estructura econòmica
ECONOMÍA APLICADA II

In-house versus External Basic Research and First-to-market Innovations

by

Dolores Añon Higón

January 2016

Working Papers in Applied Economics

WPAE-2016-01

ECONOMÍA APLICADA II

Universitat de València

Departamento de Estructura Económica (Economía Aplicada II), Facultad de Economía, Universitat de València
Avda dels Tarongers, s/n, 46022 – Valencia, Spain
Phone +34 96 382 83 49 / Fax +34 96 382 83 54
http://www.estructuraeconomica.es
e-mail: investigacion.estructura@uv.es

ISSN 2172-3036

In-house versus External Basic Research and First-to-market Innovations

Dolores Añón Higón[1]

Applied Economics II & ERI-CES, Universitat de València, Avda. de los Naranjos, s/n, 46022 Valencia, Spain, e-mail: m.dolores.anon@uv.es. Tel. +34 963828343

Abstract

This paper explores to what extent conducting internal basic research, as opposed to external basic research (i.e. outsourcing and collaboration with universities) encourages firms to bring new products into the market ahead of competitors, and contributes to innovation performance. The analysis is based on a sample of Spanish manufacturing firms over the period 2006-2012. Our findings suggest that conducting in-house basic research affects firm's propensity to introduce product novelties. Furthermore, performing this activity continuously affects the probability of being product-pioneer in low and medium-low tech sectors. Collaboration with universities also helps in introducing new products ahead of competitors, but contracting scientific research from universities does not lead to a pioneer strategy.

Key words: basic research, in-house, outsourcing, collaboration, pioneer, imitation.
JEL classification: D22, L21, O32.

[1] I thank conference participants at the IIO Conference (Chicago, 2014), Workshop IO (Alberobello, 2014) and Jornadas de Economía Industrial (Barcelona, 2014) for feedback and comments. Financial support from the Spanish Ministry of Science and Technology (ECO2011-25033/ECON) and from the Generalitat Valenciana (PROMETEO/2009/068) is gratefully acknowledged. Usual caveats apply.

1. Introduction

According to the Frascati Manual (2002: p. 30) basic research, also known as fundamental research, *"is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view*". Despite the appropriability problems and high uncertainty related to basic research activities, firms might have incentives to conduct these activities within their boundaries (Nelson, 1959). Cohen and Levinthal (1989) and Rosemberg (1990) argue that first-mover advantages may be an important benefit associated to performing basic research. These advantages may be the result from being the first to possess new knowledge resulting from basic research, or from the development of new products or processes which, brought to the market ahead of competitors, may confer a temporary monopoly. The importance of developing and bringing to market innovative products ahead of rival firms and the benefits and risks for the firm pursuing this strategy are well recognized (Lieberman and Montgomery, 1988). However, there is a lack of empirical evidence on how corporate basic research may contribute to help firms to achieve a market pioneer status.

Though most of basic research is nowadays conducted at universities, corporate research labs became widespread in the 1930, with companies such as AT&T (Bell Laboratories), Xerox (PARC) and Dupont investing seriously in basic research (Arora et al., 2015). Scholars have shown that these investments have reported important private benefits and have been a source of advantage to these firms. These include, amongst others, improvement in innovation performance (Gambardella, 1992), in productivity (Mansfield, 1980; Griliches, 1986) or in the development of firm's absorptive capacity (Cockburn and Henderson, 1998).

However, since the 1990s, there has been a gradual re-orientation towards leaner corporate research labs (Tijssen, 2004). Though companies such as Google continue to invest in in-house basic research, other leading companies (e.g. AT&T, Xerox, IBM and Hewlett-Packard) have downsized, shuttered or spun off their research labs and outsourced much of their basic research (Chesbrough, 2003; Andries and Thorwarth, 2014; Arora et al. 2015). At the same time, new companies have emerged in sectors like biotech, nanotech and also energy, which are directly engaged in basic research activities (Pisano, 2010).

This paper contributes to expand the literature by analyzing the role of conducting in-house basic research versus using other modes of open innovation, in which basic research is either outsourced or performed in collaboration with universities (Chesbrough, 2003). In particular, we are interested in analyzing the role that these different strategies of performing basic research (internal vs. external) have in shaping the firm's innovation choice, and in particular, in determining the chances to be pioneer in product development. Additionally, the literature has also embraced the concept of learning-by-doing, i.e. learning effects through the continuous engagement in an activity (Wright, 1936; Arrow, 1962). In the innovation literature, learning, experience and accumulation of knowledge are important sources of the innovation process. Rosenberg (1990, p. 173) stresses that for basic research to be successful it "*requires the making of stable, long-term commitments*". On that basis, we also test the extent to which experience in conducting internal basic research influences the odds of being a pioneer.

More specifically, the aims of this paper are twofold. First, we seek to analyze the impact of performing in-house basic research and doing it continuously, versus conducting basic research externally (either through outsourcing or in collaboration with universities) upon the choice of firms' innovative strategies. We focus on product innovation and, in line with Duysters and Lokshin (2011), we distinguishing between three possible strategies: (i) abstaining from innovation, (ii) introducing new or significantly improved products or services that are known to the market but new to the firm (referred to as an imitation strategy[1]) and, (iii) introducing original or significantly improved products or services to the firm's market (i.e. pioneer strategy). Our definition of pioneer is consistent with that used by Golder and Tellis (1993, p. 159), who define market pioneer as "*the first firm to sell in a new product category*"[2]. Second, we assess the importance of doing basic research, in-house and

[1] Other studies interpret also the introduction of products new to the firm but known to the market as resulting from an imitation strategy (Kleinknecht et al. 2002).

[2] Other studies have used market entry and market entry time to define and measure pioneering (Lieberman and Montgomery, 1998). For instance, the definition of market pioneer provided by

external, upon firm's innovative performance, measured as the sales share of new-to-the market products.

The analysis is performed for a sample of Spanish manufacturing firms draw from the Technological Innovation Panel (PITEC) database from 2006 to 2012. This provides detailed information about firms' R&D activities, allowing for differentiation between basic and applied research and development expenditures; as well as for distinguishing between in-house and external R&D activities. We find that firms performing in-house basic research are more likely to introduce product novelties ahead of their competitors, regardless of their size and technological sector. Not only are they more likely to be market leaders, but also doing basic research contributes to innovation performance. In addition, persistence in performing basic research may help firms in launching new products ahead of rivals in low and medium-low tech sectors and also for large and medium-sized firms. In contrast, not all sources of external basic research contribute to achieving a pioneer status. Our findings suggest that while collaboration with universities helps firms introduce products ahead of competitors, particularly in high and medium-high sectors and also for small firms, contracting scientific research from universities does not have a significant effect.

The next section provides an overview of the literature on the potential private benefits from conducting internal and outsourcing basic research. Section 3 presents the data and the empirical model. The empirical results are discussed in section four, and the final section concludes.

2. Related Literature

2.1 Basic research and firm's performance

Despite the extensive literature focusing on the role of R&D, the literature on firm's basic research activities is relatively scarce. Existing studies on basic research are either theoretical or focus their attention onto academic/scientific research as the source of basic research, overlooking the importance of corporate basic research. Notable exceptions, however, highlight the benefits from private basic research.

Robinson and Fornell (1985, p. 305) is "*the first entrant in a new market*", while Urban et al. (1986) define a pioneer as the first product to enter the market.

These include, amongst others, improvement in innovation performance (e.g. Gambardella, 1992, Bean 1995), in productivity (Griliches, 1986) or in the development of firm's absorptive capacity, which allows firms to better screen and absorb external information (Cockburn and Henderson, 1998).

The empirical studies by Gambardella (1992) and Fabrizio (2009) show that firms engaging in basic research activities obtain advantages in the innovation outcome, in terms of number, quality and timing. In contrast, Lim (2004) finds no significant effect of internal basic research on the patenting performance of pharmaceutical firms, while a negative effect is found for firms in the semiconductor industry. Findings from Mansfield (1980), Griliches (1986), and Czarnitzki and Thorwarth (2012) show that not only basic research is an important determinant of firm's productivity but also exhibits a premium with respect to other types of R&D, particularly in high-tech sectors. Similarly, Bean (1995) finds that basic research contributes to productivity growth, but its contribution is indirect, enhancing the gains realized through product and process development. In addition, Cassiman et al. (2002) find that basic research enhances applied research productivity and argue that it allows firms to develop their absorptive capacity, an idea previously embraced by Rosemberg (1990) and supported also by Cockburn and Henderson (1998). Complementarity effects between basic and applied research are additionally found in Henard and McFadyen (2005). Moreover, Stern (2004) shows that a focus on basic research may lead to labor cost reductions, as researchers may be willing to accept lower salaries in exchange of permission to keep up with scientific research.

From a more theoretical point of view, basic research has been linked to the generation of pioneering and revolutionary ideas, as well as breakthrough applications, even in the short term (Pavitt, 1991). Basic or fundamental research has the potential to enable significant commercial opportunities through facilitating entirely new product areas rather than just incremental changes. Many important and commercially viable products have been developed based on breakthroughs made by basic research. Examples are the birth of radio astronomy at Bell Laboratories, and the discovery of high temperature superconductivity at IBM research labs.

Breakthrough innovations are not the only economic benefits of basic research for industrial innovation. Additionally, scientific knowledge, resulting from basic research activities, helps firms to gain a better understanding of the technological landscape in which they search for new inventions, informs them about the most profitable directions for applied research, avoiding wasteful experimentation, and helps them to better interpret findings of applied research (Rosenberg, 1990; Fleming and Sorenson, 2004; Kelchtermans et al. 2013). Internal basic research capabilities also allow firms to expand firm's absorptive capacity, by allowing to better monitor, interpret and absorb scientific knowledge that is conducted externally to firms (Cohen and Levinthal, 1990; Cockburn and Henderson, 1998).

2.2 External basic research and firm's performance

The accelerating process in the use of external sources of knowledge coupled with leaner corporate labs has attracted the attention of scholars (Bönte, 2003). Recent studies have analyzed the role that external R&D plays on firm performance, but have failed to disentangle the effect of external basic research (the exception being Andries and Thorwarth, 2014). These studies have found a positive effect of external R&D on firm's productivity (Bönte, 2003; Lokshin et al. 2008) and also on innovation (Vega-Jurado et al., 2009), with mixed results about potential synergies between external and internal R&D (Cassiman and Veugelers, 2006; Vega-Jurado et al., 2009). Being able to discern outsourced basic research from other R&D activities, Andries and Thorwarth (2014) find that Flemish firms benefit in terms of productivity from outsourcing their basic research activities. Additionally, they find that for medium and large firms in-house basic research is more productive than outsourced basic research.

From a theoretical perspective there are benefits and costs associated to the use of external basic research. By contracting external basic research, firms are able to tap into a broader range of competencies and knowledge, which may improve firm's innovation capabilities. Further, collaboration with universities[3], to the extent that

[3] Although the transaction cost literature considers collaboration to be a "hybrid" between outsourcing and vertical integration, other scholars regard collaboration as a strategy in its own right (Vega-Jurado et al., 2009). Collaboration allows firms to share costs and uncertainty, to exploit synergies, to take advantage of economies of scale and scope, and even to gain government support (Becker and Dietz, 2004).

they are producers of relevant scientific knowledge and advanced technical skills, may allow firms to build faster on recent research findings in their own research activities (Fabrizio, 2009). Teece (1992) claims that partnerships with universities let firms to leverage their skills and resources and increase their competitiveness. However, outsourcing basic research or relying on collaborations for the development of basic research is not extent of problems. Andries and Thorwarth (2014) highlight the problems in assimilating and leveraging acquired scientific knowledge and the high transaction costs incurred in setting up and managing partnership agreements.

2.3 Basic research and first-movers

As Rosenberg (1990) claims, firms that perform basic research may benefit from 'first-mover advantages'. First-mover advantages (and disadvantages) have been discussed extensively in the fields of strategic management (Lieberman and Montgomery, 1988); marketing (Robinson and Min, 2002; Min et al. 2006); and industrial organization (Mueller, 1997). A pioneering or first-mover strategy may lead to different advantages such as establishing uniqueness in the market; defining standards from new technologies; preempting rivals in the acquisition of scarce resources; or using switching costs to lock up sales. In contrast, first-mover disadvantages may come from the ability of followers to free ride and to solve market or technological uncertainties; the possibility of technological discontinuities and shifts in consumer needs that create opportunities to leapfrog the pioneer with a superior product; and pioneer inertia (Lieberman and Montgomery, 1988).

Rosenberg (1990) states that some of the aforementioned advantages may apply in the case of basic research. To the extent that the findings from basic research activities may be patented, pioneers may be able to consolidate their market position through a temporary monopoly. First-movers may preempt rivals in the acquisition of assets whose commercial value may be positively affected by the findings from basic research. Pioneers may also be able to enjoy learning curves and set switching costs. However, there are also important disadvantages. Basic research is characterized by appropriability problems, since followers can free ride on the pioneer's innovation, mostly through knowledge spillovers and imitation (Nelson, 1959). However, the literature also recognizes that although knowledge from basic research may spill over, the capacity to interpret and apply that knowledge require an extensive knowledge base (Cohen and Levinthal, 1990).

Largely on the basis that first-mover advantage exists, scholars have tried to analyze the determinants of entry-timing decisions. Firm resources and capabilities, coupled with environmental conditions determine the pioneer status (Kim and Lee, 2011). In the sense that (internal and external) basic research activities contribute to expand the research base, which is acknowledged to be a critical element of a firm's innovation capability, basic research is expected to determine the pioneer status (Tijssen, 2004). Though first-mover status is a pre-condition for exploiting entry related advantages, we acknowledge that the factors involved in achieving and sustaining first-mover advantages are far more complex (Kevin et al. 1992) and beyond the scope of this study. Thus, the main aim of this study is to analyze the extent to which basic research helps firms in achieving pioneering status.

3. Data and Model

3.1. Data and measures

The data used in this paper are drawn from a yearly survey called *The Technological Innovation Panel* (PITEC)[4], a by-product of the European Community Innovation Survey. The survey is conducted by the Spanish National Institute of Statistics (INE), and contains questions characterizing the innovative activities of a panel of more than 12,000 Spanish firms since 2003 in all sectors of the economy[5]. Since 2005, the response rate to the survey is above 95%. While the sample is representative of the population of firms with 200 or more employees, the representativeness of firms with less than 200 employees is biased towards firms having internal and/or external

[4] PITEC is sponsored by *Fundación Española para la Ciencia y la Tecnología* (FECYT) and the *Foundation for Technical Innovation* (COTEC). Details on the survey as well as the database can be found at http://icono.fecyt.es/PITEC. We use the anonymized data set (López, 2012).

[5] In 2003 the sample contained only two sub-samples: a sample of firms with 200 or more employees (with an estimated representation of 73%), and a representative sample of firms undertaking intramural R&D. In 2004 the sample was enlarged to include, on the one hand, firms with less than 200 employees, external R&D and no intramural R&D; and on the other, a representative sample of small non-innovative firms (with less than 200 employees).

R&D[6].

The analysis is conducted for firms in the manufacturing sector and we use information from the PITEC survey for the period 2006 to 2012[7]. We exclude from the sample public firms and research associations as well as merged or acquired firms; and to control for possible outliers firms with turnover above or below the 1% and 99% tails of the distribution are also excluded. We also eliminate data with missing values in variables of interest. Our final sample is an unbalanced panel of 5,606 firms with 34,730 observations. These firms are at least observed for three consecutive periods. Following the classification proposed by Eurostat and based on an aggregation of NACE manufacturing sectors (see Table A.1 in the appendix), we classify industries into two main categories: low and medium-low tech manufacturing sectors (LML tech) and high and medium-high tech manufacturing sectors (HMH tech).

The PITEC survey, which follows the Oslo Manual (OECD, 2005), provides detailed information on firms' innovation strategies. In particular, the questionnaire asks firms whether they were able to introduce a product innovation and whether this innovation was new to the firm or new to the market. Following the lines of previous studies by Vinding (2006) and Duysters and Lokshin (2011) we focus on product innovation[8] and distinguish between: (i) firms that do not imitate/innovate (i.e. firms that do not introduce any new or significantly improved product or service); (ii) imitators (i.e. firms that report having exclusively introduced a product/service new to the firm but known to their market); and (iii) pioneers (i.e. firms that report having introduced new or significantly improved products/services into their market ahead of competitors)[9].

---

[6] This is so because all firms that have received any form of public support for R&D or those that have reported R&D expenses are surveyed every year. The remaining surveyed firms come from a random sample stratified by size and sector among non-R&D performing firms.

[7] Due to the enlargement of the survey suffered in 2004 and 2005, we start the analysis in 2006, although we may use data from previous years as some variables are defined as lags.

[8] In the survey, product innovation is defined as the market introduction of *"a good or service, which is either new or significantly improved with respect to its fundamental features, technical specifications, incorporated software or other intangible components, intended uses or performance*."

[9] We do not distinguish whether the firm is a one-off or serial pioneer. Further, we are not able to distinguish whether they are pioneers at the local, domestic or international markets.

The dataset has been organized in such a way that the three strategies are exclusive to each other[10].

[Insert Figure 1 around here]

Figure 1 depicts firms' innovation strategies by technological sector. Overall 42% of firms refrain from innovating[11], while 25% and 33% imitate and are pioneers respectively. In the low and medium-low tech sector (LML) the share of firms not innovating increases significantly up to 50%. In the case of high and medium-high tech sectors (HMH), 39% of firms lead innovation, 29% imitate and 32% abstain from innovation/imitation.

It should be noted that the PITEC survey, as other CIS-type surveys, has some limitations. These limitations include that some of the innovation measures are subjective in nature, fruit of evaluation or perception of the respondent firm (Frenz and Prevezer, 2012). For instance, according to the definition provided above of a pioneer innovator, this would be a firm that claims to have introduced a new or significantly improved product or service that was new to the firm's market. First, the expression 'significantly improved' is quite subjective and we may have that for the same product some firms may consider as a significant improvement while others would not. Second, the term 'market' is not defined in the questionnaire, thus respondents may interpret market in a broader or in a narrower sense. If a firm chose to interpret its market narrowly it is more likely to qualify as pioneer. Nonetheless, the evidence provided by Mairesse and Mohnen (2004) suggests that 'subjective' innovation measures (in CIS data) tend to be consistent with more 'objective' indicators of innovation.

The survey also gathers information on the three types of intramural R&D expenditures: basic research, applied research, and experimental development. Detailed definitions of the three types of R&D are provided in an annex to the questionnaire. Particularly, basic research is defined as "*experimental or theoretical*

[10] Other studies that have used this variable are Vega-Jurado et al. (2008) and Slivko (2012).

[11] This does not mean that these firms abstain from other types of innovation, such as process or organizational innovation, which are not considered in the present study.

work undertaken primarily to acquire new knowledge ..., without any particular application or use in view". Information on the percentage of R&D expenditure devoted to basic research by the firm, allows us to know whether she invested in basic research (*BR*), and whether she did it in a continuous basis (*Stable BR*).

Information on different external knowledge-acquisition strategies is also provided. Firms report whether they have externally contracted R&D from diverse parties and whether they have cooperated in innovation activities with other partners. In line with Andries and Thorwarth (2014), we assume that the type of R&D a firm outsources to universities is, in fact, basic research. We also assume that firms cooperate with universities to acquire basic research[12]. Therefore, following and extending the approach by Vega-Jurado et al. (2009), we distinguish between contracted basic research to universities (*BR outsourced*) and knowledge acquired through collaboration with universities and public research institutes (*BR collaboration*). We control also for other R&D contracted[13] to knowledge creators different from universities (*othRD outsourced*), and from other forms of partnership different to those with universities; i.e. with clients, suppliers, competitors, and companies from the same group (*oth. collaboration*). These strategies are measured using dummy variables that take the value 1 if the firm has used the strategy and 0 otherwise.

Table 1 shows the importance of in-house and external basic research activities by innovation strategy. The first evidence to notice is that the percentage of firms doing basic research internally is very low. Just about 6 per cent of firms in the Spanish manufacturing industry invest in internal basic research (in our sample this represents 325 firms of the total 5,606 analyzed). However, there are interesting differences across the three types of strategies, with the percentage of firms engaged in basic research increasing as we move from firms not doing innovation (2%), to firms that imitate (6%) and to those that are pioneer (10%). Differences are also observed for the percentage of firms that conduct persistently basic research. Only less than half of those that invest in basic research perform the activity in a continuous way (2.5%),

[12] Bayona Sáez et al. (2002) find that Spanish firms initiate cooperation with universities and research centres to acquire basic research.

[13] The PITEC survey offers only information about contractual collaboration but does not provide information on informal collaborations. We draw specifically on the responses to the questions about cooperation with external agents for R&D and innovation activities.

with the number of firms increasing as we move from abstention towards being pioneer. However, there are no major differences in terms of the percentage of total R&D invested in basic research across the three strategies.

With regard to external basic research activities, 15% of the firms in our sample (about 858 firms) engage in collaboration with universities and public research labs in innovation activities. In contrast, only 7% of them (about 409 firms) acquire external research to universities through contracts. In both cases, the percentage of firms linked to external sources of knowledge increases as we move from a non-innovation strategy towards a pioneer innovation strategy.

[Insert Table 1 around here]

3.2. Model specification

The aim of the study is to gauge the importance of in-house and external basic research in determining the firm's choice on the innovation strategy. To do so, the model takes into account that the innovation choices a firm faces are threefold: abstention from innovation, imitation and pioneering innovation. Due to the categorical nature of the dependent variable, a discrete choice model offers the best approach to assessing the determinants, including basic research, of the observed innovation choices.

Previous studies have used different model specifications to analyze the determinants that govern the choice of innovation strategies. On the one hand, Vinding (2006) suggests the existence of a natural ordering of the dependent variable according to the degree of innovativeness and uses an econometric specification based on an *ordered logit model*. On the other hand, Vega-Jurado et al. (2008) propose a *multinomial logit model*, in which categories are assumed unordered. Finally Slivko (2012) uses a *stereotype logistic regression model* developed by Anderson (1984), which can be regarded as a compromise between the previous two. Unlike the orderered logit, the stereotype model does not impose the proportional-odds assumption (McCullag, 1980). In this context the proportional-odds assumption means that the effect of the covariates on the decision to imitate versus abstaining from innovation is the same as on the decision to being pioneer versus imitate. The validity of this assumption was tested using a Brant test and the results showed that the proportional-odds assumption is not fulfilled; therefore the ordered logit model is not applied in the present analysis.

In contrast to the ordered logit, in which 1 parameter vector β is estimated, in the multinomial logistic model K parameter vectors β_k, $k = 1, ..., K$ are estimated; where $(K+1)$ are the number of categories or outcomes of the dependent variable. An assumption implicit in the multinomial model is that the choices between categories are independent of the set of available alternatives; what is known as the "*Independence of Irrelevant Alternatives*" (Long, 1997). In our case, this assumption implies that, for instance, the relative probability of engaging in imitation instead of abstaining from innovation does not change in the absence of engaging in a pioneer strategy. The result of a Hausman test used to check the validity of the assumption suggest that this does not hold, and that the multinomial logistic model appears inappropriate. Instead we use a stereotype logistic regression model, which can be more parsimonious and will allow testing for the existence of the ordering nature of the dependent variable, without imposing the proportional odds assumption (Agresti, 2010).

Assuming a categorical response variable Y with K+1 categories, and a p-dimensional vector of covariates X, the stereotype logistic model is represented by[14],

$$p(Y = k \mid X) = \frac{\exp(\theta_k + \phi_j X'\beta)}{\sum_{l=1}^{K} \exp(\theta_l + \phi_l X'\beta)} , \qquad k = 1,\ldots,K \qquad (1)$$

In our case, the above equation will indicate the implied probability that innovation strategy k is observed, where the choice set K represents when the firm chooses not to innovate, to imitate, or to be pioneer respectively. In equation (1), the θ's are unrestricted constant terms for each equation, while the ϕs are scale parameters to be estimated along with the β's. The relationship between the coefficients of the

[14] The original version of the stereotype regression model by Anderson (1984) reports a minus sign in front of ϕs , which makes the interpretation confusing. Therefore, the model here is written with a plus sign in front of ϕs . The sign of the estimated βs are reversed correspondingly (see Slivko, 2012).

stereotype logistic model, β, and the multinomial logistic coefficients is: $\beta_k = \phi\beta$. To identify the stereotype logistic regression model, we assume $\phi_1 \equiv 0$ and $\phi_k \equiv 1$, but other constrains are possible (Anderson, 1984). Thus, there are (2K-1) + p parameters to be estimated in the Stereotype model, in contrast to K+ K*p parameters in the Multinomial model.

Our interest lies in explaining the role of basic research in determining the choice of firm's innovation strategy. To this end, we assume that the vector *X* in equation (1) contains proxies for in-house basic research (*BR*) and external basic research; either basic research contracted from universities (*BR outsourced*) or basic research performed in cooperation with universities (*BR collaboration*). The vector includes also a set of other control variables, which have been previously shown to affect innovation choices at firm level.

We control for a group of variables that relate to the firm's internal capabilities. These include in-house R&D, human capital, firm's size, group membership and ownership. Following Cuneo and Mairesse (1984), the number of R&D employees by the firm is used as a proxy for the R&D stock (*R&D*). As suggested by Schankerman (1981) the number of employees is corrected for double counting by subtracting R&D employment from total employment. Human capital (*Human capital*) is measured by the share of qualified personnel (Freel and Robson, 2004). Among the rest of variables assumed to influence the innovation choices we use firm size (*Size*). The literature suggests that large established firms engage more in improving existing products (i.e. imitate), while new and small firms invest more in original innovations (Acs and Audretsch, 1988; Akcigit and Kerr, 2010). We control also for group membership (*Group*), in order to allow for the possibility of intra-firm spillovers; and for whether the firm is foreign-owned (*Foreign*).

Additionally, we control for other sources of external knowledge as described above (*OthRD outsourced*; *Oth. collaboration*); and for whether the firm has received government funding for its innovation activity (*Gvt. funding*). We also control for the market size to which firms have access (*Geo. market*) as well as the Herfindhal concentration index of the industry (*HHI*). In line with Lerner (2009) and Raymond et al. (2010), respectively, we include a proxy for appropriability conditions (*Appropriability*) and a proxy for demand-pull factors (*Demand pull*). Finally, sector dummies are also included to capture different technological opportunities and other unobserved factors varying across industries; and a set of time dummies capturing business cycle effects. To deal with the potential simultaneity bias all explanatory variables enter with one lag in the model specification. A detailed description of the variables is provided in Table 2.

[Insert Table 2 around here]

Table 3 presents the descriptive statistics of the main variables used in the empirical analysis. Statistics (mean and standard deviations) are presented for the total sample, for low and medium-low (LML) tech sectors, and for high and medium-high (HMH) tech sectors. Some interesting features may be pointed out. The share of innovative sales is about 9 percent relative to total sales (11 and 7 per cent in HMH and LML tech sectors respectively). Other sources of external knowledge rather than universities are more often used than those involving basic reach. On average, 22 per cent of firms cooperate with non-academic agents and 25 per cent acquire R&D from competitors, suppliers, clients and sister firms. We also notice that, in contrast to LML tech firms, companies in HMH tech sectors invest more in R&D, use more frequently external sources of knowledge, receive more government funding and regard demand pull and appropiability conditions as more significant for their innovation activities. LML tech firms are however larger.

[Insert Table 3 around here]

4. Empirical Results

In this section we present the analysis for the choice of innovation strategy and the role that basic research, both in-house and external, plays in this decision[15]. Table 4a provides estimates of the coefficients of the stereotype logistic regression (SLM) for the total sample, and distinguishing between LML and HMH manufacturing sectors.

[15] All estimations have been performed with the software package STATA.

As previously mentioned, the dependent variable has three different outcomes: abstaining from innovation, being and imitator and being a pioneer. For purposes of identification, category j = 1 ("non-innovator") is treated as the baseline category and therefore the constraints imposed to identify the model are $\phi_1 \equiv 0$ and $\phi_2 \equiv 1$. The estimated ϕ parameters indicate the distance between the different innovation choices, and one can appreciate that are monotonically increasing with respect to j, satisfying the condition $\phi_3 > \phi_2 \equiv 1 > \phi_1 \equiv 0$. This supports the appropriateness for the ordered dependent variable and the use of a stereotype logistic model instead of the multinomial logit model[16]. For the three samples we observe that the effect of the independent variables on firm' innovation strategy choice varies among adjacent categories, suggesting that these variables have stronger impact on the odds of a firm's choice between imitation and non-innovation ($\hat{\phi}_2 - \hat{\phi}_1 = 1$) than on the odds of the choice between being pioneer and imitator ($\hat{\phi}_3 - \hat{\phi}_2$). Additionally, the hypothesis that all ϕ parameters are equal is rejected, suggesting that the categories of the dependent variable are distinguishable.

We will base the discussion of the results on the estimated average marginal effects presented in Table 4b. Average marginal effects (AME) are a more direct interpretation of the effects of the explanatory variables on the probability of choosing a particular innovation strategy. In particular, the AME in Table 4b show that firms performing in-house basic research are about 6 percentage points (pp.) more likely to introduce new products in the market ahead of competitors, also in high and medium-high (by 4.3 pp.) and low and medium-low tech (by 8 pp.) sectors. In contrast firms doing in-house basic research are less likely to abstain from innovation activities. Regarding the effect of persistence in performing in-house basic research, results show that persistence boost the probability of being pioneer in LML-tech sectors in 7 pp., but it has no significant effect on HMH-tech sectors. In HMH-tech sectors what

[16] Results from a Multinomial Logit are available upon request. They show that in-house basic research has a positive effect on the possibility of becoming market leader and in discriminating between different strategies; with firms conducting basic research being more likely to be pioneers in the total sample and in low and medium-low (LML) tech sectors. Interestingly, in high and medium high (HMH) tech sectors, basic research constitute a key element in helping firms to become pioneer, and it makes it less likely that a firm will be imitator only. Additionally, persistence in performing basic research is also important in determining the propensity to become pioneer; in both LML and HMH tech sectors, and in the case of HMH tech it makes it less likely that a firm will be imitator only.

matters is doing basic research independently of the accumulated experience in these activities.

The results also show the different role played by distinct modalities of external basic research transfer. While collaboration with universities is positively related to a pioneer strategy, contracting basic research to universities has no significant effect. Specifically, the effect of university collaboration is larger in HMH tech sectors; with firms engaged in these partnerships being about 3 pp. more likely to introduce new products ahead of their rivals; but also being 0.5 pp. more likely to follow an imitation strategy. In both sectors, however, the odds of becoming pioneer are larger for conducting in-house basic research than performing this activity in collaboration with universities. From these findings three important points are highlighted. First, performing internal basic research is the strategy that provides larger payoffs. Second, collaboration with universities is also a useful strategy in developing new products ahead of competitors. Third, contracting basic research, which implies a more passive role by the focal firm in the generation of knowledge, does not provide a source of competitive advantage. This last result is consistent with the findings by Vega-Jurado et al. (2009).

Total in-house R&D is also significantly related to the innovation-entry choice, increasing the likelihood of being pioneer in both LML (by 5 pp.) and HMH tech sectors (by 0.2 pp.). In addition, results show that size and human capital influence the innovation strategy choice. The impact of these variables has the same significance and direction, i.e. increasing the probability of the pioneer strategy choice and reducing the likelihood of not innovating. On the other hand, foreign ownership is positively related to the likelihood of being pioneer in LML tech sector, while group-membership hinders the likelihood to introduce new products ahead of competitors in HMH tech sectors.

With regard to other sources of external knowledge, collaboration with other knowledge providers different from universities increases the odds of being market pioneer, and to a lesser degree increases the odds of following an imitation strategy. Contrary to outsourced basic research, the acquisition of contracted R&D services to clients, competitors, and sister firms is positively related to a pioneer strategy. Other variables that seem to influence positively the odds of being pioneer are government's funding, demand-pull factors, and appropriability conditions. To a lesser extent, they are also positively related to an imitative innovation strategy.

To check the robustness of the baseline results, we perform the previous analysis using the lagged levels of the basic research variables dated in t-2. Traditionally the benefits of basic research on innovation output were regarded to take place in the long term. However, long-term research projects have been often reduced to schedules of no more than two or three years, as science-intensive firms are nowadays operating in rapidly changing technology areas and markets (Tijssen, 2004). Table 5 reports the average marginal effects of the variables of interest[17]. The results are qualitatively similar to those presented in Table 4b. In-house basic research increases the probability of being pioneer in both sectors, while persistence in performing basic research only contributes to the choice of a pioneer strategy in LML-tech sectors. In addition, the results show that collaboration with universities is positively related to a pioneer strategy, but contracting basic research to universities has no significant effect. Comparing marginal effects, we show that the odds of becoming pioneer are larger for conducting in-house basic research than performing this activity in cooperation with universities.

4.1. Basic Research and Firm Size

The literature has also acknowledged the importance of firm size as a moderator in the relationship between basic research and firm performance. Overall, it has been argued that large firms may benefit more from basic research activities than their smaller counterparts. Larger market shares and a greater product diversification allow larger firms to be better able to exploit the results from basic research (Nelson, 1959; Rosenberg, 1990). More recently, Andries and Thorwarth (2014) empirically show that small Flemish firms also benefit in terms of productivity gains from basic research, and in particular from outsourcing their basic research activities. We extend their study to focus on innovation strategies instead of productivity and to include not only outsourced basic research but also cooperation with universities.

[17] The rest of control variables are included in the analysis but omitted from the table for ease of exposition. They are available upon request.

We estimate model (1) for small firms and, for medium and large firms, respectively. We follow the study by Andries and Thorwarth (2014) to classify small firms as those with less than 50 employees, and medium and large firms as those with 50 or more employees. The average marginal effects of the variables of interest are presented in Table 6. Results show that firms that invest in basic research, regardless of their size, are more likely to launch new products to their markets ahead of their competitors (about 6 and 5 pp., respectively). Persistence in conducting basic research only has a positive and significant effect on medium and large firms. The results for external basic research activities also show dissimilarities with regard to firm size. On the one hand, our results suggest that large and medium-sized firms do not benefit from external basic research. Small firms, on the other hand, benefit from cooperation with universities but are hindered in their innovation strategy from contracting their research to universities. Being more precise, our results show that small firms that cooperate with universities are 2 pp. more likely to introduce new products ahead of competitors and those that contract their basic research to universities are 3 pp. less likely to adopt a pioneer strategy. This finding differs from that found by Andries and Thorwarth (2014) who found a premium effect from outsourcing basic research activities over productivity for small firms, but not necessarily contradicts their results. As outsourcing implies reducing costs, this may have a positive effect on efficiency. However, efficiency improvements not necessarily have to translate into product innovation.

4.2. Basic Research and Innovation Performance

In addition to analyze the role of in-house and external basic research in determining the innovation strategy choice, we also study its effect on innovation performance. In doing so, we use as dependent variable the share of sales from new-to-the market products (i.e. from new or significantly improved products that are new to the market of the focal firm); which by definition is bounded between 0 and 1. While the Tobit model is often used for dependent variables of this type, Wagner (2001) points out that this may be inappropriate, because the dependent variable is bounded by definition rather than as a result of censoring. In such scenario, Papke and Wooldridge (1996) suggest to apply the so-called fractional logit model, which is estimated by the quasi-maximum likelihood estimator, with heteroscedasticity robust asymptotic variance.

Results from the fractional logit model are presented in Table 7; and are a test of robustness of the results presented earlier. Results show that in-house basic research has a positive and significant effect on the share of innovativeness sales in all samples. However, persistence in performing internal basic research does not appear related to innovation performance. Collaboration with universities is positively associated with innovation performance both in the total sample and in HMH-tech firms. However, contracted research from universities has no significant effect. These findings confirm those discussed above. Additionally, in-house R&D, human capital, government funding, other forms of collaboration and contracted R&D, demand-pull factors, and appropriability mechanisms are positively related to innovative sales both in LML and HMH-tech industries. In contrast, size shows a negative relationship. In LML tech sectors, the size of the market in which the firm operates shows a positive relation with the share of innovative sales, while in HMH tech sectors other externally contracted R&D activities seem to play a positive role.

5. Conclusion

This paper examined the effects of doing internal and external basic research on the firm's innovation strategy choice and its innovation performance. If traditionally, firms conducted basic research in their own research labs, increasing competition and shorter business cycles have led them to downsize their research activities and to rely more on external sources of knowledge. We test whether these two strategies pay off in terms of conferring the firm with a competitive advantage in terms of positioning their new products ahead of competitors. For a sample of Spanish manufacturing firms we find that, consistent with the literature, firms conducting internal basic research are more likely to introduce market novelties ahead of competitors, regardless of the technological sector and the size of the firm. Our results suggest that performing internal basic research may provide a larger payoff than conducting external basic research activities. This is in line with the result obtained by Andries and Thorwarth (2014) for large Flemish firms.

Moreover, our findings suggest that collaboration with universities is also a useful strategy in developing new products ahead of competitors. In contrast, contracting basic research, which implies a more passive role by the focal firm in the generation of knowledge, does not provide a source of competitive advantage. This last result is consistent with the findings by Vega-Jurado et al. (2009). Further, distinguishing by firm size, our results show that large and medium-sized firms only benefit from internal basic research but not from external. In contrast, small firms are more likely to introduce product novelties ahead of their rivals if they conduct internal basic research and/or cooperate with universities. However, small firms contracting basic research from universities are more likely to abstain from innovation.

In addition, our results show that accumulated experience in basic research may be a key driver of first-movers in low and med-low tech sectors. With respect to other determinants of firm's innovation choices we find that performing internal R&D, access to government funding, human capital, demand-pull factors, and appropriability mechanisms affect the likelihood of being a market pioneer. Moreover, we show that in-house basic research has a positive and significant effect on the share of innovativeness sales. However, collaboration with universities has only a positive relationship with innovative sales in high and medium-high tech sectors. Contracted basic research has no significant effect on innovative sales.

These results may have important policy and management implications. From the policy point of view, we argue that it is important to consider the heterogeneous nature of R&D activities when providing innovation incentives. Incentives to invest in corporate basic research may have the potential to enable significant commercial opportunities through facilitating entirely new product areas rather than just incremental changes. In light of our results, policymakers should also encourage closer cooperation between firms and universities or research centers in basic research activities. However, these policies should not be implemented at the expense of reducing incentives for firms to strengthen their internal capabilities. Moreover, policies only targeting the commercialization of knowledge generated by universities and public research centers do not seem to enhance firms' innovation leadership.

From the managerial point of view, our results suggest that internal basic research, rather than external basic research, is more conducive to a market pioneer strategy. In light of these findings, managers should cautiously consider outsourcing basic research activities. Unless companies play an active role in creating knowledge from basic research, the rewards from acquiring external basic research may be fruitless. Therefore, if companies aim at being first in introducing new products into their markets, they should primarily conduct a large part of their basic research in-house. Moreover, managers should promote doing this activity continuously in time. The continuous performance of basic research is particularly relevant in large firms and in in low and medium-low tech sectors. Finally, cooperation in basic research activities with universities also seems to pay off in terms of a pioneer strategy, particularly for small firms.

Although this study provides relevant insights and enriches the literature, it is not without limitations that future research should overcome. First, the results may not provide conclusive evidence of a causal relationship. As a result, the findings should be interpreted as evidence of a positive correlation between basic research and a first-to-market innovation strategy. Second, the definition of 'pioneer' used in the analysis reflects the respondent's subjective perception of being a market pioneer. As the term 'market' is not defined in the questionnaire, respondents that tend to interpret market in a narrower sense are more likely to qualify as pioneers. Finally, although the term "first mover advantage" suggests that early entry is desirable, market pioneering is a high-risk strategy. In some instances an imitation strategy may be more appropriate. Future research will be addressed to evaluate whether basic research may help firms to materialize the first-mover advantages.

References

Acs, Z. J., and D. B. Audretsch, (1988). Innovation in Large and Small Firms: An Empirical Analysis. *The American Economic Review*. 78(4)*:* 678–690.

Akcigit, U., and K. William (2010). Growth through Heterogeneous Innovations, *NBER Working Paper* 16443.

Agresti, A. (2010). *Analysis of Ordinal Categorical Data* (2nd ed.). Wiley Series in Probability and Statistics. Jonh Wiley & Sons, Inc., Hoboken, New Jersey.

Anderson, J.A. (1984). Regression and Ordered Categorical Variables. *Journal of the Royal Statistical Society Series B*, 46(1): 1-30.

Andries, P., Thorwarth, S. (2014). Should firms outsource their basic research? The impact of firm size on in-house versus outsourced R&D productivity. *Creativity and Innovation Management: 23*(3), 303-317.

Arora A., Belenzonand S., and Patacconi, A. (2015). Killing the Golden Goose? The Decline of Science in Corporate R&D. NBER Working Papers 20902.

Arrow, K. (1962). The Economic Implications of Learning-by-Doing. *Review of Economic Studies*, 29(3): 155-173.

Bayona Sáez, C., García Marco, T. and Huerta Arribas, E. (2002). Collaboration in R&D with universities and research centres: an empirical study of Spanish firms. *R&D Management*, 32 (4): 321-341.

Bean, A. S. (1995). Why Some R&D Organizations are More Productive than Others. Research Technology Management, 38(1): 25-29.

Becker, W. and Dietz, J. (2004). R&D cooperation and innovation activities of firms: evidence for German manufacturing industry. *Research Policy*, 33(2): 209-223.

Bönte, W. (2003). R&D and Productivity: Internal vs. External R&D - Evidence from West German Manufacturing Industries. *Economics on Innovation and New Technology*, 12(4): 343-360.

Cassiman, B., Perez-Castrillo, D., and Veugelers, R. (2002). Endogenizing Know-How Flows through the Nature of R&D Investments. *International Journal of Industrial Organization,* 20(6): 775–799.

Cassiman, B. and Veugelers, R. (2006). In Search of Complementarity in the Innovation Strategy: Internal R&D and External Knowledge Acquisition. *Management Science*, 52: 68-82.

Chesbrough, H. (2003). *Open Innovation*. Boston, MA: Harvard Business School Press.

Cockburn, I., and Henderson, R. (1998). Absorptive Capacity, Coauthoring Behavior, and the Organization of Research in Drug Discovery. *Journal of Industrial Economics*, 46(2): 157–182.

Cohen W.M. and Levinthal D.A. (1990). Innovation and Learning: The Two Faces of R&D. *Economic Journal*, 99. 569-596.

Cohen W.M: and Levinthal D.A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35: 128-152.

Cuneo, P., and Mairesse J. (1984). "Productivity and R&D at the Firm Level in French Manufacturing." In Z. Griliches (ed.) *R&D, Patents, and Productivity*. University of Chicago Press, Chicago: 375-392.

Czarnitzki, D., and Thorwarth, S. (2012), Productivity Effects of Basic Research in Low-Tech and High-Tech Industries, *Research Policy, 41*: 1555-1564.

Duysters, G. and Lokshin, B. (2011). Determinants of alliance portfolio complexity and its effect on innovative performance of companies. *Journal of Product Innovation Management,* 28, 570-85.

Fabrizio K.R. (2009). Absorptive capacity and the search for innovation. *Research Policy*, 38(2): 255-267.

Fleming, L., and O. Sorenson. (2004). Science as a map in technological search. *Strategic Management Journal*, 25, 909-928.

Freel, M.S. and P.J.A. Robson *(*2004). Small Firm Innovation, Growth and Performance: Evidence from Scotland and Northern England*. International Small Business Journal,* 22*(6):* 561–575.

Frenz, M. and Prevezer, M. (2012). What does CIS data tell us about technological regimes and persistence of innovation? *Industry and Innovation*, 19(4): 285-306.

Gambardella, A. (1992). Competitive advantage from in-house scientific research: the US pharmaceutical industry in the 1980s. *Research Policy*, 21: 391–407.

Griliches, Z. (1986). Productivity, R&D, and Basic Research at the Firm Level in the 1970s. *American Economic Review*, 76(1): 141–154.

Golder, P. and Tellis, G. (1993). Pioneering Advantage: Marketing Logic or Marketing Legend. *Journal of Marketing Research*, 30 (May): 158-70

Henard, D.H. and McFadyen, M. A. (2005), The Complementary Roles of Applied and Basic Research: A Knowledge-based Perspective, *Journal of Product Innovation Management*, 22(6): 503-14.

Kim, J. and Lee, C. (2011). Technological Regimes and the Persistence of First-Mover Advantages. *Industrial and Corporate Change*, 20: 1305-1333

Kelchtermans, S., B. Leten, and Belderbos, R. (2013). "Do firms benefit from investing in basic scientific research? An empirical investigation for pharmaceutical firms." In F. de Beule and Nauwelaerts (eds.) *Innovation and Creativity: Pillars of the Future Global Economy*, Edward Elgar Publishing, 155-172.

Kleinknecht, A., Van Montfort, K., and Brouwer, E. (2002). The Non-Trivial Choice between Innovation Indicators. *Economics of Innovation and New Technology*, 11(2): 109-121.

Lerner, J. (2009). The Empirical Impact of Intellectual Property Rights on Innovation: Puzzles and Clues. *American Economic Review*, 99(2), 343-348.

Lieberman, M. B. and D. B. Montgomery (1988). First-Mover Advantages, *Strategic Management Journal* 9(S1): 41-58.

Lim K. (2004). The relationship between research and innovation in the semiconductor and pharmaceutical industries (1981-1997). *Research Policy*, 33: 287-321.

Lokshin B., Belderbos, R. and Carree, M. (2008). The productivity effects of internal and external R&D: evidence from a dynamic panel data model. *Oxford Bulletin of Economics and Statistics*, 70 (3), 399-441.

Long, J. S. (1997). *Regression models for categorical and limited dependent variables*. Sage. Thousand Oaks, CA.

López, A. (2012), Effect of microaggregation on regression results: an application to Spanish innovation data, *The Empirical Economics Letters*, 10(12).

Mairesse, J. and Mohnen, P. (2004). The importance of R&D for innovation: A reassessment using French survey data, *The Journal of Technology Transfer*, 30(1-2): 183-197.

Mansfield, E. (1980). Basic Research and Productivity Increase in Manufacturing. *American Economic Review*, 70(5): 863–873.

McCullagh, P. (1980). Regression models for ordinal data (with discussion). *Journal of the Royal Statistical Society*. Series B (Methodological), 42(2): 109–142.

Min, S., Kalwani, M.U. and Robinson, W.T. (2006). Market pioneer and early follower survival risks: a contingency analysis of really new versus incrementally new product-markets. *Journal of Marketing*, 70(1): 15-33.

Mueller, D.C. (1997). First-mover advantages and path dependence. *International Journal of Industrial Organization*, 15: 827-850.

Nelson R. (1959). The simple economics of basic scientific research. *The Journal of Political Economy*, 67(3), 297-306.

OECD (2002). Proposed Standard Practice for Surveys for Research and Experimental Development – Frascati Manual. OECD, Paris.

OECD (2005). Proposed Guidelines for Collecting and Interpreting Technological Innovation Data – Oslo Manual. OECD, Paris.

Pavitt, K. (1991). What makes basic research economically useful?. *Research Policy* 20: 109-119.

Papke, L.E. and Wooldridge, J.M. (1996). Econometric methods for fractional response variables with an application to 401(k) plan participation rates, *Journal of Applied Econometrics*, 11(6): 619–632.

Raymond, W., Mohnen, P., Palm, F. and van der Loeff, S. (2010). Persistence of innovation in Dutch manufacturing: is it spurious? *The Review of Economics and Statistics,* 92(3): 495-504.

Robinson, W. T. and Fornell, C. (1985). Sources of Market Pioneer Advantages in Consumer Goods Industries. *Journal of Marketing Research*, 22: 305-317.

Robinson, W. T. and Min, S. (2002). Is the first to market the first to fail? Empirical evidence for industrial goods businesses. *Journal of Marketing*, 39(1): 120-128.

Rosenberg, N. (1990). Why do firms do basic research (with their own money)? *Research policy,* 19:165–174.

Schankerman, M. (1981). The Effects of Double-counting and Expensing on the Measured Returns to R&D, *Review of Economics and Statistics*, 63(3), 454-458.

Slivko, O. (2012). "Innovation strategies of German firms: The effect of competition and intellectual property protection," ZEW Discussion Papers 12-089, ZEW.

Stern S. (2004). Do Scientists Pay to Be Scientists?, *Management Science*, 50(6): 835-853.

Teece, D. J. (1992). Competition, cooperation, and innovation: Organizational arrangements for regimes of rapid technological progress. *Journal of Economic Behavior and Organization*, 18(1): 1-25.

Tijssen, R. J. W. (2004), Is the commercialisation of scientific research affecting the production of public knowledge? Global trends in the output of corporate research articles. *Research Policy*, 33: 709–733.

Urban. G. L., Carter, T., Gaskin, S. and Mucha, Z. (1986). Market Share Rewards to Pioneering Brands: An Empirical Analysis and Strategic Implications. *Management Science*, 32: 645-659.

Vega-Jurado, J., Gutierrez-Gracia, A., Fernández-de-Lucio, I., and Manjarrés-Henríquez, L. (2008). The effect of external and internal factors on firms' product innovation. *Research Policy*, 37: 616-632.

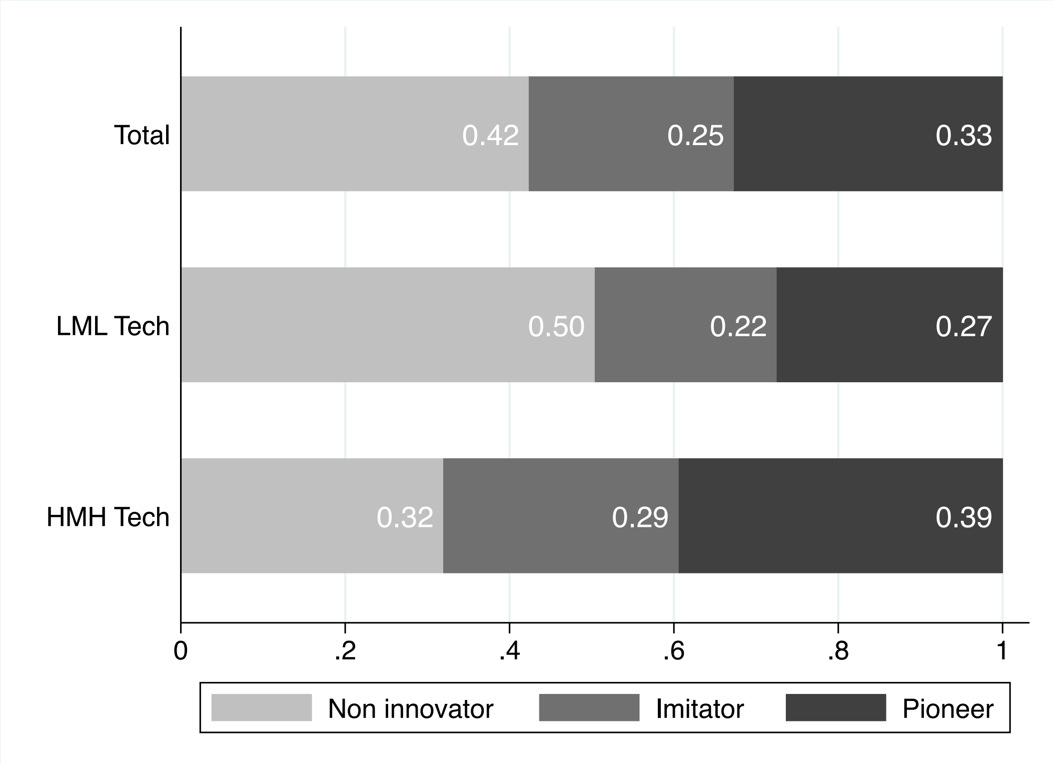
Vega-Jurado, J., Gutierrez-Gracia, A., and Fernández-de-Lucio, I. (2009). Does external knowledge sourcing matter for innovation? Evidence from the Spanish manufacturing industry. *Industrial and Corporate Change*, 18(4): 637-670.

Vinding, A.L. (2006). Absorptive capacity and innovative performance: A human capital approach, *Economics of Innovation and New Technology*, 15(4): 507 – 517.

Wagner, J. (2001). A Note on the Firm Size-Export Relationship. *Small Business Economics*, 17 (4): 229-237.

Wright, T. P. (1936). Factors Affecting the Cost of Airplanes, *Journal of the Aeronautical Sciences,* 3: 122-128.

Figure 1: Innovation strategies in Spanish manufacturing firms



Source: PITEC

Table 1: The importance of in-house and external basic research

	In-house BR			External BR	
	BR	BR/R&D	Stable BR	BR collaboration	BR outsourced
Non innovator	0.023	0.022	0.009	0.057	0.031
Imitator	0.063	0.021	0.027	0.174	0.078
Pioneer	0.098	0.025	0.043	0.262	0.125
Total	0.058	0.023	0.025	0.153	0.073
Number of Firms	[325]		[140]	[858]	[409]

Note: BR stands for basic research
Source: PITEC

Table 2: Description of Variables

Variable	Description
Innovation Strategy	Categorical variable that takes the values: 0: The firm did not introduce any new or improved product or service. 1: The firm only introduced products or services that were new to the firm, but already known to the market. 2: The firm introduced new products/services ahead of competitors.
Innovative sales	Share of sales from new-to-the-market products.
BR	Dummy that takes the value of 1 if the firm conducts in-house basic research, 0 otherwise.
Stable BR	Dummy that takes the value of 1 if the firm has conducted basic research in all the three previous years, 0 otherwise.
BR collaboration	Dummy that takes the value of 1 if the firm reports having engaged in contractual cooperation with universities and research institutes, 0 otherwise.
BR outsourced	Dummy that takes the value of 1 if the firm reports having contracted external R&D from universities, 0 otherwise.
R&D	In-house knowledge stock measured as R&D employment in logs.
Size	Number of employees in logs.
Human capital	Firm's human capital measured as the percentage of employees with a degree over total employment
Group	Dummy that takes the value of 1 if the firm belongs to a group of firms, 0 otherwise.
Oth_collaboration	Dummy that takes the value of 1 if the firm reports having engaged in cooperation in innovation activities with other agents excluding universities and research labs, 0 otherwise.
OthRD outsourced	Dummy that takes the value of 1 if the firm reports having contracted external R&D from other agents excluding universities; 0 otherwise.
Gvt. funding	Dummy that takes the value of 1 if the firm has received government funding for its R&D activities; 0 otherwise.
Demand pull	Dummy that takes the value of 1 if at least one of the following demand-enhancing objectives is given the highest score: extend product range; increase market or market share; improve quality in goods and service, 0 otherwise.
Appropriability	Dummy that takes the vale of 1 if the firm uses one of the following methods to protect intellectual property: patents, utility models, brands, and copyright; 0 otherwise.
HHI	Herfindahl index of concentration in the industry.
Geo market	Geographical size of the market in which the firm competes. Takes the following values: 1=local or regional market; 2=national market; 3=EU market, EFTA countries and EU candidates; 4=worldwide market.

Note: All explanatory variable are lagged one period

Table 3: Descriptive statistics

	Total Sample		**LML Tech**		**HMH tech**	
	Mean	*s.d.*	*Mean*	*s.d.*	*Mean*	*s.d.*
Innovator type$_{t}$	0.903	(0.86)	0.770	(0.85)	1.077	(0.84)
Innovative sales$_{t}$	0.090	(0.22)	0.074	(0.20)	0.111	(0.23)
BR$_{t-1}$	0.065	(0.25)	0.049	(0.22)	0.085	(0.28)
Stable BR$_{t-1}$	0.022	(0.15)	0.016	(0.13)	0.030	(0.17)
BR collaboration$_{t-1}$	0.178	(0.38)	0.149	(0.36)	0.215	(0.41)
BR outsourced$_{t-1}$	0.079	(0.27)	0.053	(0.22)	0.113	(0.32)
R&D$_{t-1}$	6.866	(21.67)	4.040	(10.35)	10.555	(30.32)
Size $_{t-1}$	3.961	(1.39)	4.049	(1.37)	3.847	(1.41)
Human capital$_{t-1}$	0.173	(0.18)	0.130	(0.15)	0.227	(0.20)
Group $_{t-1}$	0.390	(0.49)	0.367	(0.48)	0.421	(0.49)
Foreign $_{t-1}$	0.131	(0.34)	0.104	(0.31)	0.167	(0.37)
Oth. collaboration$_{t-1}$	0.224	(0.42)	0.197	(0.40)	0.260	(0.44)
OthRD outsourced $_{t-1}$	0.254	(0.44)	0.217	(0.41)	0.302	(0.46)
Gvt. funding $_{t-1}$	0.329	(0.47)	0.289	(0.45)	0.382	(0.49)
Demand pull $_{t-1}$	0.537	(0.50)	0.473	(0.50)	0.620	(0.49)
Appropriability $_{t-1}$	0.281	(0.45)	0.256	(0.44)	0.314	(0.46)
HHI $_{t-1}$	0.027	(0.02)	0.026	(0.02)	0.028	(0.03)
Geo. market $_{t-1}$	2.387	(0.91)	2.289	(0.95)	2.515	(0.82)
Observations	34730		19669		15061	

Note: Mean values and standard deviation in parenthesis.
Source: PITEC Dataset

Table 4a. Stereotype Logit (SLM). Coefficients

	All Sample		LML Tech		HMH Tech	
	β	s.e.	***β***	s.e.	***β***	s.e.
BR_{t-1}	0.438***	(0.058)	0.585***	(0.084)	0.275***	(0.077)
Stable BR_{t-1}	0.292***	(0.104)	0.510***	(0.169)	0.146	(0.128)
BR collaboration$_{t-1}$	0.132***	(0.040)	0.087*	(0.053)	0.170***	(0.059)
BR outsourced$_{t-1}$	-0.014	(0.054)	-0.013	(0.078)	-0.016	(0.071)
R&D$_{t-1}$	0.017***	(0.003)	0.033***	(0.005)	0.011***	(0.003)
Size $_{t-1}$	0.071***	(0.011)	0.072***	(0.014)	0.058***	(0.018)
Human capital$_{t-1}$	0.503***	(0.073)	0.507***	(0.106)	0.506***	(0.101)
Foreign $_{t-1}$	0.081**	(0.038)	0.196***	(0.053)	0.007	(0.053)
Group $_{t-1}$	-0.049*	(0.029)	0.001	(0.037)	-0.144***	(0.044)
Oth. collaboration$_{t-1}$	0.407***	(0.035)	0.415***	(0.045)	0.379***	(0.053)
OthRD outsourced $_{t-1}$	0.281***	(0.031)	0.271***	(0.042)	0.268***	(0.046)
Gvt. funding $_{t-1}$	0.375***	(0.028)	0.347***	(0.038)	0.373***	(0.042)
Demand pull $_{t-1}$	1.285***	(0.025)	1.287***	(0.034)	1.222***	(0.039)
Appropriability $_{t-1}$	0.636***	(0.027)	0.610***	(0.035)	0.667***	(0.042)
HHI $_{t-1}$	2.088*	(1.161)	1.209	(1.372)	3.568*	(2.122)
Geo. market $_{t-1}$	0.148***	(0.013)	0.118***	(0.016)	0.178***	(0.021)
$(\phi_1 = 0, \phi_2 = 1)\ \phi_3$	1.341***	(0.017)	1.339***	(0.024)	1.393***	(0.026)
$(\theta_1 = 0)\ \theta_2$	2.455***	(0.069)	2.510***	(0.084)	1.744***	(0.102)
θ_3	3.142***	(0.093)	3.144***	(0.112)	2.384***	(0.143)
Observations	34730		19669		15061	
χ^2	4882***		2651***		1823***	
Log Likelihood	-30860		-16850		-13922	

Note 1: Dependent variable is the innovation strategy chosen by the firm
Note 2: All the estimations include industry and year dummies.

Note 3: Significance level: ***p<0.01, **p<0.05, *p<0.1.

Table 4b: Average Marginal Effects (AMEs) for SLGIT

	All			LML Tech			HMH Tech		
	Non-innovator	**Imitator**	**Pioneer**	**Non-innovator**	**Imitator**	**Pioneer**	**Non-innovator**	**Imitator**	**Pioneer**
	dy/dx	*dy/dx*	*dy/dx*	*dy/dx*	*dy/dx*	*dy/dx*	*dy/dx*	*dy/dx*	*dy/dx*
	(s.e.)	*(s.e.)*	*(s.e.)*	*(s.e.)*	*(s.e.)*	*(s.e.)*	*(s.e.)*	*(s.e.)*	*(s.e.)*
BR_{t-1}	-0.086***	0.023***	0.063***	-0.119***	0.037***	0.082***	-0.051***	0.009***	0.043***
	(0.011)	(0.003)	(0.008)	(0.017)	(0.005)	(0.011)	(0.014)	(0.002)	(0.012)
Stable BR_{t-1}	-0.057***	0.015***	0.042***	-0.104***	0.032***	0.071***	-0.027	0.005	0.023
	(0.020)	(0.005)	(0.015)	(0.034)	(0.011)	(0.023)	(0.024)	(0.004)	(0.020)
BR $collaboration_{t-1}$	-0.026***	0.007***	0.019***	-0.018*	0.006*	0.012*	-0.032***	0.005***	0.026***
	(0.008)	(0.002)	(0.006)	(0.011)	(0.003)	(0.007)	(0.011)	(0.002)	(0.009)
BR $outsourced_{t-1}$	0.003	-0.001	-0.002	0.003	-0.001	-0.002	0.003	-0.001	-0.003
	(0.010)	(0.003)	(0.008)	(0.016)	(0.005)	(0.011)	(0.013)	(0.002)	(0.011)
$R\&D_{t-1}$	-0.003***	0.001***	0.002***	-0.007***	0.002***	0.005***	-0.002***	0.000***	0.002***
	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
$Size_{t-1}$	-0.014***	0.004***	0.010***	-0.015***	0.005***	0.010***	-0.011***	0.002***	0.009***
	(0.002)	(0.001)	(0.002)	(0.003)	(0.001)	(0.002)	(0.003)	(0.001)	(0.003)
Human $capital_{t-1}$	-0.098***	0.026***	0.072***	-0.103***	0.032***	0.071***	-0.094***	0.016***	0.078***
	(0.014)	(0.004)	(0.011)	(0.022)	(0.007)	(0.015)	(0.019)	(0.003)	(0.016)
$Foreign_{t-1}$	-0.016**	0.004**	0.012**	-0.040***	0.012***	0.027***	-0.001	0.000	0.001
	(0.007)	(0.002)	(0.005)	(0.011)	(0.003)	(0.007)	(0.010)	(0.002)	(0.008)
$Group_{t-1}$	0.009*	-0.003*	-0.007*	-0.000	0.000	0.000	0.027***	-0.004***	-0.022***
	(0.006)	(0.001)	(0.004)	(0.008)	(0.002)	(0.005)	(0.008)	(0.001)	(0.007)
Oth. $collaboration_{t-1}$	-0.080***	0.021***	0.058***	-0.085***	0.026***	0.058***	-0.071***	0.012***	0.059***
	(0.007)	(0.002)	(0.005)	(0.009)	(0.003)	(0.006)	(0.010)	(0.002)	(0.008)

OthRD outsourced $_{t-1}$	-0.055***	0.015***	0.040***	-0.055***	0.017***	0.038***	-0.050***	0.008***	0.042***
	(0.006)	(0.002)	(0.004)	(0.008)	(0.003)	(0.006)	(0.008)	(0.002)	(0.007)
Gvt. funding $_{t-1}$	-0.073***	0.020***	0.054***	-0.071***	0.022***	0.049***	-0.069***	0.012***	0.058***
	(0.006)	(0.002)	(0.004)	(0.008)	(0.002)	(0.005)	(0.008)	(0.002)	(0.007)
Demand pull $_{t-1}$	-0.251***	0.067***	0.184***	-0.262***	0.082***	0.180***	-0.228***	0.038***	0.190***
	(0.004)	(0.002)	(0.003)	(0.005)	(0.003)	(0.004)	(0.005)	(0.003)	(0.006)
Appropriability $_{t-1}$	-0.124***	0.033***	0.091***	-0.124***	0.039***	0.085***	-0.124***	0.021***	0.103***
	(0.005)	(0.002)	(0.004)	(0.007)	(0.002)	(0.005)	(0.008)	(0.002)	(0.007)
HHI $_{t-1}$	-0.408*	0.109*	0.299*	-0.246	0.077	0.169	-0.665*	0.111*	0.553*
	(0.227)	(0.061)	(0.166)	(0.279)	(0.087)	(0.192)	(0.395)	(0.067)	(0.329)
Geo. market $_{t-1}$	-0.029***	0.008***	0.021***	-0.024***	0.008***	0.017***	-0.033***	0.006***	0.028***
	(0.002)	(0.001)	(0.002)	(0.003)	(0.001)	(0.002)	(0.004)	(0.001)	(0.003)

Note 1: (*) dy/dx is for discrete change of dummy variable from 0 to 1.
Note 2: All the estimations include industry and year dummies.
Note 3: Significance level: ***p<0.01, **p<0.05, *p<0.1.

Table 5: Robustness Test (specification with t-2). Average Marginal Effects (AMEs) for SLGIT

	All			**LML Tech**			**HMH Tech**		
	Non-innovator	**Imitator**	**Pioneer**	**Non-innovator**	**Imitator**	**Pioneer**	**Non-innovator**	**Imitator**	**Pioneer**
	dy/dx	*dy/dx*	*dy/dx*	*dy/dx*	*dy/dx*	*dy/dx*	*dy/dx*	*dy/dx*	*dy/dx*
	(s.e.)	*(s.e.)*	*(s.e.)*	*(s.e.)*	*(s.e.)*	*(s.e.)*	*(s.e.)*	*(s.e.)*	*(s.e.)*
BR_{t-2}	-0.069***	0.019***	0.051***	-0.083***	0.026***	0.057***	-0.049***	0.008***	0.041***
	(0.009)	(0.003)	(0.007)	(0.013)	(0.004)	(0.009)	(0.012)	(0.002)	(0.010)
Stable BR_{t-2}	-0.054***	0.014***	0.039***	-0.078**	0.024**	0.054**	-0.032	0.005	0.027
	(0.020)	(0.006)	(0.015)	(0.032)	(0.010)	(0.022)	(0.025)	(0.004)	(0.021)
BR $collaboration_{t-2}$	-0.033***	0.009***	0.024***	-0.027***	0.008***	0.019***	-0.039***	0.007***	0.033***
	(0.007)	(0.002)	(0.005)	(0.010)	(0.003)	(0.007)	(0.010)	(0.002)	(0.008)
BR $outsourced_{t-2}$	-0.005	0.001	0.003	-0.011	0.004	0.008	0.001	-0.000	-0.001
	(0.010)	(0.003)	(0.007)	(0.015)	(0.005)	(0.010)	(0.013)	(0.002)	(0.010)
Rest of controls	Y	Y	Y	Y	Y	Y	Y	Y	Y

Note 1: (*) dy/dx is for discrete change of dummy variable from 0 to 1.
Note 2: All the estimations include the controls that appear in Table 4 in addition to industry and year dummies.
Note 3: Significance level: ***p<0.01, **p<0.05, *p<0.1.

Table 6: Basic Research and Firm Size. Average Marginal Effects (AMEs) for SLGIT

	Small firms			Medium and Large firms		
	Non-innovator	**Imitator**	**Pioneer**	**Non-innovator**	**Imitator**	**Pioneer**
	dy/dx	*dy/dx*	*dy/dx*	*dy/dx*	*dy/dx*	*dy/dx*
	(s.e.)	*(s.e.)*	*(s.e.)*	*(s.e.)*	*(s.e.)*	*(s.e.)*
BR_{t-1}	-0.082***	0.025***	0.056***	-0.057***	0.013***	0.045***
	(0.017)	(0.005)	(0.011)	(0.015)	(0.003)	(0.012)
Stable BR_{t-1}	-0.044	0.014	0.031	-0.064**	0.014**	0.050**
	(0.032)	(0.010)	(0.022)	(0.025)	(0.006)	(0.020)
BR $collaboration_{t-1}$	-0.031***	0.009***	0.021***	-0.017	0.004	0.013
	(0.012)	(0.004)	(0.008)	(0.010)	(0.002)	(0.008)
BR $outsourced_{t-1}$	0.049***	-0.015***	-0.034***	-0.019	0.004	0.015
	(0.017)	(0.005)	(0.012)	(0.013)	(0.003)	(0.010)
Rest of controls	Y	Y	Y	Y	Y	Y
Observations		17266			17464	

Note 1: Small firms are those with less than 50 employees. Medium and large firms are those with 50 or more employees.
Note 2: (*) dy/dx is for discrete change of dummy variable from 0 to 1.
Note 3: All the estimations include the controls that appear in Table 4 in addition to industry and year dummies.
Note 4: Significance level: ***p<0.01, **p<0.05, *p<0.1.

Table 7. Results from the Fractional logit Model

Dependent variable: ***share of sales from new-to-the-market products***

	All Sample		LML Tech		HMH Tech	
	β	s.e	β	s.e	β	s.e
BR_{t-1}	0.189***	(0.050)	0.165**	(0.082)	0.186***	(0.063)
$Stable\ BR_{t-1}$	-0.008	(0.079)	0.129	(0.128)	-0.095	(0.101)
$BR\ collaboration_{t-1}$	0.077*	(0.043)	0.015	(0.066)	0.127**	(0.057)
$BR\ outsourced_{t-1}$	-0.065	(0.051)	-0.084	(0.090)	-0.063	(0.061)
$R\&D_{t-1}$	0.004***	(0.001)	0.011***	(0.002)	0.003***	(0.001)
$Size_{t-1}$	-0.078***	(0.014)	-0.072***	(0.020)	-0.099***	(0.019)
$Human\ capital_{t-1}$	0.588***	(0.084)	0.344**	(0.140)	0.668***	(0.106)
$Foreign_{t-1}$	0.068	(0.047)	0.102	(0.072)	0.081	(0.062)
$Group_{t-1}$	-0.037	(0.036)	0.065	(0.054)	-0.153***	(0.048)
$Oth.\ collaboration_{t-1}$	0.063	(0.039)	0.073	(0.058)	0.059	(0.053)
$OthRD\ outsourced_{t-1}$	0.085**	(0.035)	0.082	(0.054)	0.087*	(0.047)
$Gvt.\ funding_{t-1}$	0.190***	(0.035)	0.163***	(0.053)	0.205***	(0.047)
$Demand\ pull_{t-1}$	0.813***	(0.038)	0.880***	(0.053)	0.711***	(0.053)
$Appropriability_{t-1}$	0.401***	(0.031)	0.326***	(0.047)	0.471***	(0.042)
HHI_{t-1}	1.523	(1.518)	1.530	(1.827)	0.821	(2.750)
$Geo.\ market_{t-1}$	0.054***	(0.020)	0.102***	(0.029)	-0.002	(0.027)
Observations	34730		19669		15061	
χ^2	2472.48***		1148.32***		1208.23***	
Log Likelihood	-8633.54		-4339.73		-4267.62	

Note 1: All the estimations include time and industry dummies.

Note 2: Significance level: ***p<0.01, **p<0.05, *p<0.1. Robust standard errors in parenthesis

Appendix

Table A.1. Industry classification

Manufacturing industries in PITEC	**CNAE-2009**	**Frequency**	**Percentage**
Low/Med-Low Sectors (LML tech)			
Low-tech			
Food, beverages and tobacco	10, 11, 12	4695	13.52
Textiles, wearing apparel and leather products	13, 14, 15	2211	6.36
Wood products, cork	16	637	1.83
Paper, publishing and printing	17, 18	1558	4.49
Furniture	31	1201	3.46
Other manufacturing	32	447	1.29
Medium-low-tech			
Rubber and plastic products	22	2180	6.28
Other non-metallic mineral products	23	2078	5.98
Basic metals	24	961	2.77
Fabricated metal products	25	3503	10.09
Building and repairing of ships and boats	30.1	198	0.57
High/Med-High Sectors (HMH tech)			
Medium-high-tech manufacturing industries			
Chemicals	20	3667	10.56
Electrical Equipment	27	5035	14.5
Machinery and equipment n.e.c.	28	1381	3.98
Motor vehicles	29	1403	4.04
Other transport equipment	30 (exc. 30.1, 30.3)	173	0.5
High-tech manufacturing industries			
Pharmaceutical	21	988	2.84

Computers, electronic and optical products	26	2280	6.56
Aircraft and spacecraft	30.3	134	0.39
Total		34730	100.01

Note: Classification according to EUROSTAT