExtKnow_Flows*) and the direct effect (*Turbulent*), into the specifications.[8]

*3.2.6. Sectors with tight IPR protection*

Firms rate, on a four-point scale, the effectiveness of four different legal methods for IPR protection: patents, utility models, trademarks and copyrights. We sum up the four scores, and standardize such that the resulting index varies between 0 (minimum protection) and 1 (maximum protection). Finally, we average the firm level index at the sector level.[9] The literature shows that there are important differences across sectors in the role played by IPR. The difference between this average and mean value of the sample (economy average) is our *proxy* for the degree of appropriability (*Appropriability*).

Finally, in order to contrast H3, as in the analysis for turbulent sectors, we construct a three-term interaction variable (*Appropriability* × *AbsCap* × *ExtKnow_Flows*). Also, we include the two-term interaction variables (*AbsCap* × *ExtKnow_Flows*, *Appropriability* × *ExtKnow_Flows*) and the direct effect (*Appropriability*).[10]

*3.2.7. Control variables*

We use the number of employees on a log scale (*Size*) as a measure of a firm's size. We control for size because previous research has found that innovation performance might benefit from economies of scale and scope (Cockburn and Henderson, 1994). We use a dummy (*New*) that signals whether or not a firm is of new creation. Indeed, several authors suggest that new ventures might have stronger incentives to innovate under certain technological regimes. We also control for the existence of factors that hinder innovation performance (*InnObstacles*). Firms rate, on a four-point scale, the impact of the following obstacles on innovation activity: (a) excessive risk; (b) large sunk investment; and (c) short pocket. We normalize the sum to vary between 0 and 1. Following Cassiman and Veugelers (2002), we control for a firm's ability to protect innovation by using strategic tools like lead time, design complexity and secrecy (*StrategicProtection*). This variable is again a normalized sum of three scores (for the importance of lead time, design complexity, and secrecy) that varies between 0 and 1. Finally, in order to control for sector and location-specific sources of heterogeneity in innovation performance, we introduce a set of dummies for our ten 1-digit sectors and a set of dummies for the 17 main Spanish regions.

A summary of the definitions of all variables is shown in Table 1.

Descriptive statistics of the main variables are shown in Table 2. Here, we also provide means and standard deviations for different sub-samples: (a) Firms with a level of absorptive capacity in the upper third of the distribution (AC = 1); (b) Firms with a level of absorptive capacity in the lower third of the distribution (AC = 0); (c) Firms with AC = 1 (0) and belonging to more turbulent sectors (i.e. the variable *Turbulent* is positive)—columns 4 (5); (d) Firms with AC = 1 (0) and belonging to sectors with stronger IPR (i.e. the variable *Appropriability* is positive)—columns 6 (7).

Table 2 shows that those firms with a level of absorptive capacity in the upper third of the distribution, display higher innovation performance than those in the lower third of the distribution (the difference in the conditional mean value of *NewProd* is 1.22).

**Table 1**
Definition of the variables.

| | Definition |
|---|---|
| NewProd | The percentage (in logs) of 2002 total annual sales that comprises new or substantially improved products, introduced over the period 2000–2002. |
| Innov | A dummy that equals 1 if the firm has introduced a product or a process innovation during the period 2000–2002, and 0 otherwise. |
| Internal_R&D | The amount of internal R&D expenditures measured on a log scale. |
| Permanent_R&D | A dummy that is equal to 1 if the firm has a fully staffed R&D department; and 0 otherwise. |
| Training | A dummy that is equal to 1 if the firm undertakes training activity for its R&D personnel; and 0 otherwise. |
| R&D_Skills | The number of scientists and researchers over total employees. |
| AbsCap | The principal component of four variables: (a) Internal_R&D, (b) Permanent_R&D, (c) Training, and (d) R&D_Skills. |
| ExtKnow_Flows | The principal component of seven variables that capture the importance of seven external knowledge sources: suppliers, clients, competitors, universities, other research institutions, specialized journals and meetings. |
| Turbulent | The difference between the sector rate of increase in sales of new or improved products and the average rate of increase for the economy (all sectors). |
| Appropriability | The difference between the sector level of protection of IPR and the economy average (all sectors). Firms rate the importance of four methods of protection: patents, utility models, trademarks and copyrights. We sum up the four scores at the firm level, and standardize so that the resulting index varies between 0 (minimum protection) and 1 (maximum protection). We then aggregate this variable at the sector level. |
| StrategicProtection | Measures the ability of the firm to protect its innovation using strategic tools like lead time, design complexity and secrecy. This is reflected by the normalized sum of three scores (for the importance of lead time, design complexity, and secrecy). |
| InnObstacles | A variable that accounts for the existence of factors that hinder innovation performance. This is based on a four-point scale related to the importance of the following obstacles to innovation activity: (a) excessive risk; (b) large sunk investment; and (c) short pocket. We normalize the sum to vary between 0 and 1. |
| Size | The number of employees on a log scale. |
| New | A dummy that captures whether or not a firm is of new creation. |
| SectorDummies | A set of dummy variables for our 10 1-digit sectors. |
| RegionDummies | A set of dummy variables for the 17 principal Spanish regions. |

[8] We do not include the interaction between *AbsCap* and *Turbulent*. There are both theoretical and practical reasons for this exclusion. Our key theoretical assumption is that absorptive capacity plays a role only when there are external knowledge flows that can be identified and captured. Thus, it should always enter the regressions multiplied by our measure of external knowledge flows. In addition, there is a 0.9 correlation between Turbulent × *AbsCap* and *Turbulent* × *AbsCap* × *ExtKnow_Flows*, which makes their joint inclusion in the regressions unfeasible.

[9] For a similar methodology, see Cassiman and Veugelers (2002).

[10] The exclusion of the interaction between *AbsCap* and *Appropriability* is due to the same reasons discussed above.

**Table 2**
Descriptive statistics of the main variables. The table presents the descriptive statistics for the variables that we use in the econometric analysis. The variables are defined in Table 1. In column 2, the statistics are from firms with an absorptive capacity in the upper third of the distribution (AC = 1), while those of column 3 correspond to the lower third of the distribution (AC = 0). The statistics in columns 4 and 5 are similar to those in columns 2 and 3, but focused on firms in more turbulent sectors (sectors with Turbulent > 0). Finally, the last two columns follow the same logic as columns 2 and 3 but focus on firms that operate in sectors with stronger IPR (sectors with Appropriability > 0).

| | All sample | AC = 1 | AC = 0 | AC = 1 and Turbulent > 0 | AC = 0 and Turbulent > 0 | AC = 1 and Approp. > 0 | AC = 0 and Approp. > 0 |
|---|---|---|---|---|---|---|---|
| NewProd | 1.16 (1.53) | 1.84*** (1.63) | 0.62 (1.25) | 2.20*** (1.61) | 0.87 (1.48) | 2.15*** (1.61) | 0.81 (1.40) |
| AbsCap | 0.04 (0.05) | 0.09*** (0.06) | 0.01 (0.01) | 0.09*** (0.05) | 0.01 (0.01) | 0.10*** (0.07) | 0.01 (0.01) |
| Internal_R&D | 8.67 (5.60) | 13.02*** (1.59) | 3.34 (4.90) | 13.40*** (1.65) | 3.83 (5.00) | 13.32*** (1.64) | 4.60 (5.15) |
| Permanent_R&D | 0.47 (0.50) | 1.00*** (0.05) | 0.00 (0.00) | 1.00*** (0.00) | 0.00 (0.00) | 1.00*** (0.00) | 0.00 (0.00) |
| Training | 0.47 (0.50) | 0.79*** (0.41) | 0.26 (0.44) | 0.81*** (0.40) | 0.32 (0.47) | 0.81*** (0.39) | 0.26 (0.44) |
| R&D_Skills | 0.03 (0.09) | 0.07*** (0.14) | 0.00 (0.01) | 0.06*** (0.09) | 0.00 (0.01) | 0.09*** (0.15) | 0.00 (0.01) |
| ExtKnow_Flows | 0.40 (0.21) | 0.48*** (0.21) | 0.33 (0.20) | 0.49*** (0.20) | 0.31 (0.20) | 0.50*** (0.20) | 0.32 (0.20) |
| AbsCap × ExtKnow_Flows | 0.07 (0.10) | 0.15*** (0.14) | 0.01 (0.01) | 0.15*** (0.12) | 0.01 (0.01) | 0.17*** (0.15) | 0.01 (0.01) |
| StrategicProtection | 0.22 (0.32) | 0.34*** (0.36) | 0.12 (0.24) | 0.35*** (0.36) | 0.15 (0.27) | 0.38*** (0.37) | 0.15 (0.27) |
| InnObstacles | 0.49 (0.31) | 0.54*** (0.28) | 0.44 (0.32) | 0.55*** (0.28) | 0.43 (0.31) | 0.56*** (0.28) | 0.46 (0.32) |
| Size | 4.89 (1.36) | 5.10*** (1.49) | 4.75 (1.28) | 5.12*** (1.48) | 4.50 (1.20) | 4.97*** (1.47) | 4.35 (1.09) |
| New | 0.03 (0.17) | 0.04** (0.20) | 0.02 (0.15) | 0.04 (0.20) | 0.03 (0.18) | 0.03* (0.18) | 0.02 (0.13) |
| Number of observations | 2265 | 755 | 755 | 213 | 213 | 488 | 488 |

*Note*: Standard deviations are shown in parentheses. We test the differences between column 2 and column 3; between column 4 and column 5; and between column 6 and column 7. The differences in the means are tested using the Mann–Whitney test.
* *p*-Value 0.10.
** *p*-Value 0.05.
*** *p*-Value 0.01.

Interestingly, this difference is higher when we focus on firms that belong to more turbulent sectors (1.33) or to sectors with stronger IPR (1.34). Thus, it seems that the role of absorptive capacity in innovation performance is particularly important in turbulent sectors and sectors with tight legal appropriability.

A second result that can be extracted from this table is that, those firms with a level of absorptive capacity in the upper third of the distribution, report higher external knowledge flows than those in the lower third of the distribution (difference = 0.15). This difference is larger when we focus on more turbulent sectors (difference = 0.18) or on sectors with stronger IPR (difference = 0.18). Hence, we see that absorptive capacity and external knowledge flows are positively correlated and, in turn, both are positively related to innovation performance. The econometric analysis below explores these relationships in greater depth.

### 3.3. *Econometric analysis*

Our unit of observation is the firm. We hypothesize that innovation performance is generated by the function $y_{t+1} = f(x_t, \beta)$, where $y_{t+1}$ is either the log of the percentage of total annual sales that consist of new or substantially improved products (*NewProd*); or a dummy (*Innov*) that equals 1 if the firm has introduced a product or a process innovation; and 0 otherwise; $x_t$ is the set of explanatory variables described above, including our measures for absorptive capacity and external knowledge flows; and $\beta$ is a vector of parameters to be estimated.

We estimate the *NewProd* equation by using least squares (OLS) with robust standard errors, and in order to make coefficients comparable across different estimations, we enter all variables in standardized form. This does not alter the significance of the coefficients; the *t*-values remain unchanged. In addition, in order to reduce multicollinearity concerns that may be particularly problematic in the estimations which include interaction terms, we orthogonalize such interaction-term variables.[11] Finally, we estimate the *Innov* equation using a Logit model.

One must bear in mind that, while our innovation performance measures (dependent variables in the estimations) are drawn from the 2002 survey, all explanatory variables come from the 2000 survey. This time lag helps us to reduce potential endogeneity problems caused by simultaneity between innovation performance and the variables capturing external knowledge flows and absorptive capacity.

The estimation results are shown in Table 3. As mentioned before, here we only focus on those firms that have invested a positive amount of resources in innovation activity.

First of all, one should note that external knowledge flows have a positive and significant impact on innovation performance; firms that enjoy more external knowledge flows are more innovative. Second, firms with higher levels of absorptive capacity benefit more from external knowledge flows. Indeed, our cross variable (*AbsCap* × *ExtKnow_Flows*) is positive and highly significant. Hence, one can conclude that, other things being equal, external knowledge flows have a direct and positive impact on innovation performance, and that the magnitude of this effect depends very much on a firm's absorptive capacity. Put differently, firms with higher levels of absorptive capacity are more innovative because they exploit external knowledge flows more efficiently.

The signs for the other variables seem plausible. Larger investments in R&D (both flow and cumulative) generate better innovation performance. Other measures of innovation inputs, *Training* and *R&D_Skills*, particularly the latter, bring up significant positive coefficients. Strategic protection and a firm's size are related, both positively and significantly, to innovation performance. Finally, start-up firms do not enjoy any advantage related to innovation activity vis-à-vis more established rivals.[12]

As a second objective of this study, we would like to investigate if the importance of absorptive capacity depends on the contingencies of the knowledge environment. We argue that absorptive

[11] We compute the variance inflation factors in all estimations and the maximum value for the interactive terms is lower than 4 in all cases; thus, well below the threshold value of 20 that it is indicative of multicollinearity problems.

[12] For the sake of completeness, we re-estimate the specifications of Table 3 distinguishing between small, medium and large firms. (Small: a firm with less than 50 employees. Medium: between 50 and 250 employees. Large: more than 250 employees.) The results are qualitatively similar across the different categories of firm size.

**Table 3**
Moderating role of absorptive capacity. All variables are defined in Table 1. Both dependent variables are led by one period to avoid simultaneity. The estimations include controls for sectoral and regional fixed effects. All regressions are contingent on observing positive expenditures in innovation activity. In columns 1 and 3 we employ robust OLS regressions to control for heteroscedasticity. In columns 2 and 4 we estimate a Logit model.

| Dependent variable | $NewProd_{t+1}$ | $Innov_{t+1}$ | $NewProd_{t+1}$ | $Innov_{t+1}$ |
|---|---|---|---|---|
| Internal_R&D$_t$ | 0.27*** (9.66) | 0.35*** (5.01) | 0.19*** (5.93) | 0.18** (2.28) |
| Permanent_R&D$_t$ | 0.00 (0.20) | 0.08*** (2.35) | 0.03*** (2.31) | 0.21*** (5.69) |
| Training$_t$ | 0.02 (0.98) | 0.10*** (2.68) | −0.01 (−0.73) | 0.00 (−0.10) |
| R&D_Skills$_t$ | 0.08*** (3.10) | 0.08** (2.13) | 0.07*** (2.44) | 0.24*** (4.19) |
| ExtKnow_Flows$_t$ | | | 0.24*** (9.96) | 0.96*** (14.19) |
| AbsCap × ExtKnow_Flows$_t$ | | | 0.47*** (4.08) | 2.70*** (18.66) |
| StrategicProtection$_t$ | 0.11*** (5.49) | 0.16*** (4.02) | 0.17*** (7.07) | 0.14*** (2.42) |
| InnObstacles$_t$ | 0.00 (0.10) | 0.00 (0.04) | −0.03 (−1.28) | 0.00 (0.09) |
| Size$_t$ | 0.06** (2.16) | 0.30*** (5.49) | −0.03 (−1.33) | 0.16*** (3.00) |
| New$_t$ | −0.01 (−0.45) | −0.03 (−0.60) | 0.02 (0.77) | 0.00 (0.06) |
| Constant | −0.03 (−0.94) | −0.08 (−0.20) | 0.19*** (5.19) | 0.54*** (5.65) |
| Number of observations | 2265 | 2265 | 2265 | 2265 |
| $R^2$ (%)[a] | 16.49 | 10.58 | 17.36*** | 12.40*** |
| Test of fitness | 13.80 (0.00) | 9.37 (0.00) | 13.78 (0.00) | 9.27 (0.00) |

*Note*: The parentheses contain *t*-values. We use the *F*-test as fitness test.
[a] Column 3 (4) contains the test for differences in variances with regard to the variance of the basic specification in column 1 (2).
* *p*-value 0.10.
** *p*-Value 0.05.
*** *p*-Value 0.01.

capacity should play a more crucial role in those sectors with greater knowledge turbulence and with stricter legal protection of IPR. Table 4 addresses this issue specifically. As discussed before, in order to contrast our conjectures, we add three additional variables to our previous list of regressors (see Table 4). The coefficient of the variable *Turbulent × AbsCap × ExtKnow_Flows* is positive and significant at the 1% level (see columns 1 and 2), meaning that absorptive capacity plays an important role in turning external knowledge flows into innovative products in those sectors with a more turbulent knowledge environment. Also, the coefficient of *Appropriability × AbsCap × ExtKnow_Flows* is positive (see columns 3 and 4), meaning that absorptive capacity has a significant impact on

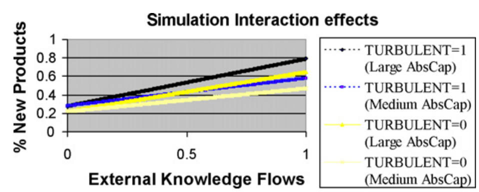


**Fig. 1.** Interaction effects of absorptive capacity and knowledge flows: comparison between turbulent and non-turbulent sectors.

**Table 4**
Turbulent knowledge sectors and sectors with strong appropriability. All variables are defined in Table 1. Both dependent variables are led by one period to avoid simultaneity. The estimations include controls for sectoral and regional fixed effects. All regressions are contingent on positive expenditures on innovation activity. In columns 1 and 3 we employ robust OLS regressions to control for heteroscedasticity. In columns 2 and 4 we estimate a Logit model.

| Dependent variable | $NewProd_{t+1}$ | $Innov_{t+1}$ | $NewProd_{t+1}$ | $Innov_{t+1}$ |
|---|---|---|---|---|
| Internal_R&D$_t$ | 0.14*** (4.57) | 0.09 (1.21 | 0.20*** (5.81) | 0.34*** (5.23) |
| Permanent_R&D$_t$ | 0.03*** (2.26) | 0.22*** (5.71) | 0.01 (0.55) | 0.08** (1.96) |
| Training$_t$ | −0.01 (−0.78) | −0.03 (−0.72) | 0.01 (0.89) | 0.08** (1.99) |
| R&D_Skills$_t$ | 0.06*** (2.38) | 0.25*** (4.79) | −0.03 (−0.19) | −0.12* (−1.67) |
| ExtKnow_Flows$_t$ | 0.24*** (10.32) | 1.00*** (14.37) | 0.10*** (3.79) | 0.16*** (3.32) |
| AbsCap × ExtKnow_Flows$_t$ | 0.47*** (4.26) | 2.77*** (18.55) | 0.11*** (2.64) | 0.36*** (2.31) |
| Turbulent$_t$ | −0.04 (−1.33) | −0.10 (−1.22) | | |
| Turbulent × ExtKnow_Flows$_t$ | −0.03 (−0.80) | 0.57*** (3.83) | | |
| Turbulent × AbsCap × ExtKnow_Flows$_t$ | 0.18*** (3.36) | 0.92*** (5.99) | | |
| Appropriability$_t$ | | | 0.22*** (5.96) | 8.14*** (2.76) |
| Appropriability × ExtKnow_Flows$_t$ | | | 0.01 (0.44) | −0.13 (−0.96) |
| Appropriability × AbsCap × ExtKnow_Flows$_t$ | | | 0.08*** (2.75) | 0.10* (1.70) |
| StrategicProtection$_t$ | 0.16*** (6.67) | 0.11* (1.84) | 0.01 (0.47) | 0.00 (0.09) |
| InnObstacles$_t$ | −0.03 (1.40) | 0.01 (0.12) | −0.01 (−0.21) | −0.04 (−0.97) |
| Size$_t$ | −0.02 (−0.80) | 0.17*** (2.93) | 0.02 (0.76) | 0.16*** (3.40) |
| New$_t$ | 0.01 (0.55) | −0.01* (−0.13) | 0.00 (−0.05) | −0.02 (−0.42) |
| Constant | 0.16 (1.38) | −1.44 (−0.89) | 0.13 (0.62) | −1.01 (−0.87) |
| Number of observations | 2265 | 2265 | 2265 | 2265 |
| $R^2$ (%)[a] | 19.74*** | 15.34*** | 18.66*** | 13.50*** |
| Test of fitness | 14.41 (0.00) | 10.90 (0.00) | 13.81 (0.00) | 9.38 (0.00) |

*Note*: The *t*-values appear in parentheses. We use the *F*-test as fitness test.
[a] In columns 1 and 3, we compare variances with those from column 3 in Table 3 (17.36%), while in columns 2 and 4, we compare such variances with column 4 in Table 3 (12.40%).
* *p*-Value 0.10.
** *p*-Value 0.05.
*** *p*-Value 0.01.

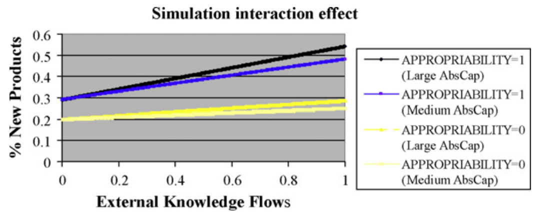


**Fig. 2.** Interaction effects of absorptive capacity and knowledge flows: comparison between sectors with high appropriability and those with low appropriability.

the conversion of external knowledge flows into innovative products, in those sectors with stricter legal enforcement of IPR.

To give a sense of the strength of the effects found, we conduct simulations using the specifications of Table 4 (columns 1 and 3). Fig. 1 plots the share of sales attributed to new and improved products, as a function of external knowledge flows, by holding all other variables at their median values, except for *abscap* that is fixed either at the mean value or at the upper quartile of the distribution. Fig. 1 shows four curves: two of them focus on turbulent sectors (*Turbulent* > 0); and the other two on non-turbulent ones (*Turbulent* ≤ 0). We find that the positive effect of external knowledge flows on the share of sales, due to new or improved products (NewProd), is more pronounced when absorptive capacity grows from the median to the upper quartile. Remarkably, this increase is larger for turbulent sectors. For example, when external knowledge flows take their maximum value (i.e. 1), the increases in NewProd, as absorptive capacity moves from the median to the upper quartile are 22% for turbulent sectors and 17.8% for non-turbulent ones. This difference increases with the amount of external knowledge flows, as Fig. 1 shows and, obviously, disappears when knowledge flows are equal to zero.

Fig. 2 is similar to Fig. 1, except that it compares sectors with strong (*Appropriability* > 0) and weak legal appropriability (*Appropriability* ≤ 0). The results show that the positive moderating role of absorptive capacity is greater for the former sectors. For example, when external knowledge flows take their maximum value (i.e. 1), the increase in NewProd as absorptive capacity moves from the median to the upper quartile is 6%, in sectors with strong legal appropriability; and only 3%, in sectors with weak legal appropriability.

### 3.4. Robustness checks

We discuss some of the econometric checks that we carry out, in order to test the robustness of our findings.

First, in our regressions (see Tables 3 and 4), we focus only on those firms that have expended a positive amount of resources on innovation activity. Since we select our sample based on a threshold (i.e. whether or not firms spend resources on innovation activity), our results could suffer from some sort of selection bias. In order to tackle this problem, we run a Heckman's two-stage selection model where, in the first stage, the inverse Mills ratio is obtained from a Logit regression (to predict whether or not a firm expends resources on innovation activity) using all available observations.[13] For the second stage, the inverse Mill ratio is included, as an additional variable, so as to explain the variation in innovation performance. We have a total of 3986 firms of which 2265 spend resources on innovation activity. The Mill ratio turns out to be insignificant at the 10% level in almost all specifications except in one that it is significant at 10%, suggesting that the sample selection bias is not a serious issue here. The results are available from the authors upon request.

A second concern arises from the measure of external knowledge flows that we employ. In the questionnaire, firms rate the importance of different external sources of information based on their positive impact on innovation activity. We exploit these answers to build a firm-specific index of external knowledge flows. Such an index accounts for the fact that not all firms are exposed to the same amount of external knowledge flows, even if they compete in the same sector or geographical area (Giuliani and Bell, 2005). However, this measure is likely to be a function the firm's ability to identify and recognize external knowledge flows, namely, absorptive capacity. Indeed, if a firm cannot identify the presence of useful external information it would tend to classify such information as unimportant. Moreover, in order to carry out any classification, one has to have the ability to study the item under scrutiny and compare it with some reference object (March, 1991; Levinthal and March, 1993). Hence, such a firm-specific measure of external knowledge flows is likely to be positively correlated to a firm's level of absorptive capacity. (This is in fact the case, as Table 2 shows.)

A third concern, which is related to the previous one, refers to the possible correlation between our measure of external knowledge flows and the degree of appropriability. As we discuss in the theory section, the amount of external knowledge flows might be closely related to the legal mechanisms that govern appropriability (patents, trademarks, etc.). Although appropriability is measured at the sector level and external knowledge flows are firm-specific, some confounding effects could still be present.

A fourth concern is the possibility that our measure of external knowledge flows is correlated with the dependent variable (recall, however, that the latter is led by one period). This may occur when there is sufficient persistence in innovation performance; when those firms that have innovated successfully in period *t*, are also successful in period *t* + 1.[14] Hence, the drivers of innovation performance may also impact a firm's rating of the importance of external knowledge flows.

In order to address the last three concerns simultaneously, we run a 2SLS estimation, where we use, as an instrument, a correction of the predicted value of external knowledge flows obtained from a specification that estimates external knowledge flows as a function of: *AbsCap*, *Appropriability* and *NewProd* and the dummies for 1-digit sectors and regions. The results from such a regression (not reported here), show that *AbsCap*, *Appropriability* and *NewProd* all have positive, substantial effect (1% significant) on external knowledge flows. The coefficients are used to construct our instrument of external knowledge flows (Inst[*ExtKnow_Flows*]), that is:

$$Inst[ExtKnow\_Flows]_{it} = ExtKnow\_Flows_{it} - (\beta_1 AbsCap_{it} + \beta_2 Appropriability_{it} + \beta_3 NewProd_{it}),$$

where $\beta_1 = 0.1$; $\beta_2 = 0.048$; $\beta_3 = 0.05$ are the coefficients estimated from the equation driving external knowledge flows described above.[15] Table 5 confirms our main empirical findings, that is, absorptive capacity positively moderates the impact of external knowledge flows on innovation performance, particularly in turbulent sectors and in those sectors with strong appropriability.

[13] The specification used to predict this probability includes the following variables (for definitions see Table 1): Abscap, StrategicProtection, InnObstacles, Size, New, and sector and regional dummies. Additionally, for identification purposes we introduce controls for total export activity and total investment.

[14] We make the point that if $ExtKnow\_Flows_t$ is correlated with the error term of $NewProd_t$ ($Innov_t$), it may also be correlated with the error term of $NewProd_{t+1}$ ($Innov_{t+1}$). This may occur when the error term has a firm-specific component.

[15] The 2SLS only applies for the estimation of *NewProd*. In the Logit estimations of *Innov*, following Wooldridge (2001) we introduce directly the instrument in the specifications, in order to deal with the endogeneity problem.

**Table 5**

Robustness checks. All variables are defined in Table 1. Both dependent variables are led by one period to avoid simultaneity. The estimations include controls for sectoral and regional fixed effects. All regressions are contingent on positive expenditures in innovation activity. The table only shows the second stage estimations where we used as an instrument the corrected predicted value of external knowledge flows obtained from a specification that explains external knowledge flows as a function of AbsCap, NewProd and Appropriability as well as dummies for 1-digit sectors and regions. In columns 1, 3 and 5 we estimate a 2SLS regression model that has NewProd as the dependent variable. Columns 2, 4 and 6 explain Innov through a Logit model that introduces the instruments directly in the specifications.

| Dependent variable | $NewProd_{t+1}$ | $Innov_{t+1}$ | $NewProd_{t+1}$ | $Innov_{t+1}$ | $NewProd_{t+1}$ | $Innov_{t+1}$ |
|---|---|---|---|---|---|---|
| $Internal\_R\&D_t$ | $0.19^{***}$ (4.97) | $0.25^{***}$ (3.55) | 0.04 (0.94) | $0.26^{***}$ (3.59) | $0.15^{***}$ (4.72) | $0.39^{***}$ (6.04) |
| $Permanent\_R\&D_t$ | $0.06^{***}$ (2.74) | $0.20^{***}$ (5.86) | $0.44^{***}$ (7.31) | 0.02 (0.50) | −0.01 (−0.62) | $0.13^{***}$ (3.91) |
| $Training_t$ | 0.00 (0.00) | 0.00 (0.03) | −0.01 (−0.04) | 0.05 (1.29) | 0.01 (0.22) | $0.10^{***}$ (2.84) |
| $R\&D\_Skills_t$ | 0.07 (1.55) | 0.01 (0.06) | $0.07^{*}$ (1.64) | $-0.10^{*}$ (1.75) | $-0.05^{***}$ (−2.46) | −0.01 (−0.04) |
| $ExtKnow\_Flows_t$ | $0.08^{***}$ (2.57) | $0.48^{***}$ (8.44) | $0.09^{***}$ (2.79) | $0.25^{***}$ (5.11) | $0.12^{***}$ (4.95) | $0.19^{***}$ (3.91) |
| $AbsCap \times ExtKnow\_Flows_t$ | $0.42^{***}$ (2.33) | $1.74^{***}$ (14.99) | $0.46^{***}$ (2.62) | $0.55^{***}$ (5.11) | $0.24^{***}$ (5.54) | −0.04 (−0.64) |
| $Turbulent_t$ | | | 0.06 (1.03) | $0.25^{***}$ (2.59) | | |
| $Turbulent \times ExtKnow\_Flows_t$ | | | −0.01 (−0.17) | $0.13^{**}$ (2.21) | | |
| $Turbulent \times AbsCap \times ExtKnow\_Flows_t$ | | | $0.14^{***}$ (3.12) | $0.12^{*}$ (1.60) | | |
| $Appropriability_t$ | | | | | $0.23^{***}$ (6.23) | $0.30^{***}$ (4.08) |
| $Appropriability \times ExtKnow\_Flows_t$ | | | | | 0.02 (0.99) | $-0.12^{***}$ (−2.62) |
| $Appropriability \times AbsCap \times ExtKnow\_Flows_t$ | | | | | $0.11^{***}$ (3.82) | $0.10^{*}$ (1.63) |
| $StrategicProtection_t$ | $0.17^{***}$ (6.97) | $0.19^{***}$ (3.58) | $0.17^{***}$ (6.98) | −0.04 (−0.96) | $0.18^{***}$ (7.46) | 0.01 (0.06) |
| $InnObstacles_t$ | −0.02 (−1.13) | 0.01 (0.11) | −0.02 (−1.01) | −0.06 (−1.36) | 0.03 (1.30) | −0.05 (−1.01) |
| $Size_t$ | $0.07^{*}$ (1.62) | $0.27^{***}$ (5.05) | $0.07^{*}$ (1.59) | $0.18^{***}$ (3.71) | $0.09^{***}$ (3.85) | $0.160^{***}$ (3.38) |
| $New_t$ | 0.01 (0.56) | 0.01 (0.11) | 0.01 (0.59) | −0.01 (−1.07) | 0.02 (0.79) | −0.01 (−0.34) |
| Constant | 0.05 (0.34) | −1.16 (−0.91) | −0.04 (−0.27) | −1.19 (−1.01) | −0.10 (−1.34) | −1.52 (−1.28) |
| Number of observations | 2265 | 2265 | 2265 | 2265 | 2265 | 2265 |
| $R^2$ (%)[a] | 18.65 | 11.73 | $20.35^{***}$ | $14.48^{***}$ | $19.78^{***}$ | $12.60^{***}$ |
| Test of fitness | 23.36 (0.000) | 13.55 (0.000) | 18.41 (0.000) | 12.20 (0.000) | 22.08 (0.000) | 12.90 (0.000) |

*Note*: The *t*-values appear in parentheses. We use the *F*-test as fitness test.

[a] In columns 3 and 5 (4 and 6) we test differences in variances with regard to the variance of the specification in column 1 (2).

* *p*-Value 0.10.

** *p*-Value 0.05.

*** *p*-Value 0.01.

In addition, we experiment with several other control variables like, for instance: export intensity; a dummy for multinational firms; provincial instead of regional dummies; 2-digit sector dummies; and a Herfindahl index to control for the degree of competition. The results do not change. Finally, since we have a sample with very heterogeneous firms – some with few employees, and others, large multinational corporations – there are sizable differences between mean and median values for several variables. This could suggest the presence of a significant amount of outliers and, in turn, potential problems in the estimations. So as to control for the effect of these outliers, we re-estimate our specifications using the correction introduced by Huber (1964). The results – available upon request – do not change qualitatively and are even stronger in comparison with those in Tables 3 and 4.

## 4. Conclusions

Cohen and Levinthal (1989) opened up a research agenda by defining the concept of absorptive capacity and emphasizing its influence on a firm's ability to innovate. However, they also point out that absorptive capacity impinges on a firm's knowledge base, and that it is difficult to separate absorption and innovation empirically. This paper looks at the moderating role played by absorptive capacity, as an avenue to measure its impact on innovation performance. We argue that firms endowed with more absorptive capacity are better equipped to identify the presence of external knowledge flows and, more importantly, exploit them efficiently.

Our results suggest that absorptive capacity is indeed a source of competitive advantage. In other words, this paper shows that it pays dividends, in terms of innovation performance, to invest in enhancing absorptive capacity. Moreover, we find that absorptive capacity plays an even more critical role in turbulent knowledge sectors and sectors with tighter IPR.

In the knowledge-based economy, where a large proportion of relevant knowledge resides outside a firm's boundaries, this is a particularly important message for managers who aim to develop sustainable competitive advantage (Arora et al., 2001). The greater availability of external knowledge, both in terms of voluntary and involuntary knowledge flows, could suggest that internal innovation becomes relatively less important. Although logically correct, this statement underestimates the importance of a firm's knowledge base in developing absorptive capacity. Internal investment in innovation is, thus, even more important because it enhances a firm's capacity to absorb external knowledge.

This research also offers some policy implications. First, by assessing how absorptive capacity affects innovation performance, it proposes a different channel for government policies that foster innovation. Since there is a link between firms' absorptive capacity and a country's absorptive capacity (George and Prabhu, 2003), then a policy aimed at stimulating firms' absorptive capacity might be very effective in making the country more receptive to international knowledge flows. These flows end up stimulating local innovation as well. Second, our results suggest that although knowledge circulates more easily in industrial clusters or geographically agglomerated industries, the degree to which firms benefit from belonging to clusters is not evenly spread (Beaudry and Breschi, 2003; Giuliani and Bell, 2005). Absorptive capacity plays a crucial role. Thus, governments that are intent on fostering the creation of industrial clusters must also establish complementary policies so as to enhance firms' absorptive capacity. Finally, our findings highlight that absorptive capacity is relatively more important in turbulent knowledge environments and when IPR protection is stronger. Governments set on formulating policies to foster firms' absorptive capacity would be well advised to do so in high tech sectors, in conjunction with initiatives aimed at increasing IPR protection.

This study is subject to a number of limitations and some of them are natural avenues for future research. First, most of our data were self-reported assessments from firms' CEOs. Although INE takes appropriate steps, both in the design and testing phases, to limit concerns regarding single-informant data, the issues of key informant bias and common method bias cannot be ruled out conclusively. Second, our research is conducted using a sample of Spanish firms. We do not have any specific reason to believe that nationality might bias our results in a specific direction. Fortunately, we can test this easily, in future research, because the very same dataset that we use for Spanish firms is available for many other European countries (the so-called "Community Innovation Survey"). Third, we are forced to be eclectic when measuring some of our variables and constructs. Although we use survey data, we did not participate in the development of the questionnaire, nor was it structured to answer the research questions addressed in this paper. In particular, we have no direct measure for absorptive capacity. However, we exploit the existing literature to provide a plausible proxy that uses several components of a firm's knowledge base. Finally, it may be worth studying, in more depth, the dynamics that link a firm's absorptive capacity to innovation performance. This would require the expansion of our panel data to include more periods. This limitation is likely to be solved in the near future. Indeed, a new wave of data will be available soon, and there is a strong commitment by INE to update the database on an annual basis.

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