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Asymmetric additionalities between R&D outsourcing locations

María García-Vega and Elena Huergo

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Asymmetric additionalities between R&D outsourcing locations

María García-Vega and Elena Huergo*

Abstract

This paper empirically examines the additionalities or crowding-out effects of international and national outsourcing of R&D to generate innovation. Using a panel database of about 10,000 Spanish firms for the period 2005-2014, we show that there is asymmetry in the effectiveness of the combined adoption of R&D outsourcing locations. International R&D outsourcing re-inforces the effect of domestic R&D outsourcing. However, national outsourcing does not re-inforce international R&D outsourcing. We next explore sources of additionality. Property Right Theory (PRT) suggests that additionality is high when holdup problems are low. We therefore analyze two important situations where holdup problems are likely to be low: with public foreign providers and in sectors with low technological complexity. Consistent with PRT, our results suggest that additionality is stronger when R&D is acquired from public providers rather than from private providers. Moreover, we find additionality in sectors with medium or low R&D complexity. In sectors with high R&D complexity, domestic and international outsourcing are largely independent. These results also suggest that international R&D outsourcing does not undermine domestic R&D.

Keywords: Imports of technology; International and national R&D outsourcing; Innovation; Additionality or crowding-out effects.
JEL classification: L25; O31; O32.

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* María García-Vega (maria.garcia-vega@nottingham.ac.uk): School of Economics. University of Nottingham. University Park, Nottingham NG7 2RD, United Kingdom. Phone: +44 1158468417. Elena Huergo (ehuergoo@ccee.ucm.es): Department of Economic Analysis. Faculty of Economics and Business. Universidad Complutense de Madrid. Campus de Somosaguas 28223. Madrid, Spain. Phone: +34 91 394 2370.
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1. INTRODUCTION

Based on principal-agent theory, the standard view in the R&D literature is that companies maintain their core technologies in-house and rely on external providers to develop non-core knowledge that supplements internal research (Milgrom and Roberts, 1992; Beneito, 2006; Lai et al., 2009).[1] The relationship between in-house R&D and external technologies features prominently in the innovation and management literature (Arora and Gambardella, 1990; Hu et al., 2005; Cassiman and Veugelers, 2006; Goyal et al., 2008; Bertrand and Mol, 2013; Ceccagnoli et al., 2014; Harhoff et al., 2014; Spithoven and Teirlincka, 2015; Añón et al., 2018). However, an important unanswered question is to what extent, foreign providers of technology add or crowd-out domestic suppliers. We address this question in this paper.

Our contributions are as follows. We study (i) whether there is additionality or crowding-out between national and international R&D outsourcing in order to generate innovation; (ii) whether there is asymmetry in this relationship; and (iii) whether the sources of additionality or crowding-out effects are explained by Property Right Theory (PRT). By R&D outsourcing, we specifically mean acquisitions of R&D services, such as product designs, clinical tests or engineering services from external providers of technology.

Understanding the interrelationship between national and international outsourcing of high-skilled tasks is important given that international R&D outsourcing might induce firms to relocate high-tech services abroad (Blinder, 2006; Head et al., 2009; Baldwin, 2016). From a managerial point of view, the evaluation of different locations from which to acquire technologies and their interactions is important for R&D management. We add to the literature the first evidence that the sequence of outsourcing between different locations matters. We contribute to the organizational economics literature by identifying mechanisms based on

[1] For a summary on technology markets, see Arora and Gambardella (2010). For studies on the economic importance of the market of ideas for innovation see Galasso et al. (2013) and Chatterji and Fabrizio (2016).

holdup problems that influence the additionality or crowding-out between national and international R&D outsourcing. Arguments based on PRT suggest that there is a positive relationship between additionality and outsourcing when holdup problems are low. The reason is that it is more likely to observe additionality between technological inputs when holdup problems are unlikely because each individual supplier maximizes his investment efforts. As a consequence, payoffs are high for the buyer, which incentivizes the buyer to outsource from different technology providers (Antràs and Chor, 2013 and Antràs, 2013). By contrast, when holdup problems are likely, a company might not outsource to providers with inputs that present additionalities because they might have an incentive to underinvest leading to low overall payoff for the buyer.

We explore two different sources of heterogeneity in our data that can lead to holdup problems: ownership of foreign providers and technological complexity. First, we study whether the ownership structure (public versus private) of the foreign R&D providers influences the additionality or crowding-out effects between domestic and foreign technological acquisitions. Following Teece (1986), we argue that additionality is more likely with public foreign providers, such as foreign universities, than with foreign private providers. The reason is that the research that public institutions generate tends to be more generic and basic than the technology produced by private institutions. As Teece (1986) explains, generic assets are less likely to be subject to appropriation hazard than specialized assets because specialized assets require irreversible investments, which can lead to holdup problems.[2] Second, we consider sectoral technological complexity. We argue that additionality is more likely in sectors with low technological complexity compared to sectors with complex

[2] For a detailed analysis of the appropriation hazards of R&D outsourcing, see Buss and Peukert (2015).

technologies because low complexity makes it easier to sign detailed contracts, and thereby reduce potential holdup problems (Lai et al., 2009).[3]

Our main contributions to the literature are to study whether there is asymmetric additionality between national and international R&D outsourcing to generate innovations, to examine the potential sources of the additionality as well as its consequences in terms of innovation outputs for the acquiring firm. For our analysis, we use a firm panel dataset that contains information on international and national R&D acquisitions from external providers for about 10,000 firms operating in Spain between 2005 and 2014. Spanish firms are a good testing case for our research questions because foreign sources of technology are potentially more important for moderately innovative countries like Spain than for technological leaders (Keller, 2004). For Spain as an EU member, intellectual property right laws follow European legislation, which facilitates technology flows.

We follow a matching procedure with multiple treatments as in Gerfin and Lechner (2002). This technique has been used in the R&D literature for the analysis of additionalities of R&D support programs (Czarnitzki et al., 2007; Czarnitzki and Lopes-Bento, 2014; Marino et al., 2016; Huergo and Moreno, 2017, among others). In our analysis, we consider the following: For each treatment (only domestic, only international and domestic and international), we find a set of firms with the same observable characteristics as the treated group but that did not receive the treatment. Then, we calculate the average treatment effect as the mean difference in the innovation output variable of the matched pairs. We look at different cases of treated and control groups. First, we consider non-outsourcers as a control group. In this way, we measure the impact of each R&D outsourcing strategy with respect to the control group of non-outsourcers. The effect of each independent outsourcing location strategy on firms'

[3] In this line, The Economist (2013), in its special report on outsourcing and offshoring, notes that international R&D outsourcing implies high coordination costs and contract difficulties, which has induced some companies to bring back offshored services to their home countries.

innovativenees is an analysis that is in the prior literature, but we restate and extend it here for completeness.

Our novel contributions are to analyse whether there is output additionality or crowding-out effects between outsourcing locations, its asymmetries and sources of variations. For these purposes, secondly, we compare differences in innovation outputs between firms that outsource both nationally and internationally (treatment group) and firms that outsource only nationally or only internationally (control groups). In this way, we measure the effect of adding international outsourcing to firms that outsource nationally. We also measure the effect of adding national outsourcing to firms that outsource internationally to study the potential asymmetry in the effectiveness of outsourcing modes.

The relationship between technology sourcing strategies has long been of interest to the literature on R&D governance, however not much is known about the potential additionality or crowding-out effect between national and international R&D outsourcing.[4] Our results have important implications for firms' strategic decisions about the location of their external R&D. We find evidence of additionality between national and international outsourcing, but this effect is asymmetric: international R&D outsourcing reinforces national R&D outsourcing, but national outsourcing does not reinforce international outsourcing. Consistent with PRT, our results suggest that additionality is more important when the international R&D provider is a public organization as opposed to a private company. Finally, we find additionality only in sectors with medium or low complexity. In sectors with high complexity, national and international outsourcing seem independent.

Our paper also contributes to the literature on the effectiveness of outsourcing strategies. Bertrand and Mol (2010) using probit models study determinants and innovation effects of

[4] See Barge-Gil et al. (2018) for a review and Mohnen and Röller (2005) for an analysis of the complementarity of the obstacles to innovation in both the probability of becoming an innovator and the intensity of the innovation.

domestic and offshore R&D outsourcing. These authors find a larger effect of offshore outsourcing than domestic outsourcing on firm innovativeness. Castellani and Pieri (2013) find a positive impact of R&D offshoring on regional productivity growth. García-Vega and Huergo (2018) analyze the impact of national and international R&D outsourcing on firms' innovativeness and find that both are important to increase the probability to innovate. We build on insights from these articles. We corroborate and extend the previous evidence and emphasize that international outsourcing is more important for radical innovation than domestic outsourcing. In contrast to previous literature, here we focus on a more general question, which is the interrelationship between the two R&D outsourcing locations. We highlight that the sequence in which the decisions to outsource are adopted might enriche our ounderstading of the effectiveness of R&D management and find sources that contribute to the additionality between outsourcing modes.

The rest of the paper is organized as follows. In Section 2, we provide the theoretical background. In Section 3, we describe the data and the empirical methodology. In Section 4, we present our results and robustness tests. In section 5, we summarize our results, discuss implications and conclude.

2. BACKGROUND

2.1. Additionality or crowding-out between national and international R&D outsourcing

Output additionality of practices is usually defined as a situation in which the returns of a practice increases with the adoption of another practice (Czarnitzki and Lopes-Bento, 2014; Liu and Rammer, 2016; Marino et al., 2016; Huergo and Moreno, 2017). Our starting point is that outsourcing technology involves some costs. Additionalities will arise if some of the costs can be shared between outsourcing modes creating synergies between national and international

R&D outsourcing. In this line, Grossman et al. (2005) show that there is a positive cross-effect between outsourcing locations when the fixed costs to outsource are low. By contrast, if one outsourcing mode rises the costs of another type of outsourcing, then national and international R&D outsourcing undermine each other and there is crowding-out. Building on Grimpe and Kaiser (2010), we identify fundamental costs for R&D outsourcing that can generate synergies between national and international R&D outsourcing: We consider intellectual property right (IPR) definitions, integration of external knowledge, management attention and monitoring.

Regarding IPRs, the transfer of knowledge between organizations requires a certain degree of coordination and communication to define the different elements of the outsourced R&D process and how these parts will be allocated between the buyer and the seller (Teece, 1981; Garicano and Wu, 2012).[5] As the *resource based view* of the firm suggests, R&D might not be completely codifiable. Or in other words, the knowledge transferred might have a tacit component that depends on human experience.[6] As a consequence, IPRs associated with international outsourcing might be more difficult to be defined than IPRs from national outsourcing. The reason is that it is more difficult to transmit personal knowledge between geographically distant groups than between closer groups (Teece, 1981; Kogut and Zander, 1992; Moreira et al., 2018).[7] Therefore, having experience with IPR definitions involved in international R&D outsourcing might facilitate potential communication problems that may arise with national outsourcing. However, this effect might not be symmetric because experience with domestically outsourced R&D might not overcome communication problems that arise with international R&D outsourcing.

[5] For a study of IPRs allocations in the outsourcing of R&D and engineering see Carson and John (2013).
[6] See Polanyi (1966) and Garicano and Wu (2012) for the study of transfers of knowledge, communication and organizational capabilities. Kotabe et al. (2003) study the effect of experience on the transmission of knowledge between vertical partnerships.
[7] In the context of university patents and scientific publications, Belenzon and Schankerman (2013) show that citations to patents decline with geographical distance, which suggests that knowledge transfers are negatively related with physical distance.

The costs of integrating external knowledge are related to the absorptive capacity of the firm (Cohen and Levinthal, 1990; Penner-Hahn and Shaver, 2005; Escribano et al., 2009, among others). The organization and quality of research teams to integrate foreign external R&D might differ from research teams that integrate domestic knowledge. With non-codifiable R&D, Garicano and Wu (2012) show that a hierarchical structure emerges in models with managerial span of control or managerial limited attention. In this situation, there is a division of labor and managers acquire knowledge that helps subordinates to economize on communication costs. Moreover, in costly communication environments, managers have higher skills and are more knowledgeable. These considerations suggest that the research team of firms with international R&D outsourcing might be able to absorb domestic external knowledge. However, the knowledge hierarchy and management in firms with hitherto only national outsourcing might not be able to integrate international knowledge without additional costs. Therefore it is likely that there is additionality from international R&D outsourcing on domestic R&D outsourcing. However, this relationship is likely asymmetric.

2.2. Holdup problems and additionality

As we have discussed in the introduction, arguments based on PRT suggest that additionality between technological providers is likely in situations where holdup problems are low. Antràs (2013) shows in a model with incomplete contracts that, when technological inputs are complements, the payoff under outsourcing for the buyer tends to be low because suppliers of technology underinvest. In this model, outsourcing is more likely when technological inputs are complements if the holdup problem is reduced. The reason is that with low holdup problems the incentives to the suppliers to invest are high.

In this paper we consider two different sources of additionality. First, we distinguish by type of international outsourcing provider. Teece (1986) argues that generic technological assets or general propose assets are less likely to suffer from appropriation hazard and holdup problems than specific assets. Generally, public institutions such as universities are more likely to produce more basic and generic knowledge than private companies and therefore holdup problems with international public providers are likely to be low.[8] Consequently, it is more likely that there is additionality between national and international R&D outsourcing with public international providers than with private international providers.

Second, we analyze sector-specific technological complexity. Theoretical and empirical literature suggest that in sectors of low technological complexity it is easier to sign detailed contracts, and monitoring and coordination costs are lower than in sectors of high technological complexity (Corcos et al., 2013). Therefore, it might be more likely to find additionality between national and international R&D outsourcing in sectors of low technological complexity than in sectors of high technological complexity.

3. DATA AND METHODOLOGY

3.1. The data

Our dataset comes from a yearly survey of Spanish firms (*Panel de Innovación Tecnológica, PITEC*) from 2005 to 2014. The Spanish National Institute of Statistics constructs this database on the basis of the annual responses to the Spanish Community Innovation Survey (CIS).[9] In the survey, each company provides information on some of its economic data, such

[8] For example, Agrawal et al. (2015), analyzing the market of technologies, find that universities are less likely to face deal failures at the end of the bargaining process than private companies because universities typically do not compete in the product market.

[9] The PITEC survey is specifically designed to analyze R&D and other innovating activities following the recommendations of the OSLO Manual on performing innovation surveys (see OECD 2005). The survey is targeted at manufacturing and services companies whose main economic activity corresponds to sections C, D,

as sales or number of employees, its ownership structure, the location of its parent company and, most importantly for our research question, very detailed information on firms' acquisitions of technology distinguished between national and international providers. Our final sample is for an unbalanced panel of 9,733 companies.

The main interests of our analysis is to test the additionality or crowding-out effect between outsourcing locations, to study whether there is asymmetry and the sources of additionality or crowding-out. The company reports its *external R&D expenditures* distinguishing between national and international locations, that is, whether it purchases R&D from external providers in Spain and/or abroad. With this information, we construct the following dummy variables: *Only national R&D outsourcing*, which is a dummy variable that takes the value one if the firm reports acquiring R&D only from national providers, *only international R&D outsourcing*, which refers to firms that purchase R&D services only from international providers, and *both national & international R&D outsourcing*, which corresponds to firms that outsource R&D both nationally and internationally.

In the sample, we observe that 23.9% of firms outsource their R&D. Domestic outsourcing is the most common type of outsourcing, followed by firms that outsource both domestically and internationally and by international outsourcers only.[10] These features are in line with results by Tomiura (2009) for outsourcing of intermediate inputs by Japanese firms, where international outsourcing of intermediates is relatively uncommon. Our numbers are also consistent with Görg and Hanley (2011) for Irish outsourcing of services.

The dataset also provides information about other key firm characteristics such as innovation output, number of employees, physical investments and sales. In particular, our

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and E of NACE 93, except non-industrial companies because of the imprecision of methodological marking in the international context by other branches of activity. Details on the survey and data access guidelines can be obtained at http://www.ine.es/prodyser/microdatos/metodologia_pitec.pdf.

[10] Both types of R&D outsourcing are very concentrated in the pharmaceutical sector, where 62% of firms outsource nationally and 24% abroad within the sector.

measures of firms' innovativeness closely follow previous literature (Mairesse and Mohnen 2010). Firstly, 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. The advantage of the indicators' having product and process innovations is that they represent the most general measure of innovativeness. The distinction between product and process innovations allows us to differentiate between demand-based and cost-reduction innovations, respectively. 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 moderately innovative company are counted the same.

Secondly, we consider three disaggregated measures of product innovation. The first two measures are dummy variables that take the value one if a firm reports having introduced products new to the market or products new to the firm, respectively, in the current or previous two years. This differentiation is important because it allows us to distinguish between radical innovations, in the case of innovations new to the market, and incremental innovations, in the case of innovations new to the firm. In addition, we use a measure of innovative sales defined as the logarithm of sales from new products. The advantage of this variable is that it provides a yearly value of product innovations in euros. 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.

Thirdly, we include three disaggregated measures of process innovation. We construct dummy variables that take the value one if a firm reports having introduced new production, new logistic, and new support processes, respectively, in the current or previous two years. To assess the robustness of our results, we examine the effect of outsourcing on the different measures of innovation.

The mean values of the innovation output variables and firm characteristics are presented in Table 1 in two panels with variable definitions in the note of the table. Panel A reports sample means for innovation output variables, and panel B reports sample means for other firms' characteristics that we use in our matching procedure, explained below. In both panels, we distinguish between R&D outsourcing types: in column (1), we show means for firms that outsource only nationally; in column (2), we present averages for firms that outsource only internationally; in column (3), we show means for companies that outsource both nationally and internationally; in column (4), we present averages for outsourcers without distinguishing by type; and in column (5), we present means for non-outsourcers.

The evidence on panel A suggests that there are significant differences between non-outsourcers and outsourcers in terms of innovation outputs. Comparing columns (1), (2) and (3) for different types of R&D outsourcers with column (5) for non-outsourcers, we observe that non-outsourcers are less innovative than any type of R&D outsourcer for any innovation output. For example, 50% of non-outsourcers have product innovations during the period analysed. This is compared with 75% of firms with only national R&D outsourcing and 76% of firms with only international R&D outsourcing. This number rises to 81% for outsourcers that simultaneously outsource nationally and internationally. These figures are similar for the different categories of process innovation. Comparing across types of outsourcers in columns (1), (2) and (3), the table reveals a "pecking order" pattern (Antrás et al., 2017) in innovation behaviour, where firms that outsource both nationally and internationally are more innovative than firms that outsource only internationally and even more than those that outsource only nationally. Those numbers suggests additionality when combining national and international R&D outsourcing. However, an alternative explanation is that these differences are due to selection in outsourcing strategy.

In Panel B, we report the main firm-level variables that we will use for our matching procedure, which reflects differences in the probability of entering into different outsourcing modes. We include the following firm characteristics: labour productivity and the average wage in the R&D department to control for absorptive capacity and skill mix. We also include the market share of the firm measured as the firm's sales relative to the sales of the industry and a dummy variable that reflects whether the market is dominated by established firms to control for competition. We include capital per employee to control for physical investments, a dummy variable if the firm belongs to a business group and the number of employees to account for firm size. Finally, we add export status and the degree of internationalisation of the sector where the subsidiary operates because trade can induce companies to engage in other globalization strategies (e.g., Tomiura, 2009). The sample means are consistent with the patterns observed in panel A. R&D outsourcers are larger, pay higher salaries in R&D and are more productive than non-outsourcers. Across types of R&D outsourcers, companies that outsource both nationally and internationally are the largest, the most productive and the most likely to be exporters. They are followed by firms that outsource only internationally and, finally, those that outsource only nationally. Note that this is the same pecking order as in panel A.

3.2. The empirical methodology

Our main objective is twofold: to examine the additionality or crowding-out effect between national and international R&D outsourcing, and potential sources for the additionality or crowding-out of these strategies. In our analysis, we also determine the asymmetry of these effects. To face these objectives, we follow a matching procedure with multiple treatments as in Gerfin and Lechner (2002). This methodology consists of two steps, described below.

In the first step, we define the different treated firms (denoted by m=only national, only international, and both national and international) and control groups (denoted by l, which will be explained in detail below). For each case, we find a set of firms in the control group with the same observable characteristics as the treated group before outsourcing but that did not receive the treatment. The matching procedure is conducted using a nearest neighbor matching based on the propensity score of receiving a certain treatment.[11] In the empirical implementation, we include a set of observable pre-treatment characteristics that we describe in detail in the following section.

In the second step, we calculate the average treatment effect as the mean difference in the innovation output variable between treated and untreated firms in matched samples. A simple representation of the estimated treatment effect is $\hat{\beta}_{m,l} = \bar{Y}_m - \bar{Y}_l$, where $\bar{Y}$ represents mean innovation output in each group. Note that our key identifying assumption is that control and treated groups are observationally equivalent before the treatment.[12]

We consider five combinations of treatments and control groups. We report the different cases in Table 2. The treated groups in the table are structured as follows: in case 1, the treated group is firms with only national R&D outsourcing; in case 2, firms with only international R&D outsourcing; and in cases 3 to 5, firms with both national and international R&D outsourcing. In cases 1 to 3, our control group is non-outsourcers. In this way, we measure the differences in innovation outputs between firms that outsource only nationally (case 1), only internationally (case 2) and both nationally and internationally (case 3) with respect to non-outsourcers. Cases 1 to 3 measure the direct impact of each R&D outsourcing strategy with respect to the control group of non-outsourcing.

In case 4, we compare differences in innovation outputs between firms that outsource both nationally and internationally (treatment group) and firms that outsource only nationally (control group). In this way, we measure the effect of adding international outsourcing to firms

[11] Formally, for each treated firm, we search for a firm in the counterfactual group that had the same probability of receiving the treatment but did not receive the treatment.

[12] See, for example, Czarnitzki and Lopes-Bento (2014) or Huergo and Moreno (2017).

that outsource nationally. If the difference of means is positive (negative), it means that international R&D outsourcing increases (diminishes) the effect of national R&D outsourcing. In case of additionality, the returns to implement national outsourcing are highest when the firm also implements international outsourcing, or in other words, international outsourcing reinforces national outsourcing. In case 5, we compare firm differences in innovation outputs between firms that outsource both nationally and internationally (treatment group) and firms that outsource only internationally (control group). In this way, we measure the effect of adding national outsourcing to firms that outsource internationally. A novelty of our approach is that it allows for asymmetric additionality or crowding-out effect between R&D outsourcing strategies. Therefore, we use cases 4 and 5 to test the existence of *additionality or crowding-out effects.*

4. RESULTS

4.1. The characteristics of national and international R&D outsourcers

Before turning to the main focus of the paper, namely, the additionality or crowding-out effect between national and international R&D outsourcing on innovation, we first summarise the estimates of the probability models that we use to obtain the propensity scores for our matching procedure. This also allows us to further explore characteristics of R&D outsourcers. For each of the five cases that we described in the previous section, we estimate probit models where we regress a dummy variable indicator of whether a firm receives the treatment during the sample period on firm characteristics that we discussed in Section 3.1.[13] Formally,

[13] We include the following variables: number of employees, labor productivity, average physical investment, market share, average salary in R&D, being an exporter, market dominated by established companies, being part of a business group. In order to take advantage of the panel structure of our dataset and to control for common pre-trends of the dependent variables, we also add pre-treatment outcome variables in the matching procedure (see, for example, Guadalupe et al., 2012; Lechner, 2015; Stiebale 2016, among others). In particular, we include the following variables: new to the market product innovation, new to the firm product innovation, new production process, new logistic process and new support process. We also add geographic, industry and year dummies.

$$Treated_{it} = \begin{cases} 1 \text{ if } \alpha + X'_{it-1}\beta + d_t + \varepsilon_{it} > 0 \\ 0 \text{ if } \alpha + X'_{it-1}\beta + d_t + \varepsilon_{it} \leq 0. \end{cases} \quad (1)$$

In equation (1), $Treated_{it}$ is a dummy variable that takes the value one if the firm receives the treatment. The vector X_{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. In all regressions, we use cluster-robust standard errors. The results are reported in Table 3, where each of the columns corresponds to the different cases defined in Table 2.

In column (1), we show the estimates for the characteristics of firms that outsource only nationally versus non-outsourcers. The results show that national outsourcers are larger (in terms of employment and physical investments, although less likely to belong to a business group), more productive and more likely to export than non-outsourcers. Our estimates suggest that national outsourcers have a larger market share than non-outsourcers. Moreover, national R&D outsourcers perceive that the market is not dominated by established companies. This suggests market competition plays a role in the decision to outsource nationally. With respect to the technological variables, national R&D outsourcers are more likely to be more innovative and pay higher salaries to employees working in R&D departments than non-outsourcers.

In column (2), the results are qualitatively the same for international outsourcers compared with non-outsourcers in terms of signs and significance of the estimated coefficients, with the exception of those for number of employees, group variable and market competition, which are not statistically significant. When we compare firms with both international and national R&D outsourcers compared with non-outsourcers in column (3), we note that the results are similar to those obtained in column (1). An important difference is the estimated coefficient for average salary for R&D workers, which is higher in column (3) than in columns

(1) or (2). These results might reflect the need for absorptive capacity to find the combination of national and international R&D outsourcing that is profitable.

In column (4), we compare firms that outsource nationally and internationally with respect to firms that outsource only nationally. There are some differences between the two groups: firms with both national and international outsourcing are larger, more globalised and more likely to belong to a business group than firms with only national outsourcing. The differences in the technological variables are interesting because they indicate that firms with both strategies are more innovative in terms of product and process innovation and pay on average more to their R&D employees, which suggests skill mix differences between firms. However, we do not observe significant productivity differences.

Finally, in column (5), we compare firms that outsource nationally and internationally with respect to firms that outsource only internationally. We find that companies with both strategies are indeed larger, more innovative and pay larger salaries than international outsourcers only. These results reinforce the idea that absorptive capacities are important when the firm decides to simultaneously outsource from domestic and foreign locations. An alternative argument proposed by Bartel et al. (2012), which is also consistent with our findings, is that the benefits of both strategies might be larger for the most innovative firms because it allows firms to further specialise in their comparative advantage.

Based on the results from equation (1), we pair each treated firm with the closest untreated firm by caliper matching with replacement.[14] The matching procedure works well. In Table 4, we report balancing tests and number of observations after matching. The statistics in Table 4 indicate that, after matching, the covariates no longer explain the probability of participation well. In none of the cases does the LR-Chi2 statistic exceed the critical value at

[14] Matching is carried out with STATA command PSMATCH2 by Leuven and Sianesi (2003). The caliper used is equal to 0.0001.

the 5% significance level. In addition, the Pseudo-R2 after matching is close to zero in most cases. Therefore, after matching, the covariates do not seem to have any explanatory power to predict the outsourcing status. In this sense, our matching specification generates well-balanced samples, which implies that control and treatment groups are equivalent in their overall observable characteristics before treatment for the different cases.

4.2. Additionality or crowding-out effects

The results from calculating differences of means after matching for our different measures of product and process innovation are presented in Table 5. We show results for product innovation measures in panel A and results for process innovation measures in panel B. The first three rows in each panel show the effects of the treatments with respect to the non-R&D outsourcing status. The last two rows show additionality or crowding-out effects.

Focusing on cases 1 to 3 in panel A, we show that national outsourcing (case 1), international outsourcing (case 2) and a combination of both (case 3) increase product innovation. The coefficients in column (1a) are very similar across the three cases. For example, only national R&D outsourcing increases the probability of product innovation by 8.2%. We observe some differences across cases once we distinguish between products new to the market, in column (2a), and products new to the firm, in column (3a). We find that international R&D outsourcing or a combination of international and national R&D outsourcing are particularly important for innovations new to the market, while national outsourcing has a larger effect for innovations new to the firm. This suggests that international R&D outsourcing leads to more radical product innovation than national outsourcing. We do not observe that any type of R&D outsourcing has a significant effect on innovative sales. The positive effect on the dummy variables and the absence of an effect on innovative sales suggests that R&D outsourcing influences the extensive margin of innovation but not the intensive margin.

Exploring the *additionality or crowding-out effects* in panel A, we find evidence of additionality for innovations new to the market and new to the firm when the comparison group is firms with national R&D outsourcing only (case 4). Firms with both national and international outsourcing are 5.7% more likely to introduce products new to the market and 6.3% more likely to introduce products new to the firm than firms with only national outsourcing. We do not find any significant effect at standard statistical levels when the comparison group is firms with international outsourcing (case 5). This indicates that international outsourcing reinforces national outsourcing to innovate. However, national outsourcing does not reinforce international outsourcing.

The results based on panel B for process innovation resemble those reported in panel A. The results for cases 1 to 3 show that any type of R&D outsourcing increases process innovation in column (1b). Disaggregating process innovation into different types, we find that national outsourcing only or a combination of national and international outsourcing increases the probability of having new production, new logistic and new support processes. We do not find a statistically significant effect for only international outsourcing. Finally, we find evidence of additionality between national and international outsourcing for new logistic processes. Similar to panel A, this additionality is in the sense that international outsourcing reinforces national outsourcing.

Our methodology relies on the assumption that the treatment and the control group share statistically similar pre-treatment trends. We perform a robustness check to control for longer pre-existing trends. We modify our matching procedure in order to include two years of pre-treatment data. The results, presented in Table A1 in the Appendix, indicate that national R&D outsourcing has a positive effect on firms' innovativeness and confirm the additionality between both outsourcing strategies for new to themarket product innovations and new logistic process innovations.

Moreover, our identification assumption for calculating the effects of R&D outsourcing on innovation is that R&D outsourcing does not generate spillovers on non-outsourcing firms (Stable Unit Treatment Value Assumption, SUTVA). To address a potential violation of SUTVA, we modify our matching procedure, excluding matched control firms located in the same region as the R&D outsourcer. Our underlying assumption is that spillovers are regionally concentrated (Griliches, 1992; Jaffe et al., 1993; Agrawal et al., 2017). The results are presented in Table A2 in the Appendix.[15] In all cases, the results are consistent with our previous estimations in Table 5 and support the asymmetric additionality of between national and international R&D outsourcing. This suggests that our results are not biased by spillover effects.

To summarise, our results consistently show, first of all, that national and international R&D outsourcing increase a firm's innovativeness. Secondly, international R&D outsourcing leads to more radical product innovations than national outsourcing. Third, there is evidence of additionality between national and international outsourcing, but this effect is asymmetric: international R&D outsourcing reinforces national R&D outsourcing; however, national outsourcing does not seem to reinforce international outsourcing.

4.3. Sources of additionality

In order to get insights into the reasons for additionality, in this section we explore heterogeneity for the case where we find additionality (when the treatment is firms with both national and international outsourcing and the comparison group is firms with national R&D outsourcing only). As we have discussed in the introduction, arguments based on PRT suggest

[15] In Table OA1 and OA2 in the on-line Appendix, we report balancing tests and number of observations after matching for the robustness checks presented in Tables A1 and A2 respectively.

that additionality between technological providers is likely in situations in which holdup problems are low (Antràs and Chor, 2013). We study two different sources of additionality.

First, we distinguish by type of international outsourcing provider. We expect additionality to be higher with public international providers than with private international providers.[16] Second, we analyze sector technological complexity. We expect that additionality is higher in sectors of low technological complexity than in sectors of high technological complexity. In our empirical analysis we consider that a sector has high sectoral R&D complexity if the sector is above the 90th percentile or 80th percentile of R&D intensity (measured as the ratio of total innovation expenditures over physical investment).[17]

In Table 6, we show results when we differentiate by type of international provider. We find additionality with both private and public international R&D providers for products new to the market and for the introduction new logistic products. Values are higher for public than for private providers. This suggests that additionality is stronger when the international R&D provider is a public organisation.

In Table 7, we present results differentiating between sectors with high sectoral complexity and medium and low sectoral complexity. We find evidence of additionality only in sectors with medium and low complexity. In sectors with high complexity, national and international outsourcing are independent. This result suggests that, as complexity increases, it might become more difficult to monitor and coordinate national and international research projects.

[16] Private providers are companies that are legally independent and do not belong to the same business group. Public providers include public administrations, universities, non-profit organisations and other international organisations.

[17] In Tables OA3 and OA4 in the on-line Appendix, we report balancing tests and number of observations after matching for the two cases.

5. Summary, discussion and conclusion

In current times, firms are increasingly outsourcing their research activities domestically and abroad. An increase in a firm's R&D outsourcing can lead to higher firms' innovativeness. However, it also involves some costs and risks (Grimpe and Kaiser, 2010; Driesde, 2018), among them holdup problems. This investigation empirically examines whether there are additionalities between national and international R&D outsourcing in order to generate innovation as well as possible sources of additionalities based on PRT. Our econometric analysis on a panel data of more than 10,000 Spanish firms for the period 2005-2014 suggests that both international and national R&D outsourcing increase firm innovation. International R&D outsourcing seems to be an important driver for radical innovations, while national outsourcing seems to be relevant for incremental innovations. Our results suggests that international R&D outsourcing reinforces national R&D outsourcing, but national outsourcing does not reinforce international outsourcing.

In this paper, we have also studied sources of additionalities. In particular, we find that additionality is more relevant when international providers are public organizations as opposed to private companies and in sectors with medium or low technological complexity. Our mechanism is based on the type of R&D that is outsourced and that can generate holdup problems but not on outsourcers' characteristics. The reason is that our empirical analysis, using matching techniques, abstracts from observable firm characteristics when we study additionalities. Our approach has two advantages. First, in the first step of our analysis, it allows us to understand reasons for outsourcing R&D nationally and internationally. Second, we can control for selection bias by restricting our sample to companies with similar observable characteristics and pre-treatment trends before outsourcing. While our dataset has many advantages to study our research question, one shortcoming is that we cannot analyse organizational differences within firms that might promote synergies between national and international R&D outsourcing. For example, the results of Arora et al. (2014) suggests that there is a relationship between firms' R&D centralization, acquisition of external knowledge and how this external knowledge is integrated within firms. In this line, firm characteristics such as absorptive capacities, firm productivity and the level of firm internationalization might play a role for the complementarity between R&D outsourcing locations.

We close with some caveats. Simultaneously outsourcing nationally and internationally can be important for reasons other than obtaining innovation output. For example, having several providers for the same intermediate input might increase buyers' bargaining power and reduce risks. In this line, Klotz and Chaterjee (1995) show that sourcing from two suppliers might be beneficial because it can increase competition among them,[18] which can reduce costs and supplier performance risks (Li, 2013). For example, having both national and international providers might reduce operational uncertainties related to specific country economic conditions. Moreover, although international R&D outsourcing is increasing over time, so far, only a small number of small companies outsource R&D internationally. This fact suggests that for small companies the sunk costs to outsource internationally might be too large to even consider potential synergies that might arise with national R&D outsourcing. These are questions that we leave for future research.

There may also be interactions between firm location and outsourcing. This is an interesting question for future research because previous literature has highlighed location choice for technology transfers, competition and spillovers (Audretsch and Feldman, 1996, 2004; Chung and Yeaple, 2008; Laursen et al., 2011; Branstetter et al., 2018). Our approach contributes to this line of research by shedding light on the interelations between outsourcing

[18] For instance, defence procurements usually use a second source of production model to enhance competition among suppliers (Riordan and Sappington, 1989); the Japanese auto industry has a hybrid sourcing structure where several firms are qualified to manufacture one component (Richarson, 1993).

location decision and by providing evidence that PRT might help to predict the location of R&D outsourcing.

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TABLES

Table 1: Mean comparisons of innovation outputs and characteristics

	R&D outsourcers				**Non R&D outsourcers**
	Only national (1)	Only international (2)	National & international (3)	All [1+2+3] (4)	(5)
Panel A: Innovation output variables:					
Product innovation (0/1)	0.75	0.76	0.81	0.76	0.50
	(0.43)	(0.43)	(0.39)	(0.43)	(0.50)
New to the market (0/1)	0.48	0.52	0.56	0.49	0.27
	(0.50)	(0.50)	(0.50)	(0.50)	(0.45)
New to the firm (0/1)	0.57	0.55	0.62	0.57	0.38
	(0.50)	(0.50)	(0.48)	(0.49)	(0.49)
Innovative sales (in logs.)	10.88	11.16	12.51	11.08	6.99
	(6.63)	(6.60)	(6.36)	(6.62)	(7.24)
Process innovation (0/1)	0.70	0.75	0.74	0.70	0.52
	(0.46)	(0.43)	(0.44)	(0.46)	(0.50)
New production (0/1)	0.52	0.60	0.62	0.54	0.35
	(0.50)	(0.49)	(0.48)	(0.50)	(0.48)
New logistic (0/1)	0.18	0.21	0.24	0.19	0.11
	(0.38)	(0.41)	(0.43)	(0.39)	(0.31)
New support (0/1)	0.43	0.46	0.46	0.43	0.29
	(0.49)	(0.50)	(0.50)	(0.50)	(0.46)
Panel B: Other firms' characteristics:					
Physical investment (in logs.)	7.05	7.52	7.97	7.17	5.37
	(3.32)	(3.06)	(2.66)	(3.25)	(3.99)
Salary in R&D (in logs.)	8.85	8.37	9.96	8.97	4.60
	(3.32)	(3.06)	(2.66)	(3.25)	(4.98)
Exporter (0/1)	0.75	0.83	0.90	0.77	0.63
	(0.44)	(0.38)	(0.31)	(0.42)	(0.48)
Group (0/1)	0.43	0.49	0.60	0.45	0.39
	(0.49)	(0.50)	(0.49)	(0.50)	(0.49)
Labour productivity (in logs.)	11.86	11.96	11.99	11.88	11.70
	(1.06)	(1.10)	(1.32)	(1.09)	(1.11)
Market share	0.46	0.45	0.42	0.45	0.52
	(0.50)	(0.50)	(0.49)	(0.50)	(0.50)
Market dominated (0/1)	1.28	1.23	2.02	1.37	0.91
	(4.94)	(2.87)	(5.81)	(5.02)	(3.99)
Employees (in logs.)	4.22	4.14	4.76	4.28	4.00
	(1.53)	(1.52)	(1.49)	(1.54)	(1.61)
No. Observations	*14,680*	*447*	*2,150*	*17,277*	*55,095*

Notes: Standard deviations in parentheses. The symbol (0/1) means dummy variable. *Product innovation, New to the market product innovation, New to the firm product innovation, Process innovation, New production process, New logistic process* and *New support process* are all indicators that equal one if the firm reports innovations of each type during the periods t to t-2. *Innovative sales* are the natural logarithm of the sales coming from new products. *Physical investment* is the natural logarithm of a firm's over its number of employees; *Salary in R&D* is the natural logarithm of total salary in R&D over the number of employees working in R&D; *Exporter* and *Group* are dummy variables that take the value one if the firm is an exporter or belongs to a business group, respectively; *Labour productivity* is the natural logarithm of the sales over number of employees; *Market share* is the ratio of a firm's sales relative to its industry sales; *Market dominated* by established firms is a dummy variable that takes the value one if the firm reports that this is a very important factor in deferring innovation relative to the average of its sector; *Employees* is the natural logarithm of the number of employees.

Table 2: Cases of treatments and control groups

Case	Actual status (treatment)	Counterfactual (control)
1	Only national	Non-outsourcing
2	Only international	Non-outsourcing
3	Both national & international	Non-outsourcing
Additionality or crowding-out effects		
4	Both national & international	Only national
5	Both national & international	Only international

Table 3: Characteristics of R&D outsourcers. Probit models.

	Case 1 Only national vs non-outsourcing (1)	Case 2 Only international vs non-outsourcing (2)	Case 3 National & international vs non-outsourcing (3)	Case 4 National & international vs only national (4)	Case 5 National & international vs only international (5)
New to the market product innovation	0.163***	0.054	0.228***	0.075**	0.136*
	(0.015)	(0.049)	(0.030)	(0.034)	(0.081)
New to the firm product innovation	0.091***	-0.031	0.098***	-0.008	0.163*
	(0.015)	(0.048)	(0.031)	(0.035)	(0.084)
New production process	0.036**	0.234***	0.073**	0.070*	-0.232**
	(0.016)	(0.051)	(0.032)	(0.036)	(0.092)
New logistic process	0.003	0.060	0.051	0.067	-0.050
	(0.021	(0.063)	(0.040)	(0.043)	(0.101)
New support process	0.152***	0.102**	0.076**	-0.035	-0.047
	(0.016)	(0.050)	(0.032)	(0.036)	(0.087)
Number of employees (in logs.)	0.020***	-0.009	0.109***	0.084***	0.131***
	(0.006)	(0.021)	(0.013)	(0.014)	(0.036)
Labor productivity (in logs.)	0.058***	0.084***	0.026	-0.024	-0.072
	(0.009)	(0.031)	(0.018)	(0.020)	(0.048)
Average physical investment (in logs.)	0.029***	0.034***	0.040***	0.013**	-0.017
	(0.002)	(0.008)	(0.005)	(0.006)	(0.015)
Market share	0.003*	-0.002	0.001	-0.001	0.005
	(0.002)	(0.006)	(0.003)	(0.003)	(0.011)
Average salary in R&D (in logs.)	0.083***	0.036***	0.105***	0.044***	0.091***
	(0.002)	(0.007)	(0.006)	(0.007)	(0.015)
Exporter	0.087***	0.219***	0.377***	0.388***	0.217*
	(0.018)	(0.065)	(0.044)	(0.050)	(0.124)
Market dominated by established companies	-0.031**	-0.057	-0.086***	-0.047	-0.008
	(0.014)	(0.046)	(0.029)	(0.033)	(0.080)
Group	-0.043**	0.128**	0.162***	0.209***	0.007
	(0.017)	(0.055)	(0.035)	(0.038)	(0.093)
No. Observations	41,927	31,517	33,357	11,366	1,684

Notes: All regressions include 14 industry dummies, three geographical dummies and year dummies. Explanation of variables in Table 1. We report marginal effects at sample means. Estimated standard errors are in parentheses. * Significant at 10%, ** significant at 5%, *** significant at 1%.

Table 4: Balancing tests and number of observations after matching

Case	Treatment	Control	Balancing tests			Number of observations		
			Ps R2	LR Chi2	p>Chi2	Total	Treated	Control
1	Only national	Non-outsourcing	0.001	23.30	0.917	14,397	7,310	7,087
2	Only international	Non-outsourcing	0.034	27.38	0.700	585	293	292
3	National & international	Non-outsourcing	0.009	27.32	0.784	2060	1042	1018
4	National & international	Only national	0.008	24.16	0.894	2063	1048	1015
5	National & international	Only international	0.064	31.58	0.538	235	118	117

Notes: 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.

Table 5: The effect of R&D outsourcing on innovative outputs. Difference of means after matching.

PANEL A: Product innovation			**Dependent variable:**			
			Product Innovation	**New to the market**	**New to the firm**	**Innovative sales**
Case	**Treatment**	**Control**	**(1a)**	**(2a)**	**(3a)**	**(4a)**
1	Only national	Non-outsourcing	0.082**	0.069***	0.056***	0.061
			(0.009)	(0.009)	(0.012)	(0.060)
2	Only international	Non-outsourcing	0.089*	0.134***	0.058	0.510
			(0.054)	(0.050)	(0.057)	(0.352)
3	National & international	Non-outsourcing	0.087***	0.114***	0.071***	0.228
			(0.024)	(0.025)	(0.027)	(0.180)
Additionality or crowding-out effects						
4	National & international	Only national	0.037	0.057**	0.063**	0.131
			(0.026)	(0.028)	(0.029)	(0.167)
5	National & international	Only international	0.000	0.060	-0.026	-0.452
			(0.061)	(0.101)	(0.103)	(0.553)

PANEL B: Process innovation			**Dependent variable:**			
			Process innovation	**New production process**	**New logistic process**	**New support process**
Case	**Treatment**	**Control**	**(1b)**	**(2b)**	**(3b)**	**(4b)**
1	Only national	Non-outsourcing	0.055***	0.050***	0.019**	0.037***
			(0.011)	(0.008)	(0.008)	(0.008)
2	Only international	Non-outsourcing	0.089*	0.062	0.025	0.086
			(0.053)	(0.051)	(0.034)	(0.054)
3	National & international	Non-outsourcing	0.065***	0.070**	0.068***	0.040*
			(0.024)	(0.029)	(0.025)	(0.027)
Additionality or crowding-out effects						
4	National & international	Only national	0.027	0.039	0.063**	-0.007
			(0.024)	(0.031)	(0.022)	(0.027)
5	National & international	Only international	-0.086	0.017	0.034	-0.052
			(0.097)	(0.093)	(0.071)	(0.091)

Notes: Explanation of variables in Table 1. Bootstrapped standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.

Table 6: Sources of additionalities. Type of international R&D outsourcing

PANEL A: Product innovation		Dependent variable:			
Treatment	**Control**	**Product Innovation (1a)**	**New to the market (1b)**	**New to the firm (1c)**	**Innovative sales (1d)**
National & international *with international private providers*	Only national	0.020	0.054*	0.039	0.001
		(0.025)	(0.028)	(0.035)	(0.033)
National & international *with international public providers*	Only national	0.055	0.111*	0.065	-0.023
		(0.051)	(0.059)	(0.052)	(0.084)
PANEL B: Process innovation		**Dependent variable:**			
Treatment	**Control**	**Process innovation (2a)**	**New production process (2b)**	**New logistic process (2c)**	**New support process (2d)**
National & international *with international private providers*	Only national	0.027	0.036	0.057**	-0.010
		(0.029)	(0.027)	(0.025)	(0.032)
National & international *with international public providers*	Only national	0.083	0.072	0.072*	0.062
		(0.060)	(0.059)	(0.041)	(0.053)

Notes: Explanation of variables in Table 1. Bootstrapped standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.

Table 7: Sources of additionalities. Sectoral complexity

PANEL A: Product innovation		**Dependent variable:**			
		Product Innovation	**New to the market**	**New to the firm**	**Innovative sales**
Treatment	**Control**	**(1a)**	**(2a)**	**(3a)**	**(4a)**
National & international	Only national				
High sectoral complexity: Above 90th percentile		-0.057	0.043	-0.043	0.065
		(0.079)	(0.086)	(0.105)	(0.143)
High sectoral complexity: Above 80th percentile		0.001	0.048	0.022	0.004
		(0.047)	(0.053)	(0.061)	(0.092)
Medium and low sectoral complexity: Below 90th percentile		0.044	0.071**	0.054	0.017
		(0.030)	(0.035)	(0.036)	(0.032)
Medium and low sectoral complexity: Below 80th percentile		0.023	0.048	0.071*	-0.012
		(0.036)	(0.043)	(0.038)	(0.055)
PANEL B: Process innovation		**Dependent variable:**			
		Process innovation	**New production process**	**New logistic process**	**New support process**
Treatment	**Control**	**(1b)**	**(2b)**	**(3b)**	**(4b)**
National & international	Only national				
High sectoral complexity: Above 90th percentile		-0.007	0.021	0.064	0.064
		(0.076)	(0.077)	(0.056)	(0.080)
High sectoral complexity: Above 80th percentile		0.017	0.054	0.051	-0.011
		(0.065)	(0.057)	(0.040)	(0.055)
Medium and low sectoral complexity: Below 90th percentile		0.059*	0.060*	0.077**	0.013
		(0.034)	(0.035)	(0.027)	(0.038)
Medium and low sectoral complexity: Below 80th percentile		0.053	0.071*	0.071**	-0.001
		(0.041)	(0.038)	(0.033)	(0.044)

Notes: Explanation of variables in Table 1. Bootstrapped standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.

APPENDIX

In this appendix, we present robustness checks based on longer pre-treatment trends and controlling for spillovers.

Table A1: Difference of means after matching, controlling for longer pre-treatment trends.

PANEL A: Product innovation			**Dependent variable:**			
			Product Innovation	**New to the market**	**New to the firm**	**Innovative sales**
Case	**Treatment**	**Control**	**(1a)**	**(2a)**	**(3a)**	**(4a)**
1	Only national	Non-outsourcing	0.094***	0.079***	0.062***	-0.216
			(0.012)	(0.011)	(0.013)	(1.912)
3	National & international	Non-outsourcing	0.122***	0.128***	0.084***	0.845
			(0.034)	(0.036)	(0.037)	(4.592)
Additionality or crowding-out effects						
4	National & international	Only national	0.069*	0.105***	0.037	0.185
			(0.038)	(0.027)	(0.038)	(3.963)
5	National & international	Only international	-0.021	-0.152	0.000	-0.039
			(0.133)	(0.148)	(0.160)	(0.322)
PANEL B: Process innovation			**Dependent variable:**			
			Process innovation	**New production process**	**New logistic process**	**New support process**
Case	**Treatment**	**Control**	**(1b)**	**(2b)**	**(3b)**	**(4b)**
1	Only national	Non-outsourcing	0.067***	0.065***	0.024**	0.037***
			(0.012)	(0.013)	(0.007)	(0.012)
3	National & international	Non-outsourcing	0.094***	0.073*	0.084**	0.043
			(0.037)	(0.042)	(0.032)	(0.037)
Additionality or crowding-out effects						
4	National & international	Only national	0.015	0.038	0.061*	0.015
			(0.031)	(0.034)	(0.034)	(0.039)
5	National & international	Only international	-0.108	0.021	0.086	-0.065
			(0.184)	(0.159)	(0.136)	(0.158)

Notes: Explanation of variables in Table 1. Bootstrapped standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively. Case 2 has been dropped as the treated group size (three observations) is not enough for a meaningful application of the matching estimator.

Table A2: Difference of means after matching, controlling for spillovers (matching outside region).

PANEL A: Product innovation			Dependent variable:			
			Product Innovation	New to the market	New to the firm	Innovative sales
Case	Treatment	Control	(1a)	(2a)	(3a)	(4a)
1	Only national	Non-outsourcing	0.092***	0.078***	0.059***	0.260
			(0.009)	(0.007)	(0.008)	(0.835)
2	Only international	Non-outsourcing	0.058	0.116*	0.102	1.223
			(0.045)	(0.051)	(0.049)	(4.307)
3	National & international	Non-outsourcing	0.082**	0.099***	0.075***	0.021
			(0.025)	(0.024)	(0.018)	(0.018)
Additionality or crowding-out effects						
4	National & international	Only national	0.011	0.056**	0.022	-0.001
			(0.023)	(0.021)	(0.024)	(0.023)
5	National & international	Only international	-0.021	-0.021	0.021	-0.040
			(0.069)	(0.097)	(0.072)	(0.078)

PANEL B: Process innovation			Dependent variable:			
			Process innovation	New production process	New logistic process	New support process
Case	Treatment	Control	(1b)	(2b)	(3b)	(4b)
1	Only national	Non-outsourcing	0.066***	0.047***	0.013**	0.058***
			(0.009)	(0.008)	(0.006)	(0.009)
2	Only international	Non-outsourcing	0.092*	0.030	0.003	0.027
			(0.047)	(0.049)	(0.027)	(0.047)
3	National & international	Non-outsourcing	0.061**	0.089***	0.080**	0.037
			(0.020)	(0.019)	(0.018)	(0.025)
Additionality or crowding-out effects						
4	National & international	Only national	0.010	0.052*	0.066**	-0.011
			(0.022)	(0.029)	(0.019)	(0.025)
5	National & international	Only international	-0.101	-0.028	0.036	-0.036
			(0.076)	(0.090)	(0.060)	(0.089)

Notes: Explanation of variables in Table 1. Bootstrapped standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.

ONLINE APPENDIX

Asymmetric additionality of R&D outsourcing locations

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Table OA1: Balancing tests and number of observations after matching corresponding to Table A1

			Balancing tests			Number of observations	
Case	Treatment	Control	Ps R2	LR Chi2	p>Chi2	Treated	Control
1	Only national	Non-outsourcing	0.002	32.27	0.553	4223	4084
3	National & international	Non-outsourcing	0.012	21.86	0.947	612	594
4	National & international	Only national	0.009	15.85	0.997	592	581
5	National & international	Only international	0.234	37.67	0.226	48	48

Notes: 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. Case 2 has been dropped as the treated group size (three observations) is not enough for a meaningful application of the matching estimator.

Table OA2: Balancing tests and number of observations after matching corresponding to Table A2

			Balancing tests			Number of observations	
Case	Treatment	Control	Ps R2	LR Chi2	p>Chi2	Treated	Control
1	Only national	Non-outsourcing	0.001	33.10	0.274	1648	5102
2	Only international	Non-outsourcing	0.014	16.86	0.964	218	376
3	National & international	Non-outsourcing	0.006	32.38	0.304	636	1261
4	National & international	Only national	0.003	15.17	0.984	501	1170
5	National & international	Only international	0.020	88.46	0.000	608	191

Notes: 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.

Table OA3: Balancing tests and number of observations after matching corresponding to Table 6

		Balancing tests			Number of observations	
Treatment	**Control**	**Ps R2**	**LR Chi2**	**p>Chi2**	**Treated**	**Control**
National & international *with international private providers*	Only national	0.009	24.29	0.715	912	878
National & international *with international public providers*	Only national	0.020	16.56	0.969	290	286

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.

Table OA4: Balancing tests and number of observations after matching corresponding to Table 7

	Balancing tests			Number of observations	
Type of sectoral complexity	**Ps R2**	**LR Chi2**	**p>Chi2**	**Treated**	**Control**
High sectoral complexity: Above 90th percentile	0.067	28.19	0.508	282	141
Medium & low sectoral complexity: Below 90th percentile	0.006	14.61	0.988	1495	761
High sectoral complexity: Above 80th percentile	0.011	11.57	0.998	697	350
Medium & low sectoral complexity: Below 90th percentile	0.014	22.59	0.795	1107	563

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.