

The role of international and domestic R&D outsourcing for firm innovation

by

María García-Vega and Elena Huergo*

Abstract

Firms are increasingly outsourcing their high-tech services. Theory suggests that R&D outsourcing allows firms to specialize in core knowledge-intensive tasks, thereby increasing innovation, but R&D outsourcing may also undermine internal capabilities. Our goal is to empirically assess the relative importance of these two possibilities, distinguishing between national and international R&D outsourcing and firms' exporting status. We examine R&D purchases of more than 10,000 Spanish firms for the period 2004-2014. We show that R&D outsourcing improves firm innovation. Product innovation rises mostly with domestic outsourcing, while process innovation increases with both domestic and international R&D outsourcing. In addition, we find that international outsourcing provides an extra premium, mostly for exporters. Our results contribute to a better understanding of how firms organize the production of knowledge and innovation.

Keywords: R&D outsourcing; transaction cost economics; innovation; international versus domestic outsourcing; exporters.

JEL classification: L25; O32

* García-Vega: School of Economics, University of Nottingham, University Park, Nottingham NG7 2RD, United Kingdom and GEP (email: maria.garcia-vega@nottingham.ac.uk); Huergo: Department of Economic Analysis. Universidad Complutense de Madrid, 28223, Spain (email: ehurgo@ccee.ucm.es).

We would like to thank Italo Colantone, Simon Gächter, Sourafel Girma, Saul Lach, Lourdes Moreno, Diego Rodriguez and Francisco J. Velázquez for their very helpful comments. This research has been partially funded by the Spanish Ministry of Economy and Competitiveness (projects ECO2014-52051-R and ECO2017-82445-R) and by the Autonomous Region of Madrid through project S2015HUM-3417 (INCOMCON-CM), co-funded by the European Social Fund (European Union).

1. Introduction

A recent and increasingly important channel of technology flows is due to exchange of knowledge-intensive services, of which R&D outsourcing is an important case (Quinn 2000; Metters and Verma 2008; Lai et al. 2009; Sener and Zhao 2009). For instance, in its survey of business trends, the European Commission (2016) reports that for more than half of their respondents, R&D outsourcing is very important as a source of obtaining new knowledge. The National Science Foundation (2010) and the Deutsche Bank (2011) show similar figures for American and German companies, respectively. Examples of R&D outsourcing include high-tech services such as engineering services, clinical tests, or designs, which are subcontracted from independent counterparts both domestically and abroad (The Economist Intelligence Unit 2007).

These acquisitions of R&D are potentially very important for global economic growth and firm management. R&D acquisitions allow accessing knowledge which cannot be easily obtained internally by a firm, and they can also be a channel of international technology transfers and foster technological change, thereby increasing innovativeness.¹ To date, however, there is scarce empirical evidence on the quantitative importance of international and domestic R&D outsourcing. In this paper, we use a unique panel dataset to analyze the consequences of the externalization of firms' research activities on firms' innovativeness by distinguishing between national and international outsourcing locations and firms' exporting status.

The organization of knowledge transfers is interesting because profit-maximizing firms can find it optimal to outsource some of their research activities in order to reduce costs or capacity constraints. However, the impact of R&D outsourcing on innovation is not straightforward. R&D outsourcing might foster specialization and thereby lead to "gains from trade" (Arora and Gambardella 2010). Moreover, transaction cost economics suggests that R&D outsourcing increases the efficiency of the innovation process.

¹ See Keller (2004) for a survey on channels and extent of international technology diffusion. Other sources of technology transfers include mobility of R&D labor force (Kaiser et al. 2015) and foreign direct investment (Blomström et al. 1999; Girma et al. 2015, among others).

According to Williamson (1985, Ch 6), firms profit from acquiring early-stage R&D from other companies or independent inventors and then pursue R&D development in their own labs. Williamson argues that the bureaucratic apparatus of some firms does not support the creativity needed for early stages of innovation. Consequently, R&D outsourcing generates a hybrid innovation structure that allows firms to focus their research on comparative advantages.

An alternative possibility is that R&D outsourcing undermines internal capabilities. An example, provided by Chesbrough and Teece (2002), is IBM with the R&D required for the production of PCs. In the 1980s, IBM's PCs were quickly introduced in the market because IBM outsourced all their major components. In particular, IBM outsourced its PC's microprocessors to Intel and its operating system to Microsoft. Both Intel and Microsoft could sell their products to IBM's competitors, which favored the imitation of IBM's PCs and the subsequent loss of IBM's market leadership. The most prominent theoretical arguments against R&D outsourcing include hold-up problems (Ulset 1996; Azoulay 2004; Lai et al. 2009) and crowding out of firms' internal capabilities (Grimpe and Kaiser 2010). In addition, offshoring of high-tech services can even diminish national competences if there is a decline in the demand for national high-skill workers (Blinder 2006).²

The costs and benefits of outsourcing can also differ depending on the outsourcing location, the type of knowledge outsourced and firm characteristics. International R&D outsourcing can be more productive than domestic outsourcing because it provides access to leading research³, although at a high cost, given the need to adapt and monitor tasks that are outsourced into a different country (Grossman and Rossi-Hansberg 2012). For example, The Economist (2013), in its special report on outsourcing and offshoring, reports that the high hidden costs of offshoring induce some firms to bring back offshore production to their home countries. Important costs for R&D outsourcing are communication costs and potential leakage of

² See Crinò (2010) for an empirical analysis on the effect of service offshoring on white-collar jobs.

³ For example, the Economist Intelligence Unit (2007), in its survey of senior executives, reports that the US is the most important destination for offshore R&D.

information. Hence, firm characteristics--in particular, firms' exporting status--can play a role in overcoming transaction costs and in reducing the need for monitoring foreign providers because of exporters' experience in foreign markets.⁴

In this paper, we assess the relative importance of the consequences of R&D outsourcing described above. For our analysis, we use a unique panel dataset that contains information on R&D acquisitions from external providers for 10,062 Spanish firms from 2004 to 2014. To our knowledge, this is the most detailed panel database worldwide for outsourcing and offshoring of R&D activities and therefore particularly suitable for our research purposes. Its panel structure permits us to treat potential selection issues and endogeneity problems. Moreover, this data base allows us to identify the type of provider (other private firms, public organizations, etc.) and whether R&D outsourcing is domestic or international. Therefore, our data allow us to analyze the relative importance of the different theories.

Our empirical analysis is structured as follows. We first study whether firms that outsource their R&D (either internationally or domestically) are more innovative than firms that do not outsource. We use several econometric specifications to control for unobserved firm characteristics and selection including instrumental variables and a matching procedure, which allows us to create a control group of non-outsourcers with observational characteristics equivalent to outsourcers. Second, we examine the different effects of international and domestic outsourcing on innovativeness using several econometric specifications and distinguishing by a firm's exporting status.

We report three main results. First, we show that R&D outsourcing is positively related to firms' innovativeness. Our results suggest that outsourcing might lead to an increase of innovation by values that range from 4.6% to 14.0% as compared with non-outsourcers. This finding supports the hypothesis that

⁴ These considerations have led to the study of the determinants of technology sourcing (Cesaroni 2004; Miozzo and Grimshaw 2005; Ito et al. 2007; Chung and Yeaple 2008), and the complementarities between internal and external R&D (Cassiman and Veugelers 2006; Goyal et al. 2008; Ceccagnoli et al. 2014).

R&D outsourcing allows firms to specialize in knowledge-intensive areas against the hypothesis that R&D outsourcing undermines internal capabilities.

Second, we differentiate between the effects of national and international outsourcing. We show that, in our sample, the impacts on product innovations are larger for firms with domestic outsourcing than for firms with international outsourcing. Moreover, process innovation seems to be related to domestic and international R&D outsourcing. These results suggest that domestic outsourcing reinforces demand (product innovations), while international outsourcing is key for firms that try to reorganize and improve their production process by generating innovations that can reduce unit costs (process innovations).

Third, we show that for exporters, national R&D outsourcing is positively related to all types of innovativeness, while international R&D outsourcing influences only exporters' process innovation. For non-exporters, domestic R&D outsourcing seems to increase process innovation while no premium is obtained from international outsourcing.

Our results suggest that domestic and international R&D outsourcing are positively related to both product and process innovation. This is consistent with transaction costs economics, which argues that a hybrid organization of knowledge where firms combine in-house and outsourced R&D is the most efficient governance mode because innovative research requires high creativity and low bureaucratic costs (Williamson 1985). We also find that these effects vary by exporting status. We show that international R&D outsourcing is positively related to process innovation, but mostly for exporters. This suggests that firms need some extra knowledge of foreign markets to improve their production process through international R&D outsourcing, possibly because of the need to find a suitable international provider.

We contribute to the literature on the governance of the production of knowledge and innovation. Recent analyses of the effects of R&D outsourcing provide some preliminary evidence on positive gains from outsourcing. For example, Cusmano et al. (2009) study the effect of production, R&D and services outsourcing on firm innovation. These authors find a positive relationship between outsourcing and

innovation, mostly for service outsourcing. A major difference with respect to this paper is that we use panel data, which allow us to address a potential reverse causation problem. Grimpe and Kaiser (2010) show that, for German firms, R&D outsourcing and innovation have an inverted U-shape relationship. An important difference in our approach with respect to this article is that we specifically distinguish between international and domestic outsourcing. Bertrand and Mol (2013) study the antecedents and consequences of R&D outsourcing using probit specifications. They find a positive effect of international R&D outsourcing on innovation and a negative effect of domestic outsourcing on innovation. In contrast to this study, we use, among other techniques, instrumental variable procedures and matching approaches in order to control for causality. A further novelty of our analysis is that we provide evidence on the role of exporting for national and international R&D outsourcing.

The rest of the paper is organized as follows. In Section 2, we review studies that analyze the consequences of R&D outsourcing. In Section 3, we describe the dataset and the main variables. In Section 4, we explain our econometric specification. Section 5 presents the results on the relationship between R&D outsourcing and firms' innovativeness. Section 6 shows the effect of domestic and international outsourcing on firms' innovativeness and the differences between exporters and non-exporters. In Section 7, we summarize the results and discuss some explanations for our findings.

2. Two hypotheses about the consequences of R&D outsourcing on innovativeness

There are two competing hypotheses about the consequences of R&D outsourcing on firm innovativeness. As for the *benefits*, standard economic theory dating back to Adam Smith already suggests that outsourcing, as a strategy of the division of labor, can increase firms' efficiency. More recently, Grossman and Rossi-Hansberg (2008) show that offshoring can permit workers to specialize on the tasks where they are more productive, which can raise their overall productivity and wages.⁵ In this line, Arora

⁵ For instance, Geishecker and Görg (2008) document a positive effect of international outsourcing and high-skilled workers.

and Gambardella (2010) argue that trade in technology encourages the division of innovative labor. From a governance perspective, Williamson (1996) considers that the advantage of market transactions over hierarchies is that markets allow for high flexibility and incentives. Markets also face less bureaucracy than hierarchies. This is particularly relevant to the way innovation is organized because timing and creativity are crucial for innovation (p. 118). Williamson (1985) advocates a hybrid innovation model where some early R&D stages are acquired from small providers or inventors and subsequent development is performed within the firm.

These positive effects can be even more important in the case of international R&D outsourcing, as it provides access to foreign knowledge in little time. For example, Görg et al. (2008) and Amiti and Wei (2009) find a positive influence of international services outsourcing on firms' productivity, while Bertrand and Mol (2013) obtain a positive effect of international R&D outsourcing on innovation.

The potential benefits of international outsourcing can differ between exporters and non-exporters for several reasons. First, the success of international outsourcing is linked with training employees (Aron and Singh, 2005), and with coordination and communication with international suppliers. Exporters have more experience dealing with foreign companies than non-exporters. As a consequence, exporters might develop more compatible forms of communication with international providers than non-exporters.⁶ Therefore, exporters might be more capable of processing foreign knowledge than non-exporters in order to generate innovations. In this line, Criscuolo et al. (2010) show that internationalized firms devote more resources to assimilating foreign knowledge than purely domestic firms. Second, exporters might be able to select compatible international providers more accurately than non-exporters. For example, Chaney (2014) shows that when a firm starts exporting, its search costs of finding new foreign providers decline. Third, exporters are exposed to more competition than non-exporters. In highly competitive environments such as those faced by many exporters, technology evolves very quickly. Companies might not have all technical

⁶ For example, Atkin et al. (2017) show for Egyptian firms that an important element of learning by exporting is the communication of exporters with their foreign customers.

expertise needed to remain competitive (Naghavi and Ottaviano 2010). International R&D outsourcing can quickly provide very specialized know-how and therefore benefit firms in highly competitive environments. For example, Grimpe and Kaiser (2010) observe that an advantage of R&D outsourcing is related to timing issues.

The outsourcing of technology can also have *detrimental* consequences for firms' innovativeness because a key characteristic of the knowledge production function is that knowledge builds on itself (Geroski 2005) and that innovation is difficult to acquire without previous experience (Griffith et al. 2004).⁷ As a consequence, R&D outsourcing can reduce firms' absorptive capacities and the creation of new knowledge can be hampered.⁸ Furthermore, outsourcing of R&D can be very costly because intellectual property rights can be difficult to allocate, and because of the existence of technological leakages (Prahalad and Hamel 1990; Cassiman and Veugelers 2006; Lai et al. 2009).

In addition, international R&D outsourcing can have different costs compared with domestic outsourcing. As Grossman and Rossi-Hansberg (2008) indicate, costs from service offshoring, especially for high-tech tasks, derive mostly from instructing and monitoring. These costs can differ across location of R&D providers. Notice that, in the case of international outsourcing, costs can be lower for firms with previous experience in foreign markets. In particular, exporters might be able to find suitable foreign providers and manage potential hold-up problems better than non-exporters because exporters have experience in international markets and they are part of an international network.⁹

In sum, R&D outsourcing entails trade-offs: on the one hand, the relative impact of specialization and, on the other hand, the potential losses of absorptive capabilities and hold-up problems. Based on transaction cost economic theory (Williamson 1985), we expect the benefits to overcome the costs. R&D

⁷ For instance, Hijzen et al. (2010) find that offshoring has a negative effect on firms' productivity for non-multinationals and non-exporters.

⁸ For example, Hecker and Kretschmer (2010) propose a model with outsourcers that lose bargain power but benefit from scale effects.

⁹ See Rauch (2001) for a summary of the importance of international networks in countries with weak contract enforcement.

outsourcing can have a positive influence on innovation because R&D outsourcing allows firms to obtain knowledge quickly and reduce bureaucracy. Those are key elements for creativity and inventiveness in competitive markets. The effects of R&D outsourcing may depend on exporter status and the location of R&D providers. We consider knowledge of foreign markets key to finding a suitable foreign provider of technology. As a consequence, being an exporter might be an important determinant for the positive relationship between international R&D outsourcing and innovation.

3. The data and description of the main variables

In this section, we describe the main variables that we use for our empirical analysis. Further details are in the next section and in Appendix A. Our goal is to analyze the relationship between R&D outsourcing and innovation. Specifically, we aim to compare the influence of domestic and international R&D outsourcing on firms' innovativeness, differentiating between exporters and non-exporters. For these purposes, we use a dataset that comes from a survey of innovating Spanish firms (*Panel de Innovación Tecnológica, PITEC*) for the period 2004-2014.¹⁰ The Spanish Institute of Statistics constructs this database on the basis of the annual Spanish responses to the Community Innovation Survey (CIS). This is a unique dataset that includes representative samples of the universe of firms that are trying to innovate in Spain.¹¹ In the survey, companies answer questions related to their innovative activities and also report some of their other economic characteristics. The companies in the dataset are from the manufacturing and the service sectors. Our final sample is for an unbalanced panel of 10,062 companies, with an average of eight observations for each firm.

¹⁰ Details on PITEC and data access guidelines can be obtained at: http://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736176755&menu=resultados&secc=1254736195616&idp=1254735576669.

¹¹ To be considered by the Spanish Institute of Statistics as a firm trying to innovate, the firm must have innovation expenditures in at least one year of the period. Following the OECD's (2015) *Oslo Manual*, innovation expenditures include intramural (in-house) R&D, acquisition of extramural R&D and expenditures in other activities for product and process innovations (acquisition of other external knowledge; acquisition of machinery, equipment and other capital goods; other preparations for product and process innovations; market preparations for product innovations; and training).

3.1. The main independent variables: Outsourcing variables

Our data provides detailed information on R&D outsourcing at the firm level. In the database, each firm indicates its purchases of *R&D services* from other companies or institutions at foreign or national locations.¹² These purchases of R&D services include “*acquisitions of R&D services outside the firm through contracts, informal agreements, etc. Funds to finance other companies, research associations, etc., which do not directly imply purchases of R&D services, are excluded*”. Note that this variable excludes the acquisition of licenses, royalties, intra-group transactions and investments in foreign R&D capacity.

With this information, we classify firms as domestic or international outsourcers depending on whether R&D services are acquired mostly from domestic or foreign providers, respectively. Specifically, we construct our measures of international and national R&D outsourcing as two dummy variables: the *domestic R&D outsourcer* variable takes the value one if a firm acquires R&D services and more than 50% of its R&D acquisitions are from providers located in Spain, and the *international R&D outsourcer* variable takes the value one if more than 50% of its R&D acquisitions are from providers located abroad.^{13 14}

Approximately 74.4% of observations in the sample correspond to firms that do not outsource. The most frequent type of R&D outsourcing is national, with 24.1% of observations associated with companies

¹² *R&D services* are defined in the survey as “*Creative work to increase the volume of knowledge and to create new or improved products and processes (including the development of software)*”.

¹³ In other words, domestic R&D outsourcers include firms with R&D providers that are located only in Spain (this represents 91.1% of domestic R&D outsourcing) and firms with R&D providers located in Spain and abroad, such that the percentage of purchases of R&D from domestic providers is higher than the percentage of R&D acquisitions from foreign providers. International R&D outsourcers include firms with R&D providers located only abroad (this represents 44.6% of international R&D outsourcing) and firms with both domestic and international R&D providers, such that the percentage of purchases from international providers is higher than the percentage of R&D from domestic providers. In our sample, there are 25 observations with identical percentages of both types of outsourcing. We exclude these observations from our analysis.

¹⁴ As robustness check, we have also used alternative classifications of domestic and international R&D outsourcers. First, we keep the cutoff rule at 50% for defining domestic versus international outsourcing, but adding the observations with exactly 50% of acquisitions of R&D services from domestic providers to the group of domestic outsourcers. Second, we define domestic R&D outsourcers as those firms with R&D services and at least 60 percent of its R&D acquisitions from providers located in Spain (60 percent included). Consequently, international R&D outsourcers are defined as firms with R&D services from foreign providers only and with both foreign and domestic providers with less than 60 percent of its R&D acquisitions coming from providers located in Spain (with 60 percent excluded). The estimates obtained with these alternative definitions are quite similar to the results shown in Section 6, and are available from the authors upon request.

that outsource R&D mostly to domestic providers, and 1.5% mostly to international providers. These features suggest that there are high fixed entry costs for international outsourcing. Even if a small number of firms are engaged in R&D outsourcing, it accounts for a very large proportion of the firms' R&D budget: for companies that outsource, on average, domestic and international R&D outsourcing represents 50.1% and 30.8%, respectively, as a percentage of their internal R&D expenditures. These figures indicate the economic importance of R&D outsourcing.

There is some persistence in outsourcing status over time. This feature is particularly relevant for firms that do not outsource, and for firms with domestic outsourcing. In particular, 91.9% of non-outsourcers in a given year are also non-outsourcers the following year, and 67.6% of firms that are classified as domestic outsourcers in year $t-1$ also outsource domestically in year t ; this frequency decreases to 41.7% for international outsourcers. In addition, exporters tend to outsource more than non-exporters. As can be seen in Table 1, 74% of firms that outsource nationally are exporters. This number rises to 87% for the case of international outsourcing. Two explanations can account for the persistence in the data. First, the existence of entry costs in starting outsourcing, which might differ between national and international R&D outsourcing and between exporters and non-exporters. Secondly, unobserved firm heterogeneity, such as, managerial skills, different usage of information and communication technologies or learning. In this line, the literature of persistence in firm's exporting status (Bernard and Jensen, 2004; Kaiser and Kongsted, 2008) considers that learning makes that the profitability of exporting rises with the exposure to exporting. Similarly, learning might be important for outsourcing and therefore it can lead to persistence in outsourcing status.

Insert TABLE 1

Given the large differences between exporters and non-exporters, we differentiate between these two groups of firms in our analysis. We show descriptive statistics that distinguish between exporters and non-exporters in Table 2. This table indicates that, on average, exporters are more innovative, and more likely to

outsource their R&D than non-exporters. For example, nearly 30% of exporters outsource either nationally (27%) or internationally (1.9%). For non-exporters, the percentage of outsourcers is 18%. Among non-exporters, 17% outsource nationally and 1% internationally.

Insert TABLE 2

3.2. *The main dependent variables*

Our main dependent variables are three measures of firms' innovativeness widely used in the literature.¹⁵ Firstly, we consider an aggregate measure of firms' *innovations*. This is a dummy variable that takes the value one if the company has introduced either product or process innovations in the current or previous two years. Secondly, we include two indicators for firms' *product* and *process innovations*. Both variables are dummy variables that take the value one if a firm reports having introduced new or significantly improved products or production processes, respectively, in the current or previous two years. Thirdly, we consider the *sales from new products* for the market. This variable is defined as the percentage of sales that come from new-to-the-market products in the current year.

The advantage of these measures of innovativeness is that they directly refer to the output in the context of a knowledge production function, in which intramural (in-house) R&D and R&D outsourcing are inputs. The advantage of the indicator's having *innovations* is that it represents the most general measure of innovativeness. The distinction between *product* and *process innovations* allows us to differentiate between demand-based innovations (product innovations) and cost-reduction innovations (process innovations).

The disadvantage of these variables is that changes in the degree of innovation for continuous successful innovators are not well-captured. For example, a highly innovative company and a company with

¹⁵ See Mairesse and Mohnen (2005) for a detailed explanation of how CIS surveys are structured and the main innovation indicators in this type of survey.

just one innovation are treated the same using these dummy variables. The variable *sales from new products* has the advantage that it provides a yearly quantitative measure of the relevance of product innovations in terms of sales. Furthermore, it allows us to measure changes of innovativeness for continuous successful innovators. The disadvantage of this measure is that it only refers to demand-enhancing innovations. To assess the robustness of our results, we examine the effect of outsourcing on these three different measures of innovation. In Section 4, we will explain the time lag that we consider in order to avoid reverse causality problems.

3.2. The control variables

As control variables, we follow Mohnen and Röller (2005), Cassiman and Veugelers (2006) and Mohnen et al. (2008) to consider determinants of firms' innovativeness. We include measures of *internal R&D intensity* in the regressions (measured as the logarithm of a firm's intramural R&D expenditures over employment), which also controls for the level of absorptive capacity of the firm, and obstacles to innovating that have been shown to be important in hampering innovation (Mohnen et al. 2008). In particular, we include four types of obstacles to innovating: *lack of finance* within the firm or from sources outside the firm or innovation costs that are too high, *lack of information* on technology or on markets, *lack of qualified personnel*, and innovation that was *not needed*. We also control for firm size, sectoral dummies and time dummies.¹⁶ We add a set of *geographical dummies*, given the importance of agglomeration effects in inducing spillovers in European regions (Botazzi and Peri 2003). We explain the detailed construction of all variables in Appendix A.

In Table 1, we report the mean and standard deviation of the key variables for three different sets of companies: domestic R&D outsourcers, international R&D outsourcers and firms without R&D outsourcing. At the top part of Table 1, we document that outsourcers (either domestic or international) are more

¹⁶ We include size dummies instead of the size variable and its square in order to control for potential non-linearities. The reason is that some of the regressions that we use are non-linear (probit and biprobit models), so the interaction terms cannot be interpreted directly (Ai and Norton 2003).

innovative than non-outsourcers, and that international outsourcers seem to be more innovative than domestic outsourcers. This feature is common for any of the innovativeness measures we consider. On average, companies that outsource are larger (in terms of number of employees), more R&D- intensive and tend to export more than firms that do not outsource. They are also more R&D-intensive than non-outsourcers. R&D outsourcing is highly concentrated in R&D-intensive sectors such as “Coke, petroleum and nuclear fuel”, “Pharmaceutical”, “Aircraft” and “R&D services”.

In summary, the descriptive analysis indicates that R&D outsourcing is a quantitatively important strategy. These results suggest that there is a positive correlation between R&D outsourcing and innovation, in particular between international outsourcing and firms’ innovativeness, and that there are differences between exporters and non-exporters. In the following section, we measure these effects after controlling for covariates. We address the following questions. Firstly, we want to know whether R&D outsourcing increases innovation. Secondly, we analyze which type of outsourcing (either domestic or international) is the most productive for enhancing innovation, and whether there are differences between exporters and non-exporters.

4. Econometric specification

We estimate three different sets of regressions of the following type:¹⁷

$$Innovativeness = f(\gamma'x + \beta'z) + \varepsilon, \quad (1)$$

The variable *innovativeness* represents measures of firms’ innovations (having innovations, having product and/or process innovation, and sales from new products). The vector x denotes dummy variables of

¹⁷ We drop company and year indices to simplify the notation.

various forms of R&D outsourcing explained below, z is a vector of control variables, and γ and β are vectors of coefficients.

The specific functional form for f and the distribution function of ε in equation (1) depend on the measure of innovativeness used as a dependent variable. The baseline specifications are as follows. Firstly, we examine the determinants of the probability of having innovations with a random effect (RE) Probit model in order to control for unobserved heterogeneity. Secondly, we analyze the probability of having product and process innovations. In order to account for the potential correlation between disturbances of the two types of innovations, we estimate (by maximum likelihood) a bivariate Probit model. Finally, we study the determinants of the percentage of the *sales from new products* for the market conditional on having product innovations. In this case, we use an RE Tobit model. In all specifications, the regressors are included with a two-period lag. That is, we study the probability of having innovations up to two years after outsourcing, and, conditional on having a product innovation, we analyse the effect on sales from new products two years after outsourcing.¹⁸

Additionally, we conduct several robustness checks that include dynamic estimations to control for the persistence of our dependent variables and instrumental variable estimations to control for time-varying unobservable factors, such as managerial skills, changes in technological knowledge or a firm-specific demand shock that we have not considered with our control variables, and that might affect both R&D outsourcing decisions and innovation. We also estimate models including firm fixed effects to control for unobserved time constant firm characteristics and a matching procedure to control for endogeneity.

With respect to our dynamic estimations, note that our measures of innovativeness are likely to be state-dependent. The omission of this persistence might lead to an overestimation of the current impact of outsourcing on firms' innovations. For this reason, we implement dynamic estimations using the

¹⁸ The reason for the two-year lag is associated with the definition of the variables in the survey. Following the usual definitions in Community Innovation Surveys, in our dataset, innovation output questions are for the current and previous two years.

methodology proposed by Woodridge (2005), who develops an estimator for dynamic nonlinear RE models where unobservable heterogeneity is modeled in terms of initial conditions and exogenous variables.

As for the instrumental variable method, we use a control function approach (Blundell and Powell 2004; Wooldridge 2010 and 2015). This methodology along with diagnostic tests for the instruments, explained in detail in Appendix B, consists of two steps. In the first step, we examine a reduced form for the endogenous variable and calculate the residuals of this estimation. In the second step, we include the residuals as an additional covariate in equation (1) to account for unobserved variables together with the full set of independent variables of the first stage. The idea behind adding residuals as a covariate is that endogeneity can be treated as an omitted variable. The advantages of this technique in our context are that it can be applied to non-linear models and it is computationally simple.

As an instrument for R&D outsourcing, we follow Buss and Peukert (2015), who use differences in sectoral *labor costs* due to unionization. In the spirit of Buss and Peukert (2015), we consider the sectoral differences in labor costs per employee. The reason to include this variable is that sectors with high labor costs might outsource in order to benefit from relative cost differences between internal and external labor costs (Egger and Egger 2005; Magnani and Prentice 2010). Our data on sectoral labor costs at the two-digit industry level come from the OECD Stan dataset. The instrument varies by industry and year and it has an aggregation level different from the industry dummies that we include as controls in our regressions.¹⁹

Regarding the matching procedure, a concern is that the results are biased because of self-selection in R&D outsourcing. We try to control for this issue by using a caliper propensity score matching approach. This methodology involves the construction of a sample of matched firms. This means that we construct a sample of outsourcers and non-outsourcers with similar observable characteristics before the treatment. This allows us to create the counterfactual of what happens with a firm's innovation by an outsourcer had it not

¹⁹ We include 10 industry dummies in the regressions, while our instrument is for 33 sectors.

outsourced.²⁰ The advantage of the matching approach as compared with the instrumental variable estimation is that the observable characteristics for the probability of outsourcing might affect the dependent variable, or in other words, the exclusion restriction does not need to be applied. The main disadvantage of the matching procedure is that we cannot control for unobservable characteristics that might affect selection. The detailed explanations about the econometric model that we use to estimate the probability of outsourcing, the propensity score, the matching procedure and the tests that we use to assess the performance of the propensity score matching can be found in Appendix C.

In synthesis, we address some empirical challenges in our estimations. First, the nature of innovation is not unique in the sense that R&D outsourcing can influence innovations related to demand and/or the production process. We deal with this issue by estimating several specifications with alternative innovation outputs. In addition, it is likely that there is selection in R&D outsourcing and therefore our estimated coefficients can be biased upwards. In order to account for selection, we include estimations with firm fixed effects that control for time-invariant observed and unobserved firm characteristics. Moreover, we include instrumental variable estimations that attempt to control for time-varying unobservable factors that might affect both R&D outsourcing decisions and innovation. Given that one might have concerns for the validity of our instrument, we also estimate regressions using a matching procedure. The advantage of this technique is that it does not need an instrument uncorrelated with the error term of the explanatory equation. The main drawback of this technique is that it relies on observable time-variant firm characteristics and therefore it is still possible that our estimates do not account for all confounding time-variant effects.

²⁰ This technique involves calculating the predicted probability of outsourcing or propensity scores. Then, for a control group, we select the nearest non-outsourcers in terms of their propensity score subject to a maximum threshold distance. The variables that we consider controls are product innovations, process innovations, sales from new products, being an exporter, belonging to a business group, sectoral patents, public support, internal R&D intensity, pull demand, push costs and sources of information (internal, suppliers, institutional and other). All these variables are included in the estimates with one lag; that is, they refer to the pre-treatment period.

5. The effect of outsourcing on firms' innovativeness

In this section, our key independent variable as a determinant of firms' innovativeness is the dummy for being an *outsourcer*. The main results are summarized in Table 3. We report marginal effects at sample means. The coefficient for the *outsourcer* dummy must be interpreted as the premium (if positive) for outsourcers compared with non-outsourcers in terms of the corresponding measure of innovativeness.

Insert TABLE 3

Our results show that the impact of R&D outsourcing on firms' innovativeness is always positive. In column [1], we show that being an outsourcer increases the probability of innovating by 14%. However, once we distinguish between product and process innovation, in columns [2] and [3], these effects are larger, showing an increase of 21.6% and 16.2%, respectively. This large difference reflects the hidden heterogeneity of the innovation dummy and the importance of differentiating between product and process innovation. In column [4], we show that being an outsourcer increases the percentage of sales from new products on average by 8.10%.²¹

The estimates for the control variables yield reasonable outcomes. The variables *internal R&D intensity* and being an *exporter* also increase firms' innovativeness, while most of the variables that capture the obstacles to innovation decrease innovation. For example, the results in column [1] suggest that being an exporter increases the probability of innovating by 6.4%. An increase in internal R&D intensity by one standard deviation increases the probability of innovating by 0.58 percentage points.²² Firms with lack of

²¹ The expected mean difference in sales from new products between outsourcers and non-outsourcers is 0.666 points holding the other variables constant (as shown in column 4). Given that the average percentage of sales from new products for non-outsourcers is 8.22 (as shown in Table 1), the estimated mean difference in sales of 0.666 means an increase of 8.10% or in other words, this number is computed as $(0.666/8.22)*100$, where 8.22 is the average percentage of sales from new products for non-outsourcers as in Table 1.

²² This is calculated as $0.2750 * 0.021$ based on the standard deviation of internal R&D intensity and the estimated coefficient in Table 3.

information on technology or on markets are 2.1% less likely to innovate than firms without lack of information.

As robustness checks, we re-estimate our equations taking into account the following potential biases: First, we consider persistence in innovations; second, we control for unobservable time-invariant firm characteristics, which can simultaneously increase the probability of outsourcing and firms' innovativeness; third, we address the selection in outsourcing. The results are reported in Table 4. All specifications include the same control variables as in Table 3. For these variables, the coefficients are quite stable in all the regressions, so for clarity of exposition, we do not report them. In order to ease comparisons, column [1] includes the estimated coefficients previously reported in Table 3.

Insert TABLE 4

In column [2], we report the results of estimating a dynamic model for the whole sample where we include the dependent variable in the estimations with a lag, given that empirical evidence suggests that the existence of persistence in innovation outputs can overstate the results.²³ In order to control for time-invariant unobserved firm characteristics, in column [3], we estimate all regressions with firm fixed effects using linear probability models. This is a strict test since the impact of outsourcing is captured through the within-firm variation in outsourcing status.

In the case of (product and/or process) innovations, the estimated coefficients are smaller than the previous ones. Being an outsourcer is associated with an increase of 10.2% in the probability of innovating in column [2] and 7.4% in column [3]. We also get smaller premiums compared with the previous estimations for having product innovations, which now range from 11.8% in the dynamic model in column [2] to 6.4% in column [3], where we include firm fixed effects. Our estimates also indicate that being an outsourcer increases the probability of having process innovation by a value that ranges from 6.1% in the firm fixed

²³ See, among others, Raymond et al. (2009), Peters (2009) and Huergo and Moreno (2011).

effects model (column [3]) to 8.4% in the dynamic model (column [2]). However, in part C, we find that the estimated coefficient for being an outsourcer is not statistically significant at standard levels in the dynamic model or the fixed effects model.

A possible concern is whether our results are overstated because more innovative firms are more likely to become outsourcers than less innovative firms. To control for this causal effect, we re-estimate the previous equations using instrumental variables and a matching procedure.

In column [4] of Table 4, we report estimated coefficients from the IV estimation using a control approach specification. In all cases, the estimated coefficient of the residuals in the innovation output regressions are statistically different from zero, which supports the exogeneity assumption. The estimated coefficients in column [4] are lower than those in column [1]. For example, the estimates in column [4] suggest that outsourcing increases the probability of innovating by 7.8%. This effect is mostly concentrated in product innovations. The estimates in panel B suggest that outsourcing increases the probability of introducing product innovations by 12.7%. A possible reason for the lower estimated coefficients in these specifications is that the reduced variability of our instrument. For this reason, these results should be taken cautiously.

In columns [5] to [7] of Table 4, we present regressions for the matched sample that corresponds to the case in which the treatment is being an outsourcer. These regressions for the matched sample follow the same econometric methods used in columns [1] to [3] for the whole sample. These estimates are, on average, the most conservative estimates. For the matched sample, in part A, we see that the premium for outsourcers in terms of having innovations is always highly significant and varies from 4.6% to 5.8%.²⁴ This premium is higher when, in part B, we differentiate between product and process innovation, showing that outsourcing

²⁴ The estimated coefficients (standard errors) for key variables help put these numbers into context. For example, the estimated coefficient for being an exporter is 0.036 (0.006), which implies that being an exporter increases the probability of innovating by 3.6%. For lack of information, the estimated coefficient is -0.011 (0.003), which implies that firms with a lack of information are 1.1% less likely to innovate than firms without a lack of information.

increases the probability of having product innovations from 4.5% to 10.4% and the probability of having process innovations from 4.7% to 9.0%. Outsourcing also seems to increase sales from new products in column [5], but again we obtain non-significant effects in the dynamic and the fixed effects models.

As we have previously discussed in sub-section 3.1, there is some persistence in the outsourcing status over time. Therefore, as a robustness check, in column [8] of Table 4, we focus on the set of firms that start outsourcing R&D services as the treated group. To do so, for the generation of the matched sample, we exclude firms from the treated group with R&D outsourcing in the previous year. This exclusion has the disadvantage that the number of observations is considerably reduced, as most firms in the sample only start outsourcing once during our sample period. Therefore, we lose the panel structure of the data. However, it has the advantage that the identification of the direction of causality is neater. The estimated effects for new R&D outsourcers are consistent with previous results.

To summarize, several robustness checks confirm that R&D outsourcers are more innovative than non-outsourcers, obtaining an extra premium in terms of both the probability of innovating and sales from new products. This result supports the hypothesis that R&D outsourcing increases firms' efficiency against the hypothesis that it can undermine firms' internal innovative capabilities.

6. The effect of domestic and international outsourcing on firms' innovativeness

6.1. Main results

In this section, we investigate the relative efficiency of domestic and international R&D outsourcing in increasing firms' innovativeness. In Table 5, we present results on the influence of national and international outsourcing on innovation. The regressions that we present in this and the following section are based on the most conservative specification, where the results are obtained using a matching approach, which is explained in Appendix C. In the following tables, we use the same specification as in Table 4.

Insert TABLE 5

The results suggest that both national and international outsourcing increase firms' innovativeness. The premium for domestic outsourcing is similar for product innovation than for process innovation, while in the case of international outsourcing, there is a stronger effect for process innovation than for product innovation. The premium for domestic outsourcing (in part A) varies from a 4.5% to 10.9% increase in the probability of introducing innovations depending on the specification. We find evidence of a positive effect of international outsourcing on innovations in columns [1] to [4], and this effect varies from 2.1% to 6.4%.

In part B in all estimations, domestic outsourcing increases the probability of having product and process innovations, by values that range from 3.7% to 11.4% in the case of product innovation, and by 5.6% to 11.7% in the case of process innovation. International outsourcing seems to increase product innovations in columns [1] and [2], but after controlling for fixed effects in column [3] or for the sample of new R&D outsourcers in column [4], this effect becomes negligible. We believe that one possible reason for this result is that our measure of product innovation, which is a dummy variable, does not capture well the changes in the degree of innovation for continuous successful innovators. Moreover, our dummy variable of product innovation does not distinguish between incremental and radical product innovation. It is possible that international outsourcing increases radical product innovation but not much incremental product innovation. If starting international R&D outsourcing makes that firms improve the quality of their product innovation, in the sense that firms move from incremental to radical product innovations, our dummy variable for product innovation will not be capturing well this increase in innovation output. Finally, we can observe that international outsourcing has a positive and significant effect on process innovation, which varies from 5.0% to 12.3% in the four different estimations.

In part C, domestic outsourcing seems to increase sales from new products in column [1], but this effect is negligible in columns [2] and [3] after controlling for dynamics and firm fixed effects, respectively. We do not find a significant effect of international outsourcing on sales from new products.

6.2. Heterogeneous effects: Differences between exporters and non-exporters

The results above suggest that domestic R&D outsourcing provides a premium on innovations. International R&D outsourcing seems to have a robust influence on firms' process innovation. In what follows, we examine heterogeneity in exports as a factor that can affect these differences. We wish to identify whether innovation might be responsive to the effect of domestic and international outsourcing depending on whether the firm is an exporter or a non-exporter. Our prior is that outsourcing results in an extra premium for firms' innovativeness but mostly for exporters. This hypothesis is consistent with Görg et al. (2008), who find that international outsourcing of services affects firms' productivity, but only for internationalized firms.

We base our argument on the differences between exporters and non-exporters on a series of stylized facts. First, exporters have experience and networks in international markets. Therefore, for exporters, the costs of R&D contract enforcement and monitoring international production might be lower than for non-exporters. As Artopoulos et al. (2011) show, one of the main characteristics of exporters consists of their knowledge about the main features and operations of foreign markets. This knowledge of foreign markets can be key to finding a suitable foreign provider of R&D. Second, exporters need to adjust their products to foreign tastes (Bratti and Felice 2012). Therefore, exporters have more incentives than non-exporters to acquire foreign technology to modify their products. This foreign technology might increase exporters' product innovations. Third, Lewin and Couto (2007), for a survey of R&D outsourcers, illustrate that reduction of costs and access to qualified personnel are the main reasons for offshoring R&D. This fact is particularly relevant for exporters given that they operate in a more competitive market than non-exporters. As a consequence, the benefits of R&D outsourcing can be higher for exporters than for non-exporters.

In Table 6, we examine our results, differentiating between outsourcers that are exporters and outsourcers that are non-exporters. Our control group is non-outsourcing firms. The results we present are based on the matching approach explained in Appendix C, and the empirical methodology follows the same sequence as in Table 5.

Insert TABLE 7

In panel A, we can see that the effect of domestic outsourcing on having innovations is positive and very similar between exporters and non-exporters. Being a domestic outsourcer and an exporter increases the probability of innovating by 3.9% in the less conservative estimates (column [1]), or by 9.1% in the most conservative estimations (column [4]). The estimated effects for international outsourcing are positive and significantly different from zero for exporters, with estimated coefficients that vary from 2.2% to 6.5%, while the effect for international outsourcers and non-exporters is not significantly different from zero, except in the first column.

In panel B, we distinguish between product and process innovations. These results show that domestic outsourcing increases both product and process innovations and that these effects are robust across specifications for exporters and non-exporters. Interestingly, international outsourcing also influences both product and process innovation positively, but this effect seems to be robust only for exporters and for process innovations. Finally, in panel C, we analyze the effect on sales from new products. The results are inconclusive as the estimated coefficients are not statistically significant at standard levels in most of the specifications.

Taken together, the results suggest the following. For exporters, domestic R&D outsourcing increases all types of innovativeness, while international R&D outsourcing is mostly associated with extra efficiency gains in the case of process innovation. For non-exporters, domestic R&D outsourcing also increases all types of firms' innovativeness, but international outsourcing does not seem to involve any significant premium. These findings suggest that the effect of R&D outsourcing follows a pattern depending on the internationalization of the firm and the type of outsourcing. Domestic R&D outsourcing enhances cost-reducing innovations for both exporters and non-exporters. International R&D outsourcing drives cost-reducing innovations, but mostly for exporters.

7. Summary and concluding remarks

The outsourcing of firms' research activities and its impact on innovation is crucial for national competencies and firm organization. In particular, R&D outsourcing is a technological strategy that allows firms to specialize in core knowledge-intensive tasks, but at the same time, it can reduce their internal capabilities, and therefore their innovativeness. It is therefore important to conduct an empirical evaluation of the net impact of R&D outsourcing on the output of firms' knowledge production function. We shed light on this question by utilizing a unique panel dataset of Spanish companies, which allows us to examine the relationship between R&D outsourcing and firms' innovativeness, distinguishing between international flows of knowledge versus domestic ones, and differentiating by firm exporting status.

We find that companies that outsource R&D are more innovative than companies that do not outsource. This result suggests that the benefits of specialization are higher than the losses of internal capabilities for the average firm. We also show that domestic outsourcing leads to both enhanced product innovations and innovations that improve production processes. International R&D outsourcing provides a premium mostly for process innovations.

A deeper look at the data suggests that domestic outsourcing increases product and process innovations for both exporters and non-exporters. We find that international outsourcing gives a premium in terms of process innovation, but mostly for exporters. The results presented here suggest that there are important differences between domestic and international R&D outsourcing. International R&D outsourcing, in contrast to national R&D outsourcing, is likely to be subject to hold-up problems given the difficulties in monitoring suppliers, avoiding leakage of information and it might require to invest in communication skills with foreign providers. For these reasons, only companies with some experience in international markets, like exporters, increase their innovativeness when they outsource R&D internationally.

The evidence we present is relevant for the management of the firm, in particular the location of research activities. Consistent with the anecdotic evidence presented by *The Economist* (2013), our study

highlights not only that companies that outsource their research activities abroad might find it difficult to improve their innovativeness unless they are already part of an international network, but also that the outsourced research might have a stronger effect in changes in the production function (process innovations) than in the creation of new products.

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TABLES

Table 1: Descriptive statistics of the main variables

	Non-outsourcers		Domestic Outsourcers		International outsourcers	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Innovativeness measures:						
Innovations (0/1)	0.70	(0.46)	0.90	(0.30)	0.91	(0.29)
Product innovations (0/1)	0.50	(0.50)	0.75	(0.43)	0.79	(0.41)
Process innovations (0/1)	0.53	(0.50)	0.71	(0.46)	0.74	(0.44)
Sales from new products (%)	8.22	(21.28)	14.10	(25.62)	15.97	(26.25)
Other variables:						
Exporter (0/1)	0.62	(0.49)	0.74	(0.44)	0.87	(0.34)
Internal R&D intensity (logs.)	0.05	(0.22)	0.13	(0.38)	0.15	(0.39)
<i>Obstacles to innovation</i>						
Lack of finance (0/1)	0.68	(0.47)	0.61	(0.49)	0.64	(0.48)
Lack of personnel (0/1)	0.66	(0.47)	0.60	(0.49)	0.59	(0.49)
Lack of information (0/1)	0.58	(0.49)	0.50	(0.50)	0.50	(0.50)
Not needed (0/1)	0.74	(0.44)	0.73	(0.44)	0.76	(0.43)
Size (number of employees)	290	(1,503)	321	(1,571)	347	(977)
<i>No. Observations</i>	60,233		19,526		1,202	

Notes: S.D.: Standard deviations. The symbol (0/1) means dummy variable.

Table 2: Descriptive statistics of the main variables by exporting status

	Exporters			Non-exporters		
	Non- outsourcers	Domestic outsourcers	International outsourcers	Non- outsourcers	Domestic outsourcers	International outsourcers
Innovativeness measures:						
Innovations (0/1)	0.75 (0.43)	0.91 (0.28)	0.92 (0.27)	0.61 (0.49)	0.86 (0.35)	0.82 (0.39)
Product innovations (0/1)	0.57 (0.50)	0.78 (0.41)	0.81 (0.39)	0.40 (0.49)	0.67 (0.47)	0.66 (0.48)
Process innovations (0/1)	0.57 (0.50)	0.73 (0.44)	0.75 (0.43)	0.46 (0.50)	0.66 (0.47)	0.68 (0.47)
Sales from new products (%)	9.15 (22.01)	13.90 (24.69)	16.36 (26.22)	6.69 (19.93)	14.69 (28.12)	13.36 (26.41)
Other variables:						
Internal R&D intensity (logs.)	0.04 (0.17)	0.09 (0.24)	0.13 (0.33)	0.07 (0.29)	0.23 (0.62)	0.27 (0.66)
<i>Obstacles to innovation</i>						
Lack of finance (0/1)	0.67 (0.47)	0.59 (0.49)	0.64 (0.48)	0.71 (0.45)	0.67 (0.47)	0.63 (0.48)
Lack of personnel (0/1)	0.65 (0.48)	0.59 (0.49)	0.60 (0.49)	0.69 (0.46)	0.62 (0.49)	0.57 (0.50)
Lack of information (0/1)	0.56 (0.50)	0.49 (0.50)	0.49 (0.50)	0.63 (0.48)	0.54 (0.50)	0.57 (0.50)
Not needed (0/1)	0.73 (0.44)	0.73 (0.44)	0.77 (0.42)	0.75 (0.43)	0.72 (0.45)	0.71 (0.45)
Size (number of employees)	240 (1,175)	285 (1,192)	381 (1,038)	371 (1,916)	425 (2,342)	126 (275)
<i>No. Observations</i>	<i>37,419</i>	<i>14,512</i>	<i>1,045</i>	<i>22,814</i>	<i>5,014</i>	<i>157</i>

Notes: Standard deviations between parentheses. The symbol (0/1) means dummy variable.

Table 3: Are R&D outsourcers more innovative than non-R&D outsourcers?

	<i>RE Probit</i>	<i>Bivariate Probit</i>		<i>RE OLS</i>
	Innovations	Product innovations	Process innovations	Sales from new products
	[1]	[2]	[3]	[4]
Outsourcer	0.140*** (0.005)	0.216*** (0.005)	0.162*** (0.005)	0.666*** (0.159)
<i>Control variables:</i>				
Exporter	0.064*** (0.007)	0.120*** (0.005)	0.069*** (0.005)	0.288*** (0.216)
Internal R&D intensity	0.021** (0.010)	0.095*** (0.009)	-0.009 (0.008)	1.307*** (0.244)
<i>Obstacles to innovation</i>				
- Lack of finance	-0.024*** (0.005)	-0.036*** (0.005)	-0.030*** (0.005)	-0.093 (0.151)
- Lack of personnel	-0.009 (0.005)	-0.034*** (0.005)	-0.017*** (0.005)	0.011 (0.159)
- Lack of information	-0.021*** (0.005)	-0.057*** (0.005)	-0.028*** (0.005)	-0.172 (0.154)
- Not needed	0.008 (0.005)	0.014*** (0.005)	-0.001 (0.005)	0.157 (0.165)
<i>No. observations</i>	60,834	60,834		28,298
<i>No. firms</i>	9,559			6,521

Notes: All regressions include four size dummies, three geographical dummies, 10 industry dummies and year dummies. All explanatory variables are included with a two-period lag. Estimated standard errors are in parentheses. RE means firm-random effects. We report marginal effects at sample means. * Significant at 10%, ** significant at 5%, *** significant at 1%.

Table 4: Robustness check: Marginal effects of being an outsourcer on innovativeness measures for different specifications

	Whole sample				Matched sample			
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Part A. Dependent variable: Innovations								
<i>Estimation method</i>	<i>RE Probit</i>	<i>RE dynamic Probit</i>	<i>FE linear probability</i>	<i>RE Probit</i>	<i>RE Probit</i>	<i>RE dynamic Probit</i>	<i>FE linear probability</i>	<i>Probit</i>
Outsourcer	0.140*** (0.005)	0.102*** (0.005)	0.074*** (0.005)	0.078*** (0.010)	0.058*** (0.005)	0.067*** (0.005)	0.046*** (0.008)	0.112*** (0.009)
<i>No. observations</i>	60,834	60,031	60,834	51,997	17,649	17,493	17,649	5,999
Part B. Dependent variables: Product and process innovations								
<i>Estimation method</i>	<i>Bivariate Probit</i>	<i>Dynamic bi-probit</i>	<i>FE linear probability</i>	<i>Bivariate Probit</i>	<i>Bivariate Probit</i>	<i>Dynamic bi-probit</i>	<i>FE linear probability</i>	<i>Bivariate Probit</i>
Outsourcer								
- on product innovation	0.216*** (0.005)	0.118*** (0.007)	0.064*** (0.005)	0.127*** (0.011)	0.104*** (0.007)	0.088*** (0.009)	0.045*** (0.007)	0.115*** (0.012)
- on process innovation	0.162*** (0.008)	0.084*** (0.006)	0.061*** (0.005)	0.077*** (0.011)	0.090*** (0.007)	0.072*** (0.009)	0.047*** (0.009)	0.125*** (0.013)
<i>No. observations</i>	60,834	60,031	60,834	51,997	17,649	17,493	17,649	5,999
Part C. Dependent variable: Sales from new products								
<i>Estimation method</i>	<i>RE Tobit</i>	<i>RE dynamic Tobit</i>	<i>FE OLS</i>	<i>RE Tobit</i>	<i>RE Tobit</i>	<i>RE dynamic Tobit</i>	<i>FE OLS</i>	<i>Tobit</i>
Outsourcer	0.666*** (0.155)	0.309 (0.196)	0.411 (0.456)	0.894*** (0.297)	0.550*** (0.244)	0.065 (0.292)	0.406 (0.733)	1.154** (0.463)
<i>No. observations</i>	28,298	28,084	28,298	27,295	11,993	11,925	11,993	3,917

Notes: The numbers in each cell correspond to the marginal effect of being an outsourcer in different estimates. There are two main sets of specifications: columns [1] to [4] are for the whole sample and the measure of outsourcing is the dummy variable for the outsourcing status; in column [4], we use an IV control function approach and therefore the regressions include the residual of the estimation of the probability of being an outsourcer, which is explained in Appendix B. The estimated coefficient of the residual is significant in all regressions. Columns [5] to [8] are for the sample of matched firms. In column [8], the treated group is the sample of new outsourcers, that is, firms that outsource R&D services in a given year, but not in the previous year. All regressions include four size dummies, three geographical dummies, 10 industry dummies and year dummies. All specifications include the same control variables as in column [1] of Table 3. RE and FE mean firm-random effects and firm fixed effects, respectively. Dynamic bi-probit means dynamic bivariate Probit model. In dynamic models, lagged dependent variables and initial conditions are also included, although not reported here. The coefficients of column [1] correspond to those of Table 3. Estimated standard errors are in parentheses. We report marginal effects at sample means. * Significant at 10%, ** significant at 5%, *** significant at 1%.

**Table 5: The effects of being a domestic or international outsourcer on innovativeness.
Matched sample**

	[1]	[2]	[3]	[4]
Part A. Dependent variable: Innovations				
<i>Estimation method</i>	<i>RE Probit</i>	<i>RE dynamic Probit</i>	<i>FE linear probability</i>	<i>Probit</i>
Domestic outsourcer	0.045*** (0.004)	0.061*** (0.005)	0.048*** (0.007)	0.109*** (0.010)
International outsourcer	0.021*** (0.003)	0.043*** (0.008)	0.025* (0.015)	0.064* (0.034)
Part B. Dependent variables: Product and process innovations				
<i>Estimation method</i>	<i>Bivariate Probit</i>	<i>Dynamic bi-probit</i>	<i>FE linear probability</i>	<i>Bivariate Probit</i>
Domestic outsourcer				
- On product innovation	0.111*** (0.007)	0.073*** (0.008)	0.037*** (0.008)	0.114*** (0.013)
- On process innovation	0.099*** (0.007)	0.071*** (0.009)	0.056*** (0.009)	0.117*** (0.013)
International outsourcer				
- On product innovation	0.090*** (0.015)	0.059*** (0.018)	0.013 (0.018)	-0.030 (0.048)
- On process innovation	0.123*** (0.016)	0.082*** (0.020)	0.050** (0.020)	0.108*** (0.028)
Part C. Dependent variable: Sales from new products				
<i>Estimation method</i>	<i>RE Tobit</i>	<i>RE dynamic Tobit</i>	<i>FE OLS</i>	<i>Tobit</i>
Domestic outsourcer	0.569** (0.226)	0.119 (0.273)	-0.063 (0.656)	0.383 (0.466)
International outsourcer	0.621 (0.550)	0.371 (0.664)	-1.294 (1.305)	2.791 (1.815)

Notes: The numbers in each cell correspond to the marginal effect of being an outsourcer in different estimates. See the number of observations in each matched sample in Table C.3 of Appendix C. All regressions include four size dummies, 10 industry dummies, three geographical dummies and year dummies. All specifications include the same control variables as in column [1] of Table 3. RE and FE mean firm random effects and firm fixed effects, respectively. Dynamic bi-probit means dynamic bivariate Probit model. In column [4], the treated group is the sample of new outsourcers, that is, firms that start to outsource R&D services in a given year, but not in the previous year. Estimated standard errors are in parentheses. We report marginal effects at sample means. * Significant at 10%, ** significant at 5%, *** significant at 1%.

Table 6: The effects of being a domestic or international outsourcer on innovativeness depending on exporting status. Matched sample.

	[1]	[2]	[3]	[4]
Part A. Dependent variable: Innovations				
<i>Estimation method</i>	<i>RE Probit</i>	<i>RE dynamic Probit</i>	<i>FE linear probability</i>	<i>Probit</i>
Domestic outsourcer & exporter	0.039*** (0.004)	0.056*** (0.005)	0.046*** (0.007)	0.091*** (0.010)
Domestic outsourcer & non-exporter	0.025*** (0.003)	0.048*** (0.005)	0.053*** (0.012)	0.106*** (0.010)
International outsourcer & exporter	0.022*** (0.003)	0.045*** (0.008)	0.028* (0.016)	0.065* (0.035)
International outsourcer & non-exporter	0.015* (0.009)	0.033 (0.022)	0.000 (0.040)	0.043 (0.045)
Part B. Dependent variables: Product and process innovations				
<i>Estimation method</i>	<i>Bivariate Probit</i>	<i>Dynamic bi-probit</i>	<i>FE linear probability</i>	<i>Bivariate Probit</i>
Domestic outsourcer & exporter				
- <i>On product innovation</i>	0.118*** (0.007)	0.078*** (0.008)	0.039*** (0.009)	0.103*** (0.014)
- <i>On process innovation</i>	0.099*** (0.007)	0.059*** (0.009)	0.051*** (0.010)	0.115*** (0.014)
Domestic outsourcer & non-exporter				
- <i>On product innovation</i>	0.078*** (0.016)	0.048*** (0.011)	0.029** (0.013)	0.125*** (0.017)
- <i>On process innovation</i>	0.090*** (0.010)	0.069*** (0.012)	0.071*** (0.015)	0.112*** (0.018)
International outsourcer & exporter				
- <i>On product innovation</i>	0.098*** (0.016)	0.055*** (0.019)	0.009 (0.018)	-0.051 (0.053)
- <i>On process innovation</i>	0.129*** (0.017)	0.000 (0.000)	0.058** (0.020)	0.120** (0.047)
International outsourcer & non-exporter				
- <i>On product innovation</i>	0.054 (0.042)	0.043 (0.046)	0.049 (0.045)	0.042 (0.085)
- <i>On process innovation</i>	0.080* (0.045)	0.000 (0.000)	-0.024 (0.052)	0.046 (0.081)

Table 6 continued

	[1]	[2]	[3]	[4]
Part C. Dependent variable: Sales from new products				
<i>Estimation method</i>	<i>RE Tobit</i>	<i>RE dynamic Tobit</i>	<i>FE OLS</i>	<i>Tobit</i>
Domestic outsourcer & exporter	0.456* (0.245)	0.118 (0.295)	-0.291 (0.728)	0.586 (0.522)
Domestic outsourcer & non-exporter	0.924** (0.373)	0.107 (0.446)	0.633 (1.040)	-0.146 (0.761)
International outsourcer & exporter	0.289 (0.572)	0.042 (0.692)	-2.452* (1.351)	2.642 (1.961)
International outsourcer and non-exporter	3.275** (1.664)	3.293 (2.074)	8.743* (4.767)	3.832 (4.184)

Notes: The numbers in each cell correspond to the marginal effect of being an outsourcer in different estimates. See the number of observations in each matched sample in Table C.3 of Appendix C. All regressions include four size dummies, 10 industry dummies, three geographical dummies and year dummies. All specifications include the same control variables as in column [1] of Table 3. RE and FE mean firm random effects and firm fixed effects, respectively. Dynamic bi-probit means dynamic bivariate Probit model. In column [4], the treated group is the sample of new outsourcers, that is, firms that outsource R&D services in a given year, but not in the previous year. Estimated standard errors are in parentheses. We report marginal effects at sample means. * Significant at 10%, ** significant at 5%, *** significant at 1%.

Appendix A: Definitions of variables

In this appendix, we define the variables we use in our empirical analysis and describe the data sources.

The source of the following variables is the PITEC dataset:

Business group: Dummy variable which takes the value one if the company is part of an enterprise group.

Exporter: Dummy variable which takes the value one if the enterprise has exported.

Geographical dummies: We construct three dummy variables which take the value one if the majority of their R&D researchers are located in the **Basque Country**, **Catalonia** and **Madrid**, respectively.

Innovation objectives: In the database, the companies are asked: “During the current and previous two years, innovation activity undertaken in your company could be oriented to different objectives. Indicate the degree of importance of the following objectives”. For each of the objectives, the company can answer that the importance of the effect was high, intermediate, or low, or that the factor was not experienced. We construct two dummy variables which take the value one if any of the corresponding objectives explained below was of high importance.

Pull demand: This variable includes the following effects: increased range of goods or services, new markets entered or increased market share, and improved quality of goods or services.

Push cost: This variable includes the following effects: improved flexibility of production or service provision, increased capacity for production or service provision, reduced labor costs per unit produced, and reduced material or energy costs per unit produced.

Internal R&D intensity: R&D expenditures undertaken within the enterprise or intramural (in-house) over employment (in logarithms) in the current year.

Obstacles to innovation: In the database, the companies are asked: “During the current and previous two years, how important were the following factors for hampering your innovation activities?” For each of the factors, the company can answer that the importance of the factor was high, intermediate, or low, or that the factor was not experienced. We assign a number that varies from zero (not experienced) to three (high importance) for each answer. We calculate the average importance of the corresponding factors. Then, we calculate the average importance of the factors at the sector level. We construct a dummy variable which takes the value one if the average answer of the company is higher than the average value for its sector.

Lack of finance: This variable includes the following factors: lack of funds within your enterprise or group, lack of finance from sources outside your enterprise, and innovation costs too high.

Lack of information: This variable includes the following factors: lack of information on technology, and lack of information on markets.

Lack of personnel: This variable includes the lack of qualified personnel factor.

Not needed: This variable includes no need to innovate because of prior innovations, and no need to innovate because of no demand for innovations.

Public support: Dummy variable which takes the value one if the company has received any public financial support during the current year for innovation activities.

R&D outsourcing:

In the database, the companies are asked about the expenditures corresponding to “acquisitions of R&D services outside the firm through contracts, informal agreements...”. The companies also distinguish the expenditures by the location of the provider. We construct two dummy variables: the ***domestic R&D***

outsourcer variable if the firm acquires R&D and more than 50% of the R&D acquisitions are from national providers, and the *international R&D outsourcer* variable if the firm acquires R&D and more than 50% of the R&D acquisitions are from international providers.

Sectoral patents: Sample average of patent applications by activity sector during the current or previous two years.

Size: Number of employees in the current year.

Sources of information:

In the database, the companies are asked: “In the current and previous two years, what was the importance of each of the following sources of information in order to innovate?” For each of the sources, the company can answer that the importance of the source was high, intermediate, or low.

Internal: Dummy variable which takes the value one if information from internal sources (within the company or the firm’s group) was of high importance.

Suppliers: Dummy variable which takes the value one if information from suppliers was of high importance.

Competitors: Dummy variable which takes the value one if information from competitors was of high importance.

Customers: Dummy variable which takes the value one if information from customers was of high importance.

The source of the following variable is explained after the definition of the variable:

Sectoral differences in labor costs per employee: Ratio of labor cost per employee at the sectoral level. These data come from the OECD STAN Database for structural analysis: <https://stats.oecd.org/Index.aspx?DataSetCode=STANI4>

Appendix B: Instrumental variables estimations: Control function approach

In this section, we describe the procedure that we use in order to estimate the IV regressions in column [4] of Table 4.

In order to control for endogeneity, we follow a control function approach.²⁵ The basic idea behind this methodology is that endogeneity can be treated as an omitted variable problem (Blundell and Powell, 2004). By adding an appropriate control function to the estimations of an equation with an endogenous variable, the selection bias is corrected and the endogenous variable becomes exogenous. The advantages of this technique in our context are that it can be applied to non-linear models and it is computationally simple. This methodology consists of two steps: In the first step, we examine a reduced form for the characteristics of firms that outsource (the instruments) based on a Probit model and calculate the residuals of these estimations. In the second step, we include the residuals as an additional covariate in equation (1) to account for the unmeasured confounders together with all independent variables from the first step.

In our identification strategy, we follow Buss and Peukert (2015), for whom differences in sectoral *labor costs* due to unionization is an instrumental variable. In Table B.1, we present the estimations from the Probit model in column [1] and from a linear probability model in column [2]. In both regressions, the estimated coefficient of labor cost is positive and highly statistically significant, which indicates the relevance of the instrument. In particular, the estimates suggest that an increase in labor costs by one standard deviation increases the probability of outsourcing by 0.49 percentage points.²⁶ Moreover, the overall F-statistics for the first stage is highly significant, which indicates the strength of the instrument.

The specification selected to obtain the estimates that we show in column [4] of Table 4 includes all variables in column [1] of Table B.1.

Table B.1: Instrumental variables used for control function approach

	[1]	[2]
<i>Estimation method:</i>	<i>Probit</i>	<i>Linear Probability</i>
Labor costs	0.0004** (0.0002)	0.0004** (0.0002)
Industry FEs	Yes	Yes
<i>No. Observations</i>	60,119	60,119
<i>R-Squared</i>		0.073

Notes: All regressions include all the controls in equation (1) and year dummies. We report marginal effects at sample means. Estimated standard errors are in parentheses. * Significant at 10%, ** significant at 5%, *** significant at 1%.

²⁵ For a recent summary of the control function approach, see Wooldridge (2015).

²⁶ This is calculated as $12.21 * 0.0004$ based on the standard deviation of labor costs and the estimated coefficient in Table B.1.

Appendix C: Description of the matching method for the outsourcing status

In this appendix, we describe the Propensity Score Matching (PSM) technique that we use to construct a sample of firms with characteristics similar to each treated group in Tables 4, 5 and 6. In these tables, we consider six different treatments that correspond to six different types of outsourcing status. In columns [5] to [7] of Table 4, the matched sample corresponds to the case in which the treatment is “being an outsourcer” (case [A]). In column [8] of Table 4, we focus on firms that start outsourcing R&D services in year t (case [B]). Therefore, we exclude persistent outsourcers from the treated group, that is, we exclude those firms outsourcing in t that also outsourced in $t-1$. The results in columns [1] to [3] of Tables 5 and 6 combine the estimations performed in two different matched samples. Coefficients for *domestic outsourcer* are obtained from the matched sample where the treatment is “being a domestic outsourcer” (case [C]), while coefficients for *international outsourcer* are achieved from the matched sample where the treatment is “being an international outsourcer” (case [D]). Finally, in cases [E] and [F], we also exclude persistent outsourcers from treated groups of domestic and international outsourcers, respectively. These matched samples are used to obtain the results in column [4] of Tables 5 and 6.

To compute the propensity score for our matching routine, in a first stage for each treatment we estimate the following Probit model:

$$treated_{it} = \begin{cases} 1 & \text{if } \alpha + w'_{it-1}\delta + d_t + \varepsilon_{it} > 0, \\ 0 & \text{otherwise,} \end{cases}$$

where $treated_{it}$ is a dummy variable that takes the value one if firm i receives the treatment in year t . The vector w_{it-1} reflects pre-treatment firm characteristics that influence the treatment, d_t denotes time dummies, and ε_{it} is the error term, which we assume is normally distributed with variance σ_ε^2 . We follow Cassiman and Veugelers (2006) to select the vector of control variables denoted by w , which are documented in Appendix A.

Based on these estimations, in a second stage, we use a caliper matching algorithm with replacing, in which non-outsourcers are matched with the outsourcers that are closest in terms of the propensity score subject to the constraint that there has to be at most a maximum distance of 0.0001 between the treated and non-treated firm. We assign the matched control observations to the same industry as the outsourced company. The procedure is performed in Stata 13, using the `psmatch2` routine implemented by Leuven and Sianesi (2003). In order to assess the matching quality, we check whether the distribution of covariates is balanced in the treated and control groups.

The results of the estimations of Probit models are reported in Table C.1. Regardless of the case of treatment, we see that being an exporter, having public financial support and internal R&D intensity in year $t-1$ increase the probability of outsourcing R&D in year t . The estimates also show that demand-enhancing reasons seem more important than cost reduction motives for engaging in R&D outsourcing. As explanatory variables, we also include the measures of innovativeness that have already been described. The results show a positive relationship between these measures and outsourcing.

To assess the matching quality, in Table C.2 we report the difference of means of covariates between treated and control groups for case [A].²⁷ We can see that, after matching, the majority of variables have the same mean in the two groups. In addition, the balancing tests in Table C.3 suggest that, overall, in all cases the matching procedure has been able to balance the treated and non-treated groups, creating a homogenous group with common characteristics before outsourcing.

²⁷ The results are quite similar in the rest of the cases, and are available from the authors upon request.

Table C.1: Characteristics of R&D outsourcers. Probit model

Case	Outsourcer [A]	New outsourcer [B]	Domestic outsourcer [C]	International outsourcer [D]	New domestic outsourcer [E]	New international outsourcer [F]
Product innovations _{t-1}	0.054*** (0.005)	0.009** (0.004)	0.051*** (0.005)	0.002* (0.001)	0.007* (0.004)	0.001 (0.001)
Process innovations _{t-1}	0.030*** (0.005)	0.009** (0.004)	0.025*** (0.005)	0.003** (0.001)	0.006 (0.004)	0.002*** (0.001)
Sales from new products _{t-1}	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Exporter _{t-1}	0.057*** (0.005)	0.012*** (0.004)	0.046*** (0.005)	0.009*** (0.001)	0.008** (0.004)	0.003*** (0.001)
Sectoral patents _{t-1}	0.154*** (0.009)	0.012 (0.009)	0.126*** (0.009)	0.009*** (0.002)	0.008 (0.009)	0.003** (0.001)
Business group _{t-1}	0.007 (0.005)	-0.001 (0.004)	0.001 (0.005)	0.004*** (0.001)	-0.004 (0.004)	0.002** (0.001)
Public support _{t-1}	0.225*** (0.005)	0.077*** (0.004)	0.212*** (0.005)	0.008*** (0.001)	0.073*** (0.004)	0.003*** (0.001)
Internal R&D intensity _{t-1}	0.053*** (0.008)	0.025*** (0.006)	0.049*** (0.008)	0.004*** (0.001)	0.019*** (0.007)	0.003*** (0.001)
<i>Innovation objectives</i>						
- Pull demand _{t-1}	0.058*** (0.005)	0.015*** (0.004)	0.056*** (0.005)	0.002** (0.001)	0.015*** (0.004)	0.001 (0.001)
- Push costs _{t-1}	-0.006 (0.005)	0.003 (0.004)	-0.008 (0.005)	0.001 (0.001)	0.000 (0.004)	0.002** (0.001)
<i>Sources of information</i>						
- Internal _{t-1}	0.006 (0.005)	0.002 (0.004)	0.002 (0.005)	0.003*** (0.001)	0.000 (0.004)	0.001 (0.001)
- Suppliers _{t-1}	-0.007 (0.006)	-0.001 (0.004)	-0.009* (0.005)	0.002* (0.001)	-0.001 (0.004)	0.001 (0.001)
- Competitors _{t-1}	0.013* (0.007)	0.009 (0.006)	0.008 (0.007)	0.002 (0.002)	0.005 (0.006)	0.002 (0.001)
- Customers _{t-1}	0.027*** (0.005)	-0.003 (0.004)	0.025*** (0.005)	0.001 (0.001)	-0.002 (0.004)	-0.001 (0.001)
<i>No. Observations</i>	44,682	30,471	44,110	44,110	30,058	30,058

Note: All regressions include the four size dummies, 15 industry dummies, and year dummies. We report marginal effects at sample means. All independent variables are lagged one period. Estimated standard errors are in parentheses.

* Significant at 10%, ** significant at 5%, *** significant at 1%.

Table C.2: Matching method for R&D outsourcing
Balancing tests: Difference of means

Variables	Mean		% bias		t-test	
	Treated	Control	% bias	Reduction	t-value	p-value
Product innovations _{t-1}	0.77	0.76	1.4	97.5	1.17	0.243
Process innovations _{t-1}	0.73	0.72	0.6	98.4	0.54	0.590
Sales from new products _{t-1}	13.99	13.99	0	99.8	0.03	0.979
Exporter _{t-1}	0.74	0.74	0.3	98.9	0.22	0.829
Business group _{t-1}	0.40	0.41	-0.7	88.5	-0.54	0.588
Sectoral patents _{t-1}	0.17	0.17	1.1	96.4	0.94	0.346
Public support _{t-1}	0.63	0.64	-0.4	99.4	-0.34	0.733
Internal R&D intensity _{t-1}	0.11	0.11	1.2	94.0	1.03	0.304
<i>Innovation objectives</i>						
- Pull demand _{t-1}	0.72	0.72	0.6	98.7	0.49	0.621
- Push cost _{t-1}	0.45	0.45	0.4	98.4	0.28	0.780
<i>Sources of information</i>						
- Internal _{t-1}	0.64	0.63	0.8	94.7	0.60	0.545
- Suppliers _{t-1}	0.22	0.22	1	55.6	0.77	0.443
- Competitors _{t-1}	0.15	0.15	0	99.6	0.04	0.971
- Customers _{t-1}	0.33	0.33	0	100.0	0.00	1.000

Note: The econometric model used for the matching procedure is based on Table C.1, case [A].

Table C.3: Matching method for R&D outsourcing.
Overall measures of covariate balancing and number of observations after matching

Case	Treatment	Control	Balancing tests			Number of observations		
			Ps R2	LR Chi2	p>Chi2	Total	Treated	Control
[A]	Outsourcer	Non-outsourcer	0.001	18.88	0.992	17649	8933	8716
[B]	New outsourcer	Non-outsourcer	0.003	27.58	0.842	5999	3073	2926
[C]	Domestic outsourcer	Non-outsourcer	0.001	44.97	0.145	16975	8612	8363
[D]	International outsourcer	Non-outsourcer	0.008	16.80	0.997	1406	709	697
[E]	New domestic outsourcer	Non-outsourcer	0.001	12.54	1.000	5701	2913	2788
[F]	New international outsourcer	Non-outsourcer	0.029	15.21	0.999	374	189	185

Note: LR Chi2 reports the test on overall significance of the Probit model after the matching. Observations for total, treated and control samples are obtained after applying the matching procedure.