Turning external technology into new products: the moderating role of absorptive capacity

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Since the 1980s external technology acquisition has been a vital component of firms' technology strategy and today it ranks even higher on the agenda of technology managers of the most innovative firms, as the impact on management practice that Open Innovation has had suggests. In parallel with the increasing reliance on external sources of technology, scholars have started to caution about the potential drawbacks of adopting a too open policy in technology acquisition. Adding to prior research that has offered contrasting evidence on the benefits of external technology acquisition on innovation performance, this paper offers an original and through analysis of the impact of technology in-licensing on a firm's new product development.
Adopting an absorptive capacity perspective and using longitudinal data of Spanish manufacturing firms, this paper finds that an inverted U-shaped relationship exists between external technology acquisition and product innovation performance, which is moderated by internal R&D expenditures. Interestingly, the direction of such moderation appear to depend on the extent to which firms conform themselves to the Open Innovation paradigm. These results suggest, among the others, the need for a re-conceptualization of absorptive capacity that accounts for other managerial mechanisms than internal R&D in order to turn external technologies into new products.

1. Introduction

External technology acquisition has been a vital component of firms' technology strategy since the second half of the 1980s (Magee, 1992; Chatterji and Manuel, 1993; Chatterji, 1996). As the huge impact that the Open Innovation paradigm has had on management practice in the last years suggests (Gassmann, 2006; Chesbrough et al., 2006), external technology acquisition still ranks high on the agenda of technology managers of the most innovative firms today.

Several dynamics have recently lowered the barriers a firm has to overcome when it comes to access technology from outside its boundaries, i.e., the strengthening of Intellectual Property regimes (Teece, 1998), increased division of labor in innovative activities and diffusion of the "serial innovator" business model (Arora and Gambardella, 2008; Hicks and Hedge, 2005), stronger reliance on External Technology Commercialization strategies from large innovators (Kline, 2003; Gassmann and Enkel, 2009), birth of technology brokers (Lichtenthaler and Ernst, 2008; Chesbrough, 2006).

The reasons why firms have been increasingly acquiring technology from external sources and the risks underlying this strategy have been extensively debated in the literature (e.g., Hagedoorn, 1993; Jones et al., 2000; Chesbrough, 2003). Firms acquire technologies from outside their boundaries with the aim to share the risks and costs that developing new technologies entail, to increase the flexibility of internal R&D activities, to scout developments in distant disciplines and geographies, to enable cross-functional innovation processes and ultimately improve their competitive advantage. In parallel with this increased reliance on external sources of technologies, scholars have started to caution about the risks and potential drawbacks associated with this policy (Laursen and Salter, 2006; Cassiman and Veugelers, 2006). Relying on technologies developed outside the firm increases the likelihood of losing control over core competencies, it lowers appropriability and might determine high transaction costs. Literature on the absorptive capacity and Not-Invented-Here syndrome concepts (Katz and Allen, 1982; Cohen and Levinthal, 1990; Rothaermel and Alexandre, 2009) suggests that technology acquisition will have a different impact on different organizations, i.e. how will a company be able to absorb and effectively use technology developed elsewhere depends on several factors related to the firm's strategic investments, internal organization and past experience.

A rich body of empirical research has flourished around a related problem, i.e. whether acquiring technology from external sources positively impacts firm's performance. Results from these empirical analyses are contrasting, with some scholars suggesting that a positive relationship is in place between external technology acquisition and firm's performance (MacPherson, 1997a,b,c) and others who find instead no relationship or even a negative link between them (Kessler et al., 2000; Jones et al., 2000; Bruce et al., 1995). These divergent findings can be in part explained with the heterogeneity of the variables used to measure the extent of a firm's reliance on external technology sources and especially its performance (being them product-, market- or financial-related).

If we focus in particular on the impact of external technology acquisition on product innovation performance, an important contribution comes from Brown and Eisenhardt (1997), who find that firms that rely on external technology sourcing to explore and absorb cutting-edge knowledge residing beyond their boundaries are more successful in new product introductions than companies focused on internal technology sourcing. There are other scholars demonstrating that accessing technological knowledge held beyond the focal firms' boundaries improve their innovativeness (Ettlie and Pavlou, 2006; Spencer, 2003). Some contrasting findings are however reported by Zahra (1996), who shows that corporate-sponsored ventures making more extensive use of external technology sources exhibit no significant differences in the introduction of new product developments.

A critical contribution to this debate comes from the absorptive capacity research (Cohen and Levinthal, 1990; Zahra and George, 2002), which suggests that, in order to extract value from external technologies, a firm needs to invest as well in internal R&D to develop and nurture technical capabilities. Following this line of reasoning, some scholars have demonstrated that external technology acquisition is complementary to internal R&D (e.g., Cassiman and Veugelers, 2006; Jones et al., 2000; Laursen and Salter, 2006; Rothaermel et al., 2006; Vanhaverbecke et al., 2002; Veugelers, 1997), i.e. external technology acquisition positively affects firm's performance only if complementary R&D activities are in place.

We believe that there is the need for a thorough analysis and critical re-examination of external technology acquisition and its impact on firm's product innovation performance. This article contributes to the current debate by proposing a conceptual model (see Figure 1) which: (i) focuses on in-licensing as the main contractual form for external technology acquisition; (ii) assesses the impact of in-licensing on the firm's product innovation performance; (iii) explores the moderation effects played by a firm's absorptive capacity. These relationships among the model's constructs are tested using a longitudinal dataset consisting of 27,153 firm-year observations for more than 3,800 Spanish manufacturing over the period 1995-2006.

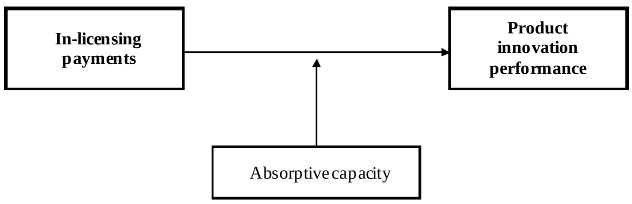

Figure 1.Conceptual model.

This article contributes to existing research by: (i) showing the existence of an inverted U-shaped relationship between external technology acquisition and firm's innovation performance, therefore confirming, generalizing and extending to manufacturing firms and other contractual forms, such as in-licensing, results from alliance literature (Deeds and Hill, 1996); (ii) demonstrating that not only an optimal level of external technology acquisition exists, but that such optimal configuration is influenced by an idiosyncratic firm-specific factor: absorptive capacity; (iii) specifying that the moderation effect of absorptive capacity varies according to the level at which external technology acquisition is undertaken, therefore supporting a contingent rather than absolute view of the absorptive capacity concept. Finally, this paper noticeably contributes to the Open Innovation literature by showing that the implementation of Open Innovation requires firms, that are in a constantly unstable equilibrium, to balance internal and external technologies.

Moreover, several practical insights are given to Chief Technology Officers and R&D managers about how to increase their firm's product innovation performance by acquiring external technologies through in-licensing agreements. The structure of the article is as follows. The next section develops theory and hypotheses. Section 3 gives an overview on data and methodology used in the analysis, whereas Section 4 describes the empirical results. Section 5 discusses the findings of the econometric analyses and Section 6 concludes and outlines some directions for future research.

2. Theory and hypotheses development

2.1 Technology in-licensing and product innovation performance

There are several theoretical reasons why external acquisition of technologies by means of in-licensing may have a beneficial effect on firm's product innovation performance. First of all, it contributes to speed up the NPD process (Leone and Reichstein, 2010) and it lowers the high risks inherent in R&D activities (Rothaermel and Alexandre, 2009), as technologies acquired from outside are already totally or partly developed. Furthermore, technology in-licensing allows the firm to turn large fixed R&D costs and capital expenditure into variable costs, as royalties are often calculated as a percentage of the licensee's sales from products incorporating the in-licensed technology. As a result, the flexibility of the firm's R&D activities is strongly enhanced (Tapon and Thong, 1999; Kessler et al., 2000). Acquiring technologies through in-licensing further allows the firm to access breakthrough technologies from distant technological fields. As noted by Gavetti and Levinthal (2000), "best opportunities are distant". In a context of distributed knowledge, it is impossible indeed to keep abreast of all relevant technological advances exclusively through internal technology sourcing (Rothaermel and Alexandre, 2009).

However, increased reliance on external sources of technologies by means of in-licensing may show diminishing return effects on firm's product innovation performance and, past some point, may have a negative impact on performance. First of all, the economic "law" of diminishing returns suggests that, the more a firm relies on external technology sources, the more likely it is to acquire technologies whose marginal contribution to product innovation performance is relatively smaller (Deeds and Hill, 1996). Moreover, the more a firm acquires technology from external sources, the higher the risk of losing control over critical competences (Hamel, 1991). In particular, the more dispersed a firm's knowledge basis, the higher the risks of competencies hollow out as a result of interrelated phenomena such as large numbers, knowledge asymmetries and uncertainty (Becker, 2001). Differently put, very dispersed knowledge becomes more difficult to integrate in NPD (Becker and Zirpoli, 2003). Finally, acquiring technology from external sources entails significant transaction costs, which can be ex-ante (e.g., costs for the search for partners, evaluation of the available alternatives, negotiations) and ex-post (e.g., costs for absorbing the externally acquired technologies, integrating them with internal pieces of knowledge, manage the relationship with the external provider of this technology). The more a firm acquires technology from external sources, the more ex-post transaction costs increase, which in turn create information processing overloads (Rothaermel and Deeds, 2006; Hitt et al., 1996; Zahra et al., 2000) and distract resources from NPD. The arguments related to the loss of control over core competencies and to ex-post transaction costs together suggest that, past some point, in-licensing will negatively impact on product innovation performance.

Therefore we posit the following:

Hypothesis 1: *An inverted U-shaped relationship exists between the acquisition of external technologies through in-licensing and product innovation performance.*

2.2 Technology in-licensing, product innovation performance and internal R&D expenditures

As regards the role of internal R&D investments in moderating the relationship between the acquisition of external technologies by means of in-licensing and product innovation performance, there are a number of theoretical reasons which suggest that the impact of in-licensing on product innovation performance is stronger in the presence of higher levels of R&D investments. First, the concept of absorptive capacity, i.e. the capability of a firm to screen, identify, evaluate, assimilate and exploit external knowledge (Cohen and Levinthal, 1990). This ability requires in-house R&D capability and expertise on the part of the innovating firm. A vast body of empirical research has documented this role of internal R&D. In the seminconductor industry, Tilton (1971), for example, argues that strong R&D capabilities allow firms to keep abreast of the latest technical developments and ease the assimilation of new technology developed elsewhere. Cassiman and Veugelers (2006) suggest that internal and external sources of knowledge are complements, rather than substitutes. A firm's absorptive capacity allows indeed for superior monitoring, understanding, screening, evaluation and exploitation of externally generated knowledge (Helfat, 1997; Mowery, 1983) and for the effective spanning of organizational and technological boundaries (Tushman, 1977, Tushman and Katz, 1980). This spanning of different organizational and technological boundaries, in turn, permits a firm to make novel linkages among different types of knowledge (Simon, 1985). Furthermore, absorptive capacity is critical for selecting the most suitable partners (Stuart et al., 1999). Similar to the concept of "absorptive capacity" is the one of "combinative capability", i.e. the firm's ability "to synthesize and apply current and acquired knowledge", which allows it to identify and harness the spillovers due to the simultaneous pursuit of internal learning through R&D and external learning through alliances, joint ventures, and acquisitions (Kogut and Zander, 1992). As suggested by Teece (2007) talking about the "sensing" capability, stronger internal R&D makes firms more sensitive to opportunities that present themselves in their technological environments. This makes them more successful in identifying in-licensing opportunities with a stronger potential to result in new products. Finally and more simply, in-licensed technologies need further R&D efforts to be turned into new products (Huston and Sakkab, 2007). This aspect has been captured by the concept of "Realized Absorptive Capacity" (Zahra and George, 2002), i.e. a firm's ability to process knowledge internally. Overall, existing empirical research strongly points to the importance for a firm, in order to generate knowledge spillovers between internal and external technology sourcing, to pursue both sourcing strategies simultaneously (Cassiman and Veugelers, 2006; Laursen and Salter, 2006; Rothaermel et al., 2006; Vanhaverbeke et al., 2002; Veugelers, 1997).

However, we believe that there are also several theoretical reasons suggesting that high reliance on internal R&D might hinder a firm's ability to turn external technologies acquired through in-licensing into new products, i.e. internal R&D might negatively moderate the inverted U-shaped relationship between the acquisition of external technologies and product innovation performance. First of all, the so-called Not-Invented-Here Syndrome (Chesbrough, 2003). The existence of Not-Invented-Here (NIH) syndrome (Katz and Allen, 1982), i.e. the internal resistance by R&D staff to external ideas, can be thought as a behavioral response inducing a substitution relationship between the use of external sources and internal R&D activities. In surveying about 2700 UK manufacturing firms, Laursen and Salter (2006) find evidence of a substitution effect between the openness of external search activities and internal R&D, thus showing the existence of a NIH syndrome. The more a firm invests in R&D activities (e.g., the higher the number of employees dedicated to R&D, the larger the laboratories), the more cognitive barriers it erects to the internal acceptance and exploitation of externally acquired technologies. The organizational phenomenon underlying the Not-Invented-Here syndrome can be also explained applying neo-classical theories of investment behaviors (Arrow, 1962; Gilbert and Newberry, 1982; Reinganum, 1983), whereby firms that strongly invest in internal R&D activities perceive a lower incentive (in comparison with firms investing smaller resources in internal R&D) toward turning externally acquired technologies into new products because this might render obsolete previous investments in R&D and technology development (Conner, 1988; Scherer, 1980). Second, there might be a problem of organizational inertia (Hannan and Freeman, 1977; 1984). The more resources a firm devotes to internal R&D activities, the stronger the organizational routines it develops and employs when it comes to develop new products and address technical problems during the NPD process. The likelihood that technologies coming from outside a firm's boundaries requires different approaches to be handled down and turned into new products is particularly high, this reducing the ability of a firm with strong investments in R&D to turn them into higher product innovation performance. Moreover, firms that are extremely focused on internal technology creation and development may devote insufficient managerial attention to external scouting, this resulting in a poor ability to recognize and select the most viable acquisition options (Hoang and Rothaermel, 2010). Taken together, this may be indicative of a situation where core competencies in internal R&D can turn into core rigidities (Leonard-Barton, 1992) when combining them with in-licensed technological knowledge.

Therefore we posit that:

Hypothesis 2A: *A firm's R&D expenditures moderate the inverted U-shaped relationship between in-licensing and product innovation in such a fashion that the effect of in-licensing on performance is stronger when the firm has higher R&D expenditures.*

Hypothesis 2B: *A firm's R&D expenditures moderate the inverted U-shaped relationship between in-licensing and product innovation in such a fashion that the effect of in-licensing on performance is weaker when the firm has higher R&D expenditures.*

3. Data and Methodology

In order to test our hypotheses, we draw on longitudinal data from the Spanish Business Strategy Survey (SBSS), an annual survey of a representative sample of Spanish manufacturing firms conducted by the Spanish Ministry of Industry, Tourism and Commerce. Firms in the survey represent 20 industrial sectors according to the NACE-Rev.1 classification (National Classification of Economic Activities, revised in year 1993). Respondents to the SBSS survey are CEOs, and data is collected using direct interviewers supported by a questionnaire. Overall, our sample ranges from 1995 to 2006. Because some firms stopped providing information during the sample period for several reasons, including mergers, changes to nonindustrial activity, or shutdown of the production process, we have an unbalanced panel. After accounting for missing data, we have an unbalanced panel of 3,874 firms, consisting of 27,153 firm-year observations crossing all 20 industrial sectors. The Kolmogorov-Smirnov tests on four important variables from the dataset – age, number of employees, sales, and number of innovations – reported no significant differences between respondents and nonrespondents. In the final sample, the chemicals, motor vehicles, machines and mechanical equipment, and food and tobacco sectors rank among the most populated sectors, which coincides with the actual distribution of Spanish manufacturing firms.

3.1 Measures

Dependent variable

Product innovation$_{it}$. We measure a firm's product innovation performance using the new number of new products developed by firm *i* in year *t*. In our data the number of new products developed is directly related to innovativeness: “new products” are recognized as such only if they are completely different to previous product lines or if they have suffered substantial modifications from previous products. The number of new products not only measures a firm’s ability to introduce new products in the market but also its ability to upgrade current ones. Also, this measure is closely related to similar measures of innovative strength such as patents (Scherer and Ross, 1990; Ahuja and Katila, 2001), sales growth (Scherer, 1983), and invention counts (Achilladelis et al., 1987). The ability to produce multiple product innovations in a given period is critical in high-velocity environments and is considered a key indicator of innovative performance (Schoonhoven et al.,1990).

Independent Variable

In-license expenditures$_{it-1}$. To approximate firms’ commitment to external technology acquisition we use the log of firms’ in-licensing expenditures in Euros. To capture the curvilinear effect of in-licensing expenditures on the dependent variable, we construct a squared term named *In-license expenditures*$^2_{it-1}$, which allow us to test for the hypothesized curvilinear (inverted U-shaped) effect of in-licensing expenditures on innovation. Bear in mind that the explanatory variables in this model are lagged one period to avoid potential endogeneity problems caused by simultaneity between innovative performance and the variables related to external knowledge flows (Escribano et al., 2009).

Moderating Variable

R&D expenditure$_{it-1}$. Following our arguments developed earlier, we use R&D expenditures as a variable moderating the curvilinear effect of in-licensing expenditures on innovation. To measure firms’ R&D expenditures, we use the log of total R&D expenditures. This variable is lagged one period with respect to the dependent variable because R&D investments are likely to take some time before they actually have an effect on performance.

Control Variables

As organizational controls we include the size of firms, as measured by the log of sales. We include firm age measured by the log of age, which controls for the overall generic experience of firms. We also control for possible macroeconomic and business cycle shocks common to all industrial sectors, using time dummies for all the years in the sample, as well as time-invariant shocks, using industry dummies reflecting the 20 different industrial sectors.

3.2 Estimation procedure

Because the dependent variable is a count outcome variable taking non-negative integers, a regression approach for Poisson data is suitable (Henderson and Cockburn, 1996; Ahuja and Katila, 2001). We specified the following regression model:

$$\textit{Product innovation}_{\,it} = e^{(X_{it-1}\beta_1)},$$

where, X_{it-1} is a vector of regressors containing independent and control variables, as well as interaction terms to test for moderation effect. We assume that the impact of the regressors is not contemporary with the dependent variables and therefore we lag them one period. Following Ahuja and Katila (2001) we apply the Generalized Estimating Equations (GEE) methodology for estimating Poisson data because it helps reduce problems caused by overdispersion. We also correct for possible violations of the independence assumption of the independent variable by specifying an exchangeable correlation matrix, which assumes interdependence of subsequent observations of the dependent variable through time without imposing a specific type of correlation (Diggle et al., 2002). Moreover, in order to provide a meaningful comparison of the regression coefficients across different models and to reduce potential multicollinearity problems, we entered all the regressors in a standardized form. This procedure does not affect the level of significance of beta coefficients. As it is often the case, quadratic and cross-product terms tend to be highly correlated with the variables used to construct them. We examined the variance inflation factors (VIFs) for direct effects, and the average VIF is 1.50, which is well below the recommended threshold of 10 (Cohen et al., 2003).

4. Empirical results

Table 1 provides the descriptive statistics and bivariate correlation matrix for all the variables included in our analysis. The average sample firm develops between 2 and 3 new products annually.

Table 2 shows the panel regression results using GEE Poisson estimators when predicting firm product innovation performance (Models 1-3) .

In testing our theoretical model, we applied a hierarchical moderated regression (Jaccard et al. 1990). According to this method, the moderation effect of R&D expenditure are appropriately examined as the interaction terms are tested for significance after all lower-order effects have been entered into the regression equation. Moderation effect is supported only if the model containing the interaction terms represents a statistically significant improvement over the model containing the direct effects (Hoang and Rothaermel, 2010; Baron and Kenny 1986).

Model 1 depicts the baseline model including all control variables as well as the moderating variable. As expected, the level of a firm’s R&D expenditure is positively correlated with the firm’s product innovation performance.

		Mean	Std. Dev.	1	2	3	4
1	Number new products	2.546	20.167				
2	Log(sales)t-1	14.342	2.283	0.0300*			
3	Log(Age)	2.920	0.897	0.0230*	0.4193*		
4	Log(R&D spending)t-1	3.778	5.352	0.0796*	0.5709*	0.2626*	
5	Log(In-licensing payment)t-1	1.222	3.605	0.0394*	0.3585*	0.1516*	0.3187*

Table 1. Means, standard deviations and correlations.

	Panel data Model predicting the Number of Product Innovations at time *t*		
	Model 1	Model 2	Model 3
Log(sales) *t-1*	**0.077*** **	**0.083*** **	**0.059*** **
	(0.004)	(0.004)	(0.005)
Log(age)	**0.010**	**0.022*** **	**0.027*** **
	(0.006)	(0.006)	(0.006)
Log(total R&D) *t-1*	**0.071*** **	**0.074*** **	**0.102*** **
	(0.001)	(0.001)	(0.001)
IN-Licensing experience	**0.054*** **	**-0.006**	**0.023*** **
	(0.004)	(0.005)	(0.005)
Log(IN-Licensing payment) *t-1*		**0.204*** **	**0.399*** **
		(0.005)	(0.009)
Log(IN-Licensing payment) *t-1*^2		**-0.015*** **	**-0.025*** **
		(0.000)	(0.001)
Log(IN-Licensing payment) *t-1* * Log(total R&D) *t-1*			**-0.028*** **
			(0.001)
{Log(IN-Licensing payment) *t-1*}^2 * Log(total R&D) *t-1*			**0.002*** **
			(0.000)
Sector controls (20 sectors)	Yes	Yes	Yes
Year controls	Yes	Yes	Yes
Constant	**-0.088**	**0.011**	**0.176** **
	(0.062)	(0.061)	(0.060)
N	27210	27153	27153
***p<0.001; **p<0.01; *p<0.05; †p<0.1			

Table 2. GEE Poisson estimation model predicting product innovation performance.

In Hypothesis 1, we suggested that the relationship between the firm's acquisition of external technologies and its product innovation performance is an inverted U-shape, implying that in-licensing expenditures enhance the number of new products developed by the firm. In Models 2-3, because the linear terms for in-licensing payment are positive and significant, whereas the squared terms are negative and significant ($p<0.001$ for all models), we find strong support for our hypothesis.

In Hypothesis 2A, we proposed that a firm's R&D investments moderate the inverted U-shaped relationship between external technology acquisition and firm product innovation performance, so that the effect of in-licensing on new product development is stronger when the firm possesses higher levels of R&D expenditures. To test this hypothesis, we inserted the interactions between the in-licensing payment variables (linear and squared terms) and R&D expenditures in Model 3. The results obtained support Hypothesis 2B as the interaction between the linear in-licensing payment term and R&D expenditure is negative and significant (whereas the interaction between the squared in-licensing payment term and R&D expenditure is positive and significant). To further investigate such relationship, we followed Aiken and West (1993) and plotted the significant results obtained in Model 3 in correspondence to the main quartiles of the R&D expenditure distribution (see Figure 2). The plots reveal that the negative sign for the linear in-licensing payment term and R&D expenditure is the product of a steeper (more positive) slope for the relationship between in-licensing and new product development, when the R&D expenditures are low and a less steep slope when R&D expenditures are high. It emerges that for low levels of in-licensing, the results are consistent with Hypothesis 2B, which postulates that the positive effect of in-licensing on firm innovation performance is weaker when the firm possesses higher levels of R&D expenditures, whereas for high levels of in-licensing, the results show that the negative effect of in-licensing on firm innovation performance is weaker when the firm possesses higher levels of R&D expenditures. Therefore, the direction of the moderation of absorptive capacity appears to depend on the extent to which firms conform themselves to the Open Innovation paradigm.

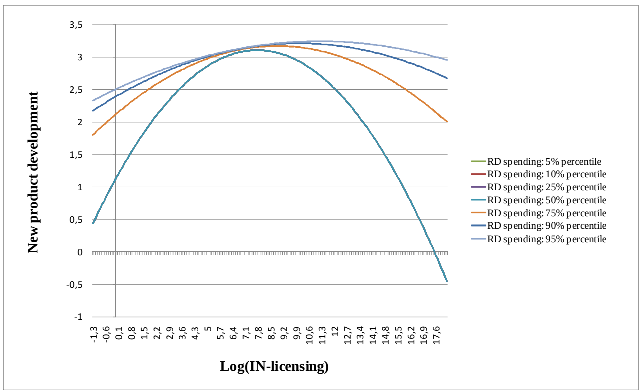

Figure 2. Moderating effect of R&D expenditure on the relationship between in-licensing and product innovation

5. Discussion

5.1 Technology in-licensing and product innovation performance

Our analysis shows that external acquisition of technologies by means of in-licensing is beneficial for a firm's product innovation performance, but it shows diminishing returns effects and, past some points, it has a negative impact on performance. In other words, acquiring technologies from external sources helps the firm increase the speed of its NPD process and reduce its inherent risks, to improve its ability to access technologies and to enhance the flexibility of internal R&D activities. However, relying too much on technology in-licensing might hinder the firm's capability to develop and commercialize new products as a result of increased difficulties in integrating very dispersed pieces of knowledge and soaring ex-post transaction costs. Therefore, if it is true that a firm willing to improve its product innovation performance should rely on technologies acquired from outside, we cannot say that the more a firm relies on external technologies, the better its product innovation performance. For a firm that aims to maximize product innovation performance, the paper shows the existence of an optimal level of external technology acquisition through in-licensing. The decision to rely on external technologies to a higher extent (e.g., because of lack of internal competencies resulting from an unexpected leave of some star scientists) requires to adopt appropriate managerial and organizational solutions to improve the integration of very dispersed knowledge and reduce the associated costs (e.g., creation of dedicated organizational units to centrally manage acquired technologies, establishment of rewarding and incentive systems that encourage the integration of external technologies with internally available competencies). The role of internal R&D expenditures in reducing the negative effects of relying too much on external technologies will be discussed ahead.

Our findings are consistent with those reported in Deeds and Hill (1996) and more recently Rothaermel and Deeds (2006), although they consider the impact of strategic alliances on product innovation performance of entrepreneurial biotech firms. Taken together, these studies suggest that the inverted U-shape relationship between external technology acquisition and product innovation performance is highly generalizable, regardless of the means through which technologies are acquired from outside (in-licensing, strategic alliances, joint ventures, acquisition) and the characteristics of the innovative firm (start-up or large, incumbent firms, novel and dynamic or mature industries). Testing this generalizability represents a promising avenue for future research.

5.2 The moderating role of internal R&D expenditures

Most importantly, our findings about moderating effect suggest that the impact of internal R&D investments on the relationship between external technology acquisition and product innovation performance will be significantly different for firms which rely on external technologies at dissimilar extents. For descriptive purposes, we categorized the firms according to their degree of reliance on external technology acquisition, as measured by the log of firms' in-licensing expenditures. We cluster analyzed, using a hierarchical clustering method with k-means and euclidean distance (Rencher, 2002), the firms on three levels, ranging from low- to high-reliance on external technology, and the resulting groups were the following:

- Closed Innovators, i.e. those companies that are spending at year t a very small amount of resources in in-licensing external technologies (less than 3.41 of our independent variable). 89.3% of our observations fall in this category.
- Semi-Open Innovators, i.e. companies that are spending a sizable amount of resources in in-licensing (between 3.41 and 10.1 of our independent variable). This category represents 5.2% of our sample.
- Open Innovators, i.e. companies which spend a large amount of resources into in-licensing (more than 10.1 of our independent variable) and represent the 5.5% of our sample. In this category we can find both companies with a consistent record of heavy use of in-licensing or "compulsive buyers" that have signed una tantum a very relevant in-licensing deal. Our analysis shows that external acquisition of technologies by means of in-licensing is beneficial for a firm's product innovation performance, but it shows diminishing

As regards the moderating role of internal R&D expenditures, it is interesting to comment on the different slope of the curves for high-R&D spending and low-R&D spending companies depicted in Figure 2. As regards the left part of the curves, with low levels of external technology acquisition through in-licensing (i.e. for Closed Innovator firms), additional acquisition of external technologies has a higher marginal effect on new product performance in firms with low R&D in comparison with firms with high R&D expenditures. In other words, the benefit in terms of product innovation from increasing external technology acquisition of 1 Euro is higher for low R&D spending firms. It is therefore more difficult to increase product innovation performance through acquiring external technology for Closed Innovators which invest a lot of money in internal R&D than for Closed Innovators with limited internal R&D expenditures. A Closed Innovator that carries out a lot of internal R&D will suffer from stronger NIH and cognitive barriers to the acceptance of externally acquired knowledge than a Closed Innovator with limited internal R&D expenditure. At the same time, it is likely that a Closed Innovator with strong internal R&D will in-license from outside only marginal technologies, which complement internal knowledge (whereas this might not be the case for Closed Innovator with limited internal R&D, that might use external technologies as substitute to internal knowledge). Under this circumstance, absorptive capacity is less important to determine the firm's ability to make the most out of the acquired technologies in terms of product innovation performance. Taken together, these results indicate that moving from a Closed to an Open approach to innovation might be more difficult for firms with stronger internal R&D investments. This is an important contribution to the literature which has recently looked at the organizational implications of a transition toward Open Innovation (Chiaroni et al., 2010; Di Minin et al., 2010), and is consistent with the neoclassical theories of investment behavior mentioned in Section 2.

Moving toward higher levels of external technology in-licensing (i.e. for Semi-Open and Open Innovators) it emerges that high R&D expenditures help firms mitigate the diminishing returns and, past some point, the negative effect of in-licensing on product innovation performance (see Figure 2). Therefore, the point of maximum for firms investing a lot of money in internal R&D lies in correspondence with higher level of in-licensing payments than for low R&D spending firms (see Figure 2). Intuitively, this can be justified by the fact that higher R&D expenditures allow firms to better manage external technologies without suffering the negative effects due to difficulties in integrating dispersed knowledge and soaring ex-post transaction costs. Therefore R&D expenditures act as a cushion that avoids dysfunctions from increasing an Open Innovator's reliance on external technologies in terms of product innovation performance. Firms with low R&D lack indeed an adequate level of absorptive capacity to understand, screen, select and absorb a large amount of external technologies and to turn acquired technologies into new products. Open and Semi Open Innovators thus need an internal R&D powerhouse.

From a practical point of view, this analysis indicates that the best solution for firms willing to maximize the number of new products developed and introduced into the market is to rely on relatively high levels of external sources of technologies combined with strong internal R&D expenditures. Because this approach might be very costly to pursue, some companies might lack the financial resources to adhere to this policy. If this is the case, it is not advisable to simply out-source technology development by substituting internal R&D investments with external shopping of technologies. Rather, a "second best" approach seems to be the reduction of both internal R&D expenditures and external technology acquisition, so as to maintain consistency between the amount of technologies acquired from outside and internal knowledge development efforts.

From a theoretical point of view, this analysis suggests that a firm's absorptive capacity is much more important in determining a firm's ability to turn the externally acquired technologies into new product when high-levels of external technologies are acquired (i.e. for Open Innovator firms). With low levels of external technology acquisition (i.e. for Closed Innovator firms), relying very much on internal R&D might on the contrary reduce the firm's ability to turn new technologies acquired from outside into new products, because of NIH and organizational inertia, which instead do not appear to affect firms which are already Open Innovators, and thus are likely to have learned how to overcome these barriers. This line of reasoning has two complementary (or perhaps opposite) implications:

- The importance of absorptive capacity (measured as internal R&D spending) in affecting a firm's ability to turn external technologies into product innovation is dependent on the amount of technology that the firm already acquires from outside (i.e. on the fact of being a Closed or an Open Innovator). Therefore, absorptive capacity seems not to be an absolute concept, but it is dependent on the amount of external technology that the firm already acquires;
- There might be different ways to operationalize absorptive capacity in innovation and technology

management research. Absorptive capacity can be measured through internal R&D expenditures, as done by most prior research (Cohen and Levinthal, 1990; Rothaermel and Alexandre, 2009; Escribano et al., 2009), for firms that already rely on high levels of external technologies, but it takes something different than internal R&D to increase a Closed Innovator firm's capacity to absorb new pieces of technologies acquired from outside. Future research should try to unearth the mechanisms that enhance the marginal returns of in-licensing for firms relying on external technology acquisition to a limited extent.

6. Conclusions

Considering the importance that external technology acquisition still has in the most innovative firms' technology strategy, this article investigates the impact of technology in-licensing on a firm's product innovation performance. Relying on a longitudinal dataset consisting of 27,153 firm-year observations for more than 3,800 Spanish manufacturing over the period 1995-2006, we find that a curvilinear inverted U-shaped relationship exists between the money spent on technology in-licensing and the number of new products that the firm develops and commercializes. Differently put, external acquisition of technologies by means of in-licensing is beneficial for a firm's product innovation performance, but it shows diminishing return effects and, past some points, it has a negative impact on performance. We further considered how internal R&D spending moderates the relationship between external technology acquisition through in-licensing and product innovation performance. We find that the positive and, past some point, negative effect of in-licensing on product innovation performance is weaker for firms with higher R&D expenditures. Our results indicate that the benefit of internal R&D on a firm's ability to turn further technologies acquired from outside into new products varies depending on how much money the firm is already spending on in-licensing (i.e., whether the firm is a Closed, a Semi-Open or an Open Innovator), with high R&D expenditures determining a higher marginal benefit for Open Innovator than Closed Innovator firms.

From a practical point of view, the article suggests that a firm should identify an optimum level of external technology acquisition through in-licensing which maximizes its product innovation performance. The decision to rely on external technologies to a higher extent (e.g., because of lack of internal competencies resulting from an unexpected leave of some star scientists) requires to adopt appropriate managerial and organizational solutions to improve the integration of very dispersed knowledge and reduce the associated ex-post transaction costs. Moreover, a firm which is willing to make the most out of the technologies acquired from external sources should complement them with internal R&D. In particular, our analysis indicates that the best solution for firms willing to maximize the number of new products developed and introduced into the market is to rely on relatively high levels of external sources of technologies combined with strong internal R&D expenditures. Because this approach might be very costly to pursue, some companies might lack the financial resources to adhere to this policy. If this is the case, it is not a clever strategy to simply out-source technology development by substituting internal R&D investments with external shopping of technologies. Rather, a "second best" approach seems to entail the reduction of both internal R&D expenditures and external technology acquisition, so as to maintain consistency between the amount of technologies acquired from outside and internal knowledge development efforts.

As regards implications for research, the article is the first contribution that illustrates from both a theoretical and an empirical point of view the existence of an inverted U-shape relationship between technology in-licensing and product innovation performance. Taken together with the results of prior research about the impact of strategic alliances on product innovation performance of entrepreneurial biotech firms (Deeds and Hills, 1996; Rothaermel and Deeds, 2006), our findings points to a broad generalizability of the above mentioned curvilinear relationship in the field of external technology acquisition, which should be tested in future research. Furthermore, our analysis indicates that absorptive capacity, operationalized through a firm's internal R&D expenditures, has a different impact on the firm's ability to turn externally acquired technologies into new products depending on how much external technology the firm already acquires from outside. This suggests that future research should focus on what makes the difference between Closed and Open Innovator firms as regards their ability to turn new technologies acquired from outside into new products and hence to develop a more fine grained theoretical understanding of the absorptive capacity concept.

As regard limitations, it should be noted that we only account for the quantitative aspect of new product innovation, and not for its quality (e.g., whether the new products developed through integration of external technologies result in higher market share or financial performance that those developed relying on internal R&D). Second, our work may be at risk of aggregation bias as we do not distinguish between in-licensing deals at different stages of the innovation value chain and with different partners. Also we focus on outcomes at the firm level of analysis: a more fine grained analysis that assess performance at the single deal level may offer a more subtle understanding of the impact of in-licensing over performance and of the moderating effect of internal R&D.

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