Organization of R&D outsourcing: Asymmetric cross-effects between locations

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Abstract

When companies acquire R&D from external *national* providers, would they benefit if they also acquired knowledge from *foreign* providers? And the other way around? These questions are important for the organization of firm knowledge-based activies and R&D governance. In this paper, we try to answer these questions by empirically examining the cross-effects of international and national R&D outsourcing to generate innovation. Using a panel database of about 10,000 Spanish firms, we show that there is asymmetry in the effectiveness of the combined adoption of R&D outsourcing locations: international R&D outsourcing reinforces national R&D outsourcing, but national outsourcing does not reinforce international outsourcing. Therefore, the order of adoption matters; i.e., on average, companies are more innovative if they acquire R&D first from external domestic providers and afterwards from foreign providers. We also find that the mechanism for these effects is related to organizational and management changes in sharing responsibilities and decision-making.

Keywords: Organization of international and national R&D outsourcing; Innovation; Cross-effects; Management practices in the organization of work; Sharing responsibilities and decision-making.

JEL classification: L25; O31; O32.

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1. INTRODUCTION

Markets of technology are important for innovation and long-term economic growth (Spulber, 2008; Arora and Gambardella, 2010; Spulber, 2015; Arqué-Castells and Spulber, 2019a). Based on principal-agent theory, the standard view in the literature on the organization of R&D 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). The relationship between in-house R&D and external technologies features prominently in the innovation and organizational literature (Arora and Gambardella, 1990; Cassiman and Veugelers, 2006; Goyal et al., 2008; Moeen et al., 2012; 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 how firms might organize the location of external R&D in order to maximize firm innovation: when a company acquires R&D from external national providers, would it benefit if it also acquired knowledge from foreign providers? And the other way around? Does the sequence of adoption matter? These are key questions for the economics and management of firm knowledge-based activities and R&D governance, which we empirically address in this paper.

Recent trends show that companies are increasingly outsourcing their R&D from both domestic and foreign providers (Quinn, 2000; Spithoven and Teirlinck, 2015; and Wadhwa et al., 2017, among others). When companies decide to outsource their R&D, that is, the acquisition of R&D services, such as product designs, clinical tests or engineering services from external independent suppliers of technology,[1] some companies initially outsource their R&D from domestic technological providers like local technological firms or universities in their region. As companies grow and become more globalized, companies might decide to import R&D from foreign providers.[2] This is a risky and costly strategy for the firm because outsourcing from foreign providers implies important organizational changes in order to

[1] Reasons for R&D outsourcing include the reduction of research costs, the possibility of getting knowledge and technologies promptly, and increasing firm technological comparative advantages. For studies on the economic importance of the markets of technology for innovation, see Galasso et al. (2013), Spulber (2013) and Chatterji and Fabrizio (2016).

[2] The main reasons for international R&D outsourcing is the need to adapt products to foreign tastes and regulations (Bratti and Felice, 2012), to acquire some specific knowledge or to reduce costs (this is, for example, the case for clinical tests). For a summary of the main reasons for international R&D outsourcing, see Martinez-Noya et al. (2012).

instruct and monitor the foreign suppliers (Federico, 2010; Grossman and Rossi-Hansberg, 2012; Castellani and Pieri, 2013), to integrate foreign knowledge and, as Property Right Theory (PRT) suggests, to avoid potential holdup problems (Ulset, 1996; Azoulay, 2004; Wadhwa et al., 2017) and business stealing effects (Arqué-Castells and Spulber, 2019b).

However, adding international outsourcing to an existing research structure with experience with national R&D outsourcing might be beneficial for innovation. One benefit is that international outsourcing might re-inforce the effect on innovation of national R&D outsourcing. The reason is that firms might need better management practices and improvements in their R&D organizational structure in order to coordinate and absorb foreign knowledge. For example, firms might need a careful collection of information related to performance indicators of external R&D that could also be applied to domestic R&D outsourcing; companies might decide to introduce changes in the way that innovation targets are integrated or to standardize different processes (Chaudhuri, 2013); firms might need to implement total quality management techniques (Bourke and Roper, 2017), hire new researchers or middle-managements (Arroyabe et al., 2020) and, as a consequence, reorganize their policies on incentives, promotions or dismissals. These organizational changes that might be needed to integrate foreign knowledge are important for firm productivity, innovation (Bloom et al., 2019) and for domestic outsourcing. Therefore, the introduction of international R&D outsourcing might increase the efficiency of the domestic R&D outsourcing, or in other words, international R&D outsourcing might generate a positive cross-effect or re-inforcement to domestic R&D outsourcing.

The concept of cross-effects or re-inforcement effects of R&D practices has been used in the R&D literature before and it is usually defined as a situation in which the returns of a practice increase with the adoption of another practice (Czarnitzki and Lopes-Bento, 2014; Liu and Rammer, 2016; Marino et al., 2016; Huergo and Moreno, 2017). Note that cross-effects differ from “complementarity”. Complementarity is defined in the R&D literature as a situation where the innovation output is higher when two types of R&D (usually in-house and external R&D) are simultaneously used than when these two types of R&D are used separately (Cassiman and Veugelers, 2006). The main advantage of analyzing cross-effects instead of complementarities for our research question is that it allows us to identify asymmetric effects. Therefore, it is especially suitable for studying the order of adoption of national and international R&D outsourcing and consequently the organization of the location of R&D outsourcing.

As the previous argument suggests, the cross-effects between national and international R&D outsourcing might be asymmetric. Introducing national R&D outsourcing to an existing research structure where the firm already imports foreign technologies might not enhance the capabilities of international R&D outsourcing. The reason is that key efficiency-improved organizational changes have already taken place. In other words, the additional effect of national R&D outsourcing on international R&D outsourcing might be limited.

From an organizational point of view, the evaluation of different locations from which to acquire technologies and their interactions is important for R&D governance. However, not much is known about the potential reinforcement-effects between national and international R&D outsourcing. In this paper, we analyze whether there are cross-effects between R&D outsourcing locations, the asymmetries of these effects and the existence of a key mechanism based on organizational and management changes in sharing responsibilities and decision-making that can influence these effects.

For our analysis, we use a firm panel survey 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. Moreover, the dataset provides exhaustive information on R&D outsourcing, including its amount, together with detailed information on managerial changes. Therefore, to our knowledge, the dataset that we use is the most suitable for answering our research question.

Our empirical analysis is structured as follows. Firstly, we measure the impact of each R&D outsourcing strategy with respect to a control group of non-R&D outsourcers. To do so, we follow a matching procedure with multiple treatments as in Gerfin and Lechner (2002).[3] For each treatment (only domestic outsourcing, only international, and both domestic and international), we find a set of firms that have 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 condition on the non-outsourcing status in the previous period for both treated and control groups. The effect of each independent outsourcing location strategy on firms' innovativeness is an analysis that is in prior literature, but we restate and extend it here for completeness.

Secondly, also using the matching procedure, 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). To take into account the persistence and the sequence of adoption, for both the treated and the control group, we condition on only national outsourcing or only international outsourcing status in the previous period. In this way, first, we measure the effect of adding international outsourcing to firms that outsource nationally with respect to firms that outsource nationally and remain nationally. Second, we measure the effect of adding national outsourcing to firms that outsource internationally with respect to firms that outsource internationally and remain internationally. By comparing these two cases, we study the potential asymmetry in the effectiveness of outsourcing modes, or in other words, whether the sequence of adoption of R&D outsourcing locations matters.

Thirdly, we empirically explore the relationship between organizational changes and innovation cross-effects. We find that the positive reinforcement-effect of international R&D outsourcing on national outsourcing is driven by firms that have introduced new management practices in the organization of work or new organizational methods for sharing responsibilities and decision-making. This is consistent with international R&D outsourcing's providing better managerial practices and generating a more efficient R&D organizational structure, thereby increasing the marginal returns of national outsourcing.

[3] 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).

Finally, we combine the propensity score matching procedure with OLS regression analysis. In particular, among other firm characteristics, we include lagged total innovation investments (which include all of the firm's R&D investments plus the investment in other innovation activities) in the probit models to obtain the matched samples. Then, we use OLS regression analysis to calculate the effect of contemporaneous R&D outsourcing expenditures (measured in terms of natural logarithms) on future innovation, controlling for contemporaneous internal R&D (measured in terms of natural logarithms). This allows us to measure the effect on innovation outcomes after changes in R&D outsourcing expenditures, controlling for selection and time-variant R&D expenditures. We find for the matched sample of firms that the intensity of R&D outsourcing generates a positive cross-effect (or re-inforcing effect) in particular for firms that undertake managerial and organizational changes.

Our results have important implications for firms' organizational decisions about the location of their external R&D. We add to the literature the first evidence of asymmetric cross-effects between national and international R&D outsourcing: international R&D outsourcing reinforces national R&D outsourcing, but national outsourcing does not reinforce international outsourcing. Therefore, the order of adoption matters; i.e., on average, companies are more innovative if they acquire R&D first from external domestic providers and afterwards from foreign providers. We find that the positive cross-effect is concentrated in firms that have introduced new management or organizational changes. These effects are sizeable. For example, our results suggest that firms that outsource nationally and afterwards outsource internationally are 7.5% more likely to have product innovations, 13.5% more likely to have product innovations new to the market, 8.1% more likely to have product innovations new to the firm, and 5.5% more likely to have a new production process than firms that outsource internationally and outsource nationally after that.

Our paper also contributes to the literature on the effectiveness of outsourcing strategies. Using probit models, Bertrand and Mol (2013) study determinants and innovation effects of 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 (2019) analyze the impact of national and international R&D outsourcing on firms' innovativeness and find that both are important in increasing the probability of innovating. We build on insights from these articles. We corroborate and extend the previous evidence and emphasize that international R&D 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, "What is the best way to organize R&D outsourcing locations?" We highlight that the sequence in which the location to outsource is adopted might enrich our understanding of the effectiveness of R&D governance and as a consequence of the markets of technologies.

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. Finally, in Section 5, we discuss implications and conclude.

2. CROSS-EFFECTS BETWEEN NATIONAL AND INTERNATIONAL R&D OUTSOURCING

Our starting point is that outsourcing technology involves some costs. Positive cross-effects 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 raises the costs of another type of outsourcing, then national and international R&D outsourcing undermine each other and there is a negative cross-effect or 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).[4] As

[4] For a study of IPR allocations in the outsourcing of R&D and engineering, see Carson and John (2013).

the *resource-based view* of the firm suggests, R&D might not be completely codifiable. In other words, the knowledge transferred might have a tacit component that depends on human experience.[5] As a consequence, IPRs associated with international outsourcing might be more difficult to define 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).[6] Therefore, adding highly skilled experts and monitoring staff needed to deal with IPR definitions involved in international R&D outsourcing might facilitate solving communication problems that may arise with domestic providers to identify and clarify ownership. However, this effect might not be symmetric because adding the specific expertises needed with domestically outsourced R&D might not overcome more complex communication and legal problems that might arise with international R&D outsourcing.

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 that 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 economize on communication costs. Moreover, in costly communication environments, managers have higher skills and are more knowledgeable. These considerations suggest that modifying the research team that firms need in order to absorb international R&D outsourcing might reduce the costs to absorb domestic external knowledge. For instance, companies from moderatively innovative countries, such as Spain, that import foreign technologies with higher standards than domestic technologies might hire more knowledgable managers, and as a consequence marginal costs of assimilating domestic technologies might decline. In this sense, a recent article by Ceccagnoli et al. (2014) shows that the potential

[5]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.

[6]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 to physical distance.

complementarity between in-house R&D and in-licensing is related to a firm's absorptive capacity and economies of scope. In our context, adding international R&D outsourcing to an existing structure that deals with national R&D might enhance innovation. However, the knowledge hierarchy and management needed to introduce national outsourcing to a structure with hitherto only international outsourcing might not increase the absorption of international knowledge.

In synthesis, these arguments suggest that international R&D outsourcing might generate a positive re-inforcing effect to national outsourcing provided managerial and organizational changes required to absorb, coordinate and adapt foreign knowledge are implemented. Otherwise, international R&D outsourcing might crowd out national outsourcing. The reason is that, without these managerial changes, the operational time and costs of the research units might increase. Moreover, international R&D outsourcing might suffer from holdup problems and appropriation hazards, particularly in countries with weak enforcement of intellectual property rights or rule of law (Grimpe and Kaiser, 2010). If international R&D outsourcing is acquired without the implementation of detailed contracts or monitoring, then its potential positive impact might be limited or even detrimental.

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).[7] In the survey, each company provides information on some of its economic data, such as sales or number of employees, its ownership structure, the location of its parent company and, most importantly for our research question,

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[7] 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, 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.

very detailed information on firms' acquisitions of technology, distinguishing between national and international providers. Our final sample is for an unbalanced panel of 9,733 companies.

The main interests of our analysis are to test the cross-effects between outsourcing locations, to study whether there is asymmetry and whether organizational changes are a key mechanism for the cross-effects. 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.[8] 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.[9] 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.

Table OA1 in the Online Appendix presents the transition probabilities of the different modes of R&D oustsourcing status over the sample period. The status in t-1 is positively correlated with the status in t, especially for non-outsourcing. The data indicate that 92% of non-outsourcing firms in t-1 are also non-outsourcers in t. Additionally, around 65% of firms with only national outsourcing in a given year remain in the same status the following year, 38.8% of firms with only international outsourcing in t-1

[8] Note that by external we mean R&D acquisitions outside the firm and the business group; that is, we do not include R&D services within the business group. Our definition of international R&D outsourcing follows Feenstra (2010), who considers that captive R&D offshoring (that is, technology transfers within multinational enterprises) is not part of international R&D outsourcing, because the control of the production remains within the group. As we want to isolate the discussion of our results from the topic of the governance mode of the firm, we do not include captive R&D in our analysis.

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

continue in the same status in t, and 60.7% of firms with both national and international R&D outsourcing in a given year continue having both national and international outsourcing the following year.

In panel A of Table 1, we present the mean values of the expenditures that correspond to national and international R&D outsourcing (in logarithmics). 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 average expenditures of outsourcing indicates that firms with both national and international outsourcing spend more on outsourcing than firms with only international outsourcing and firms with only national outsourcing.

The dataset also provides information about other key firm characteristics such as innovation output, number of employees, total innovation expenditures, physical investments and sales. Our measures of firms' innovativeness closely follow previous literature (Mairesse and Mohnen 2010). Firstly, we consider 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.[10] 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, the innovation output of a highly innovative company and a moderately innovative company are counted the same.

[10] In our empirical model, innovation output variables refer to period t+3. That is, we study the probability of having innovations up to three years after outsourcing. The reason for the three-year lead is the definition of the variables in the survey. Following the usual definitions in Community Innovation Surveys, in our dataset, innovation output questions refer to the current and previous two years, while innovation inputs and accounting variables correspond to the current period.

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 panels B and C of Table 1, by type of R&D outsourcing (with variable definitions in the note of the table). Panel B reports sample means for technological innovation output variables, and panel C reports sample means for other firms' characteristics that we use in our matching procedure, explained below.

The evidence on panel B 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 analyzed. 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 behavior, 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 suggest a positive re-inforcing effect 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 C, 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: total innovation investment and labor productivity to control for absorptive capacity and skill mix. We also 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. We include a dummy variable that measures whether the market is dominated by established companies to account for the perceived degree of competion in the market. This variable takes the value one if the firm reports a higher degree of established companies than the industry average. We add export status and the degree of internationalization of the sector where the subsidiary operates because trade can induce companies to engage in other globalization strategies (e.g., Tomiura, 2009).

Finally, we consider organizational changes. In the dataset, firms answer two different questions related to organizational changes. First, firms report whether they have introduced new management practices in the organization of work in the current or previous two years. Second, firms report whether in the current or previous two years they have introduced new organizational methods with the objective of improving responsibility sharing and decision-making. We construct a dummy variable that takes the value one if firms report positively on any of these two organizational changes.

The sample means in panel C are consistent with the patterns observed in panel B. R&D outsourcers are larger, invest relatively more in innovation activites 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, the most likely to be exporters and the most likely to have organizational changes. 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 B.

3.2. The empirical methodology

Our main objective is to examine the cross-effects between national and international R&D outsourcing. To face this objective, 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 that have 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 on the treated 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. Given the observed persistence in the oursourcing status in our sample and in order to control for the sequence of outsourcing, when applying our matching procedure,

[11] 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).

we condition on the *non-outsourcing* status in the previous period for both treated and control groups.[13] In this way, for example, case 1 accounts for the differences in innovation outputs for firms that add national outsourcing to non-outsourcing with respect to firms that remain non-outsourcers. Therefore, cases 1 to 3 measure the direct impact of each R&D outsourcing strategy with respect to the control group of firms that remain non-outsourcers.

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). For both the treated and the control group, we condition on the *only national outsourcing* status in the previous period.[14] In this way, we measure the effect of adding international outsourcing to firms that outsource nationally with respect to firms that outsource nationally and continue to outsource only 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 positive cross-effects, 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). For both the treated and the control group, we condition on *only international outsourcing* status in the previous period.[15] In this way, we measure the effect of adding national outsourcing to firms that outsource internationally with respect to firms with only international outsourcing and which remain international. One novelty of our approach is that it allows for asymmetric cross-effects between R&D outsourcing strategies. Therefore, we use cases 4 and 5 to test the existence of positive or negative cross-effects.

4. RESULTS

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[13] Formally, we introduce the lagged dummy for the non-outsourcing status as an explanatory variable in the probit specification in order to obtain our matched samples.

[14] As in the previous case, we introduce the lagged dummy for only national outsourcing status as an explanatory variable in the probit specification in order to obtain our matched samples.

[15] Similar to case 4, we include the lagged dummy for only international outsourcing status as an explanatory variable in the probit specification in order to obtain our matched samples.

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

Before turning to the main focus of the paper, namely, the cross-effects between national and international R&D outsourcing on innovation, we first summarize 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.[16] Formally,

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

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), more productive and more likely to export than non-outsourcers. National outsourcers are also more likely to have undertaken organizational changes than non-outsourcers. The estimated coefficients for the variable *market dominated by established companies* is negative, although it is not significant at standard statistical levels. With respect to the technological variables, national R&D outsourcers invest more in innovation activities and are more innovative than non-outsourcers. The effect of the lagged dummy for the non-outsourcing status in column (1) is negative and statistically significant.

[16] We include the following variables: number of employees, having organizational changes, labor productivity, average physical investment, being an exporter, market dominated by established companies, being part of a business group and innovation investment. 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 dummies for product and process innovation. We also add geographic, industry and year dummies.

That is, conditional on other firms' characteristics, a firm which does not outsource in t-1 is 48 percentage points less likely to outsource only nationally in the next period.

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 for the input variables, with the remarkable exception of those for number of employees, which is not statistically significant, and belonging to a business group, which is positive. 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 that the estimated coefficient for market dominated by established companies now turns statistically significant. These results might reflect the importance of competition for investing in a combination of national and international R&D outsourcing that is profitable. A second difference is that, although the impact of the lagged dummy for the non-outsourcing status is also negative, the magnitude of the effect is smaller. This suggests that, conditional on other firms' characteristics, a firm which does not outsource in t-1 is less reluctant to start outsourcing internationally (with or without domestic outsourcing) than to start outsourcing only nationally.

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 more globalized and more likely to belong to a business group. The differences in the technological variables are interesting because they indicate that firms with both strategies invest, on average, more in innovation activities. 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 globalized and invest more in innovation activities 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 specialize 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.[17] The matching procedure works well. In Table OA2 in the Online Appendix, we report balancing tests and number of observations after matching. The statistics in Table OA2 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 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. Cross-effects

The results from calculating differences of means after matching for our different measures of product and process innovation are presented in Table 4. 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 cross-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 different types of product innovations. The coefficients in column (1a) are higher for national outsourcing than for a combination of the two cases. For example, only national R&D outsourcing increases the probability of product innovation by 10.5%, and national and international outsourcing increase the probability of product innovation by 8.9%. 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 only national R&D outsourcing, only international R&D outsourcing, and a combination of both R&D outsourcing are important for

[17] Matching is carried out with STATA command PSMATCH2 by Leuven and Sianesi (2003).

innovations new to the market, while only national outsourcing and a combination of both R&D outsourcing types have an 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 so much the intensive margin.

Exploring the *cross-effects* in panel A, we find evidence of a positive cross-effect or re-inforcing effect for product innovations and innovations new to the market when the comparison group is firms with national R&D outsourcing only (case 4). Firms with both national and international outsourcing are 6.2% more likely to introduce new products and 9.9% 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 new products. However, national outsourcing does not seem to reinforce international outsourcing.

The results based on panel B for the different types of process innovation resemble those reported in panel A for national outsourcing only. Disaggregating process innovation into different types, we find that outsourcing only nationally increases the probability of having new production processes. We also find statistically significant effects for the direct effect of only international outsourcing on process innovation outputs and production processes. Finally, we find evidence of a positive cross-effect between national and international outsourcing for new production processes. Similar to panel A, international outsourcing reinforces national outsourcing.

One explanation for the lack of reinforcement when firms add national outsourcing to an existing research structure with international R&D outsourcing is that the effects of international R&D outsourcing have not been as successful as expected. In this circumstance, firms might have incentives to reduce or eliminate their international R&D outsourcing and acquire national R&D resources instead. In this case, firms that start only with international outsourcing and subsequently add national outsourcing might not show higher R&D expenditures than firms that continue only with international R&D outsourcing. We explore this possibility by analyzing the difference of means of total R&D expenditures for case 5. The difference of means is positive (equal to 0.401) but not significant at standard statistical levels (the standard error is equal to 0.283), which is consistent with the hypothesis that in some cases international R&D outsourcing is unsuccessful and therefore firms might have incentives to invest nationally instead.

We next turn to studying whether organizational and management changes explain the additionality between international and national R&D outsourcing (case 4). We approach this question by distinguishing between firms that outsource both nationally and internationally and introduce new management and organizational changes and those with national and international outsourcing but do not introduce these changes. First, we compare firm differences in innovation outputs between firms *with organizational changes* that outsource both nationally and internationally with only national R&D outsourcing in the previous period (treatment group) and firms that outsource only nationally in the current and previous period (control group). Second, we compare firm differences in innovation outputs between firms *without organizational changes* that outsource both nationally and internationally with only national R&D outsourcing in the previous period (treatment group) and firms that outsource only nationally in the current and previous period (control group).

We present the results in Table 5 and the balancing tests in Table OA3 in the On-line Appendix. Our results suggest that firms with both national and international outsourcing and with organizational changes are, on average, more innovative than firms with only national outsourcing. The estimated coefficients range from 13.3% for the case of product innovations new to the market to 5.5% for the case of new production processes. We find that all estimated coefficients have a negative sign when the treated group is firms with both national and international R&D outsourcing without organizational changes and the comparison group is firms with national outsourcing. These estimates are significant at standard statistical levels for the case of process innovation, new production processes and new support processes. Our findings suggest that, when adding international R&D outsourcing to national outsourcing, firms increase the marginal returns of national outsourcing but only if they have introduced organizational changes; otherwise, international R&D can even be detrimental.

To summarize, 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 a positive cross-effect 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. Fourth, the mechanism behind the positive effect of international R&D outsourcing on national R&D outsourcing is related to the existence of changes in the organization and management of work.

4.3. Robustness checks

We perform two sensitivity tests of our main specification results that we present in Tables 6 and 7 and in the Appendix. In these robustness checks, first we address the possibility that our results are not only driven by the choice of outsourcing strategies but by the total amount of R&D invested. Second, we perform an additional test in order to control for longer common pre-existing trends.

As a first robustness check, we explore the effect of the volume of R&D outsourcing on innovation outputs. In this analysis, we also control for other contemporaneous R&D expenditures. To do so, we present controlled comparisons between treated and controlled firms where our main independent variable is R&D outsourcing expenditures. We use the previously constructed matched samples to estimate the following regression:

$$Y_{it+1} = \alpha + \gamma X_{it} + \phi Z_{it} + c_j + s_t + \varepsilon_{it}, \tag{2}$$

where Y_{it+1} denotes firm innovation output and X_{it} is the natural logarithm of R&D outsourcing expenditures for each of the previously described cases. For case 1, X_{it} is the natural logarithm of national outsourcing; for case 2, X_{it} is the natural logarithm of international outsourcing; and for cases 3 to 5, X_{it} is the natural logarithm of both national and international outsourcing, Z_{it} is the natural logarithm of internal R&D expenditures, and c_j and s_t are sector and year dummies, respectively. The samples in each of the analyzed cases are the matched samples described in Section 3.2 and in Table 2.

Our empirical approach combines a propensity score matching with an OLS regression. With the propensity score matching, we find the set of firms that have the same observable characteristics in t-1, including total innovation investment, as the corresponding treated group (before being treated) but that did not receive the treatment. The regression estimation measures the changes to innovation outcome between the treated versus the control group associated with the change in the volume of R&D outsourcing expenditures. Note that in equation (2), we control for time-variant total R&D expenditures given that we simultaneously include internal and outsourced R&D expenditures.

In Tables 6 and 7, we show estimated coefficients for parameter γ, which is our parameter of interest. The pattern that we find in Table 6 is similar to the one that we obtain in Table 4: firms that outsource only nationally, only internationally or with a combination of both nationally and internationally are more innovative than non-outsourcers. Similarly, we only find a positive cross-effect in the case of firms with both national and international outsourcing when the comparison group is firms with national R&D outsourcing only (case 4). As in Table 4, we do not find any significant effect at standard statistical levels when the comparison group is firms with international outsourcing (case 5). These findings are robust after controlling for R&D expenditures. Therefore, the results suggest that the sequence of outsourcing strategies affects innovation outputs. In Table 7, we distinguish by the existence of organizational and management changes to explain the positive cross-effect between international and national R&D outsourcing (case 4). As in Table 5, we only find a reinforcing effect in firms with organizational and management changes.

In order to get further details of our results, we replicate case 4 for the matched sample, distinguishing between national and international R&D outsourcing. In Table 8, we report the estimated coefficient of the natural logarithm of international R&D outsourcing expenditures. We control for national R&D outsourcing expenditures and internal R&D expenditures. The results suggest that, for the average firm, adding international outsourcing expenditures to national outsourcing increases the probability of innovating products new to the market and introducing new production processes as compared with firms that outsource nationally, continue to outsource only nationally and increase their national R&D outsourcing expenditures by the same amount. For completeness, in Table OA4 in the

Online Appendix, we replicate case 5, distinguishing between national and international outsourcing. We report the estimated coefficient of the logarithm of national R&D outsourcing, and we control for international R&D outsourcing expenditures and internal R&D expenditures. In this case, we do not find any estimated coefficients significant at standard statistical levels, which again is consistent with the idea that adding national outsourcing to international outsourcing does not increase the probability of innovating.

In Table 9, we disaggregate between national and international outsourcing expenditures and distinguish by organizational changes. We report the estimated coefficients of the logarithm of international R&D outsourcing and we control for contemporaneous national outsourcing expenditures and internal R&D. The estimated coefficients are all positive for the firms that have undertaken organizational and managerial changes. Our findings suggest that, for firms without these organizational changes, international R&D outsourcing undermines innovation.

As a second robustness check, we control for longer pre-existing trends. Our methodology relies on the assumption that the treatment and the control group share statistically similar pre-treatment trends. We modify our matching procedure in order to include two years of pre-treatment data. We present balancing tests for the matching procedure in Tables OA5 in the Online Appendix. The results, presented in Tables OA6 to OA8 in the On-line Appendix for the different disaggregations and organizational changes, indicate that there is a positive cross-effect between both outsourcing strategies for products new to the market and new support process innovations. The evidence presented above shows that international R&D outsourcing reinforces national R&D outsourcing in order to generate innovations. However, national R&D outsourcing does not add to international R&D outsourcing. As in previous estimations**,** the effects are concentrated in firms that have undertaken managerial and organizational changes.

To conclude, the analysis in this section suggests that, after controlling for contemporaneous R&D expenditures and longer pre-treatment trends, there is evidence that international outsourcing reinforces national outsourcing to innovate, but national outsourcing does not seem to reinforce international outsourcing. The positive cross-effect is concentrated in firms that have undertaken organizational and managerial changes. This suggests that our results are not biased by different pre-treatment trends or the volume of R&D expenditures.

5. 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 greater firm innovativeness. However, it also involves some costs and risks (Grimpe and Kaiser, 2010; Driesde, 2018), holdup problems and business stealing among them (Arqué-Castells and Spulber, 2019b). This research empirically examines whether there are asymmetric cross-effects between national and international R&D outsourcing in order to generate technological innovations, and also whether managerial and organizational changes can play a role for the strategic outsourcing decisions. These questions are important for the organization of firm knowledge-based activities and R&D governance.

Our econometric analysis, which uses matching techniques 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 suggest that international R&D outsourcing reinforces national R&D outsourcing, but national outsourcing does not reinforce international outsourcing. We also find strong evidence that a positive cross-effect is relevant when firms undertake organizational and management changes related to sharing responsibilities and decision-making. Otherwise, adding international outsourcing to national outsourcing can be detrimental to technological innovation. Our results are in line with Arora et al. (2014), who suggest 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 in the cross-effect between R&D outsourcing locations. These are channels that we have not analyzed in this paper and we believe they merit future research.

The quantitative results of this paper have clear implications for the organizational science of R&D governance. In order to maximize the generation of technological innovations, firms might start outsourcing their R&D domestically and afterwards internationally. However, firms might be cautious and implement managerial and organizational changes that help to integrate foreign knowledge; otherwise, international R&D outsourcing can undermine national outsourcing.

Nevertheless, our analysis should not be regarded as a blow against the necessity to start outsourcing internationally in some special circumstances. Internationalized firms, such as exporters, might need to adapt their products to the tastes and regulations of foreign markets (Bratti and Felice, 2012). Therefore, exporters might need to acquire foreign knowledge before starting to export or to outsource nationally. This is consistent with Görg et al. (2008) and Amiti and Wei (2009), who find that international services outsourcing increases firms' productivity. In highly competitive sectors, product cycles are short and technologies evolve very quickly. In these environments, companies might need to acquire very specialized foreign technologies in order to remain competitive. Therefore, they might not profit from following a sequence of domestic and then foreign R&D outsourcing.

Moreover, simultaneously outsourcing nationally and internationally can be important for reasons other than obtaining technological 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). Having both national and international providers might also reduce operational uncertainties related to specific national economic conditions. Moreover, Bidwell (2012) shows that make-or-buy decisions depend prominently on managers' interests. Trojer and Ahuja (2015) stress the role of ownership composition for R&D risk-taking decisions and Atkin et al. (2017) provide evidence consistent with the hypothesis that a misalignment of incentives within firms between owners and key employees is a significant barrier to

[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).

technology adoption. Therefore, it is possible that R&D outsourcing locations are also motivated by ownership composition and managers' interests and behaviors such as searching for arbitrage opportunities or promotion, overconfidence or loss aversion.

Although international R&D outsourcing has increased over time, only a small number of 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. Furthermore, we provide evidence that, on average, international R&D outsourcing reinforces national R&D outsourcing to generate innovation. However, it is possible that there is heterogeneity depending on the specific country of origin from which R&D is outsourced. Variability in the enforcement of intellectual property rights or the rule of law are important factors for international relationships. Therefore, they might also be relevant for the effects of international R&D outsourcing on innovation, and for the effects found in this study.

Another possible explanation for the lack of positive effect when firms add national R&D outsourcing to a previous research structure with international R&D outsourcing is that international outsourcing has not been as successful as expected. Under this situation, firms might decide to buy R&D resources nationally after outsourcing internationally. We find some suggestive evidence in this direction since total R&D expenditures seem to decline for firms that change from international R&D outsourcing to national R&D outsourcing as compared with firms that continue with international R&D outsourcing. More work is needed to understand whether and how firms learn from R&D outsourcing failure. Finally, we have investigated the role of managerial and organizational changes to induce cross-effects. An alternative explanation for managerial and organizational changes is that international R&D outsourcing is of higher quality than national outsourcing. Consequently, it might be that the effects that we find are partly driven by differences in quality and potentially high standards associated with international R&D outsourcing.

There may also be interactions between firm location and outsourcing. This is an interesting question because previous literature has highlighed location choice for technology transfers, competition and spillovers (Audretsch and Feldman, 1996; 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 interrelations between outsourcing location decisions. Moreover, the idea that the order of adoption of activities is a relevant factor for the organizational science of R&D could be applied to a wide array of R&D-related practices, such as the order of outsourcing from different R&D providers, the adoptions of different advertising campaigns or the order to apply for different public subsidies or loans. These are questions that we leave for future research.

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TABLES

Table 1: Means of main variables

	R&D outsourcers				Non R&D outsourcers
	Only national (1)	Only international (2)	National & international (3)	All [1+2+3] (4)	(5)
Panel A: Volume outsourcing measures:					
National R&D outsourcing (in logs.)	10.90	0	11.82	10.73	0.00
	(1.57)	0	(2.02)	(2.40)	(0.00)
International R&D outsourcing (in logs.)	0.00	10.96	10.87	1.60	0.00
	(0.00)	(1.92)	(2.09)	(3.94)	(0.00)
Panel B: Technological 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 C: Other firm characteristics:					
Innovation investment (in logs.)	8.68	8.93	9.56	8.79	4.50
	(1.54)	(1.54)	(1.37)	(1.55)	(4.14)
Physical investment (in logs.)	7.05	7.52	7.97	7.17	5.37
	(3.32)	(3.06)	(2.66)	(3.25)	(3.99)
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)
Labor productivity (in logs.)	11.86	11.96	11.99	11.88	11.70
	(1.06)	(1.10)	(1.32)	(1.09)	(1.11)
Market dominated (0/1)	1.28	1.23	2.02	1.37	0.91
	(4.94)	(2.87)	(5.81)	(5.02)	(3.99)
Number of employees (in logs.)	4.22	4.14	4.76	4.28	4.00
	(1.53)	(1.52)	(1.49)	(1.54)	(1.61)
Organizational changes (0/1)	0.61	0.61	0.70	0.40	0.45
	(0.49)	(0.49)	(0.46)	(0.49)	(0.50)
Internal R&D expenditures (in logs.)	11.15	10.58	13.32	11.40	5.34
	(4.27)	(5.06)	(3.03)	(4.22)	(6.04)
No. Observations	*17,130*	*523*	*2,435*	*20,088*	*64,128*

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 that come from new products. *Innovation investment* and *Physical investment* are, respectively, the natural logarithms of a firm's total innovation expenditures or physical investment over its number of employees; *Exporter* and *Group* are dummy variables that take the value one if the firm is an exporter or belongs to a business group, respectively; *Labor productivity* is the natural logarithm of sales over number of employees; *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 deterring innovation relative to the average of its sector; *Employees* is the natural logarithm of the number of employees. *Organizational changes* is a dummy variable that takes the value one if the firm reports having introduced new management practices in the organization of work or new organizational methods with the objective of improving responsibility sharing and decision-making. *Internal R&D expenditures* is the natural logarithms of spending on internal R&D activitities.

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
Cross-effects		
4	National & international	Only national
5	National & international	Only international

Notes: In cases 1 to 3, we condition on the non-outsourcing status in the previous period for both treated and control groups. In case 4, we condition on the only national outsourcing status in the previous period, while in case 5 we condition on the only international outsourcing status in the previous period.

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

	Case 1		Case 2		Case 3		Case 4		Case 5	
Dependent variable:	**Only national outsourcing**		**Only international outsourcing**		**Both national and international outsourcing**		**Both national and international outsourcing**		**Both national and international outsourcing**	
	dy/dx	S.E.	dy/dx	S.E.	dy/dx	S.E.	dy/dx	S.E.	dy/dx	S.E.
Product innovation$_{t-1}$	0.0177***	(0.003)	-0.0001	(0.000)	0.0008***	(0.000)	0.0049	(0.006)	0.0238	(0.020)
Process innovation$_{t-1}$	0.0002	(0.003)	0.0005	(0.001)	-0.0006***	(0.000)	-0.0082	(0.006)	-0.0189	(0.016)
Innovation investment (in logs.) $_{t-1}$	0.0144***	(0.001)	0.0004***	(0.000)	0.0009***	(0.000)	0.0269***	(0.001)	0.0227***	(0.004)
Physical investment (in logs.)$_{t-1}$	0.0015***	(0.000)	0.0001***	(0.000)	0.0001**	(0.000)	0.0006	(0.001)	-0.0027	(0.003)
Exporter$_{t-1}$	0.0133***	(0.004)	0.0013***	(0.000)	0.0018***	(0.000)	0.0426***	(0.005)	0.0593**	(0.027)
Group$_{t-1}$	-0.0112***	(0.003)	0.0009**	(0.000)	0.0006***	(0.000)	0.0117**	(0.005)	-0.0155	(0.016)
Labor productivity (in logs.)$_{t-1}$	0.0066***	(0.002)	0.0004**	(0.000)	0.0001	(0.001)	-0.0016	(0.002)	-0.0131	(0.007)
Market dominated by established companies$_{t-1}$	-0.0017	(0.003)	-0.0001	(0.001)	-0.0005***	(0.000)	-0.0113**	(0.004)	-0.0114	(0.014)
Number of employees (in logs.)$_{t-1}$	0.0142***	(0.001)	0.0000	(0.000)	0.0011***	(0.000)	0.0237***	(0.002)	0.0407***	(0.006)
Organizational changes$_{t-1}$	0.0234***	(0.003)	0.0007*	(0.000)	0.0008***	(0.000)	0.0096**	(0.005)	0.0012	(0.016)
Non-outsourcing $_{t-1}$	-0.4888***	(0.005)	-0.0223***	(0.003)	-0.0609***	(0.005)				
Only national$_{t-1}$							-0.2270***	(0.007)		
Only international$_{t-1}$									-0.6378***	(0.035)
No. Observations	64,151		51,404		52,973		15,126		2,379	
Sample:	*Only national and non-outsourcers*		*Only international and non-outsourcers*		*Both nat. and internat. and non-outsourcers*		*Both nat. and internat. and only national*		*Both nat. and internat. and only international*	

Notes: All regressions include 14 industry dummies, three geographical dummies and year dummies. Explanation of variables in Table 1. The explanation of the treatment and control groups for each case is in Table 2. We report marginal effects at sample means. Estimated standard errors are in parentheses. * Significant at 10%, ** significant at 5%, *** significant at 1%.

Table 4: The effect of R&D outsourcing on innovative outputs

PANEL A: Product innovation			Dependent variable:			
Case	Treatment	Control	Product Innovation (1a)	New to the Market (2a)	New to the firm (3a)	Innovative sales (4a)
1	Only national	Non-outsourcing	0.105***	0.084***	0.073**	-0.001
			(0.016)	(0.017)	(0.018)	(0.004)
2	Only international	Non-outsourcing	0.039	0.125**	-0.090	0.006
			(0.058)	(0.049)	(0.055)	(0.005)
3	National & international	Non-outsourcing	0.089**	0.086*	0.094**	0.001
			(0.042)	(0.047)	(0.039)	(0.006)
Cross-effects						
4	National & international	Only national	0.062*	0.099***	0.059	0.002
			(0.031)	(0.040)	(0.038)	(0.005)
5	National & international	Only international	-0.047	-0.031	0.047	0.008
			(0.101)	(0.139)	(0.126)	(0.013)

PANEL B: Process innovation			Dependent variable:			
Case	Treatment	Control	Process innovation (1b)	New production process (2b)	New logistic process (3b)	New support process (4b)
1	Only national	Non-outsourcing	0.082***	0.083**	0.005	0.046**
			(0.019)	(0.017)	(0.012)	(0.015)
2	Only international	Non-outsourcing	0.105**	0.109**	0.027	0.074
			(0.053)	(0.055)	(0.039)	(0.049)
3	National & international	Non-outsourcing	0.047	0.032	0.041	0.047
			(0.042)	(0.044)	(0.037)	(0.047)
Cross-effects						
4	National & international	Only national	0.023	0.063*	0.040	0.012
			(0.037)	(0.037)	(0.031)	(0.037)
5	National & international	Only international	0.078	0.069	0.109	0.094
			(0.121)	(0.155)	(0.107)	(0.124)

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

Table 5: The effect of R&D outsourcing on innovative outputs and organizational changes

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 organizational changes*	Only national	0.075**	0.133***	0.081**	-0.003
		(0.030)	(0.039)	(0.032)	(0.003)
National & international *without organizational changes*	Only national	-0.041	-0.021	-0.074	-0.0001
		(0.063)	(0.058)	(0.063)	(0.007)

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 organizational changes*	Only national	0.052	0.055*	0.080***	0.064**
		(0.035)	(0.033)	(0.027)	(0.030)
National & international *without organizational changes*	Only national	-0.140**	-0.128*	-0.045	-0.174***
		(0.055)	(0.061)	(0.039)	(0.043)

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

Table 6: The effect of R&D outsourcing on innovative outputs. OLS estimations for the matched samples

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	0.0035***	0.0028**	0.0019	0.0005***
			(0.001)	(0.001)	(0.001)	(0.001)
2	Only international	Non-outsourcing	0.0001	0.0083**	-0.0072*	0.0002
			(0.004)	(0.004)	(0.004)	(0.004)
3	National & international	Non-outsourcing	0.0022	0.0047**	0.0018	0.0003
			(0.002)	(0.002)	(0.002)	(0.002)
Cross-effects						
4	National & international	Only national	0.0119	0.0162*	0.0097	0.0052***
			(0.008)	(0.009)	(0.009)	(0.001)
5	National & international	Only international	-0.0087	0.0084	-0.0218	0.0018
			(0.026)	(0.019)	(0.026)	(0.025)

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	0.0043***	0.0035***	-0.0009	0.0022**
			(0.001)	(0.001)	(0.001)	(0.001)
2	Only international	Non-outsourcing	0.0057	0.0068*	0.0016	0.0034
			(0.004)	(0.004)	(0.004)	(0.003)
3	National & international	Non-outsourcing	-0.0004	-0.0022	0.0033*	0.0024
			(0.002)	(0.002)	(0.002)	(0.002)
Cross-effects						
4	National & international	Only national	0.0014	0.0023	0.0104	0.0130
			(0.008)	(0.009)	(0.007)	(0.009)
5	National & international	Only international	0.0025	0.0146	0.0041	0.0195
			(0.026)	(0.022)	(0.023)	(0.024)

Notes: Explanation of variables in Table 1. We present OLS estimators for the matched samples. The main independent variable is the natural logarithm of R&D outsourcing expenditures. We control for internal R&D expenditures. All regressions include year and industry dummies. Estimated standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.

Table 7: The effect of R&D outsourcing on innovative outputs and organizational changes. OLS estimations for the matched sample

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 organizational changes*	Only national	0.0168**	0.0307***	0.0034	0.0060***
		(0.007)	(0.007)	(0.009)	(0.008)
National & international *without organizational changes*	Only national	-0.0098	-0.0187	0.0174	0.0013
		(0.014)	(0.015)	(0.015)	(0.016)
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 organizational changes*	Only national	0.0169**	0.0183**	0.0347***	0.0214**
		(0.008)	(0.008)	(0.008)	(0.008)
National & international *without organizational changes*	Only national	-0.0322**	-0.0234	-0.0146	0.0107
		(0.015)	(0.016)	(0.016)	(0.009)

Notes: Explanation of variables in Table 1. We present OLS estimators for the matched samples. The reported independent variable is the natural logarithm of R&D outsourcing expenditures. We control for internal R&D expenditures. All regressions include year and industry dummies. Estimated standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.

Table 8: The effect of R&D outsourcing on innovative outputs disaggregating by national and international R&D outsourcing expenditures. OLS estimations for the matched samples

PANEL A: Product innovation		Dependent variable:			
Treatment	Control	Product innovation (1a)	New to the market (2a)	New to the firm (3a)	Innovative sales (4a)
National & international	Only national	0.0029	0.0063**	0.0033	0.0006*
		(0.008)	(0.002)	(0.003)	(0.003)
PANEL B: Process innovation		**Dependent variable:**			
Treatment	**Control**	**Process innovation (1b)**	**New production process (2b)**	**New logistic process (3b)**	**New support process (4b)**
National & international	Only national	0.0014	0.0045*	0.0024	0.0006
		(0.002)	(0.003)	(0.002)	(0.003)
Reported independent variable: Ln(international R&D outsourcing)					

Notes: Explanation of variables in Table 1. We present OLS estimators for the matched samples. In all regressions, we control for contemporaneous national R&D outsourcing and internal R&D expenditures. All regressions include year and industry dummies. Estimated standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.

Table 9: The effect of R&D outsourcing on innovative outputs and organizational changes disaggregating by national and international R&D outsourcing. OLS estimations for the matched sample

PANEL A: Product innovation		**Dependent variable:**			
Treatment	**Control**	**Product innovation (1a)**	**New to the market (2a)**	**New to the firm (3a)**	**Innovative sales (4a)**
National & international *with organizational changes*	Only national	0.0043**	0.0090***	0.0062**	0.0006**
		(0.002)	(0.003)	(0.002)	(0.000)
National & international *without organizational changes*	Only national	-0.0089**	-0.0064	-0.0107**	-0.0012**
		(0.004)	(0.004)	(0.004)	(0.001)
PANEL B: Process innovation		**Dependent variable:**			
Treatment	**Control**	**Process innovation (1b)**	**New production process (2b)**	**New logistic process (3b)**	**New support process (4b)**
National & international *with organizational changes*	Only national	0.0038*	0.0031	0.0060***	0.0048*
		(0.002)	(0.002)	(0.002)	(0.003)
National & international *without organizational changes*	Only national	-0.0127***	-0.0122***	-0.0033	-0.0148***
		(0.004)	(0.004)	(0.002)	(0.003)
Reported independent variable: Ln(international R&D outsourcing)					

Notes: Explanation of variables in Table 1. We present OLS estimators for the matched samples. In all regressions, we control for contemporaneous national R&D outsourcing and internal R&D expenditures. All regressions include year and industry dummies. Estimated standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.

ONLINE APPENDIX

Organization of R&D outsourcing: Asymmetric cross-effects between locations

By María García-Vega and Elena Huergo

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Table OA1: Transition probabilities of R&D outsourcing status

t-1 \ t	Non-outsourcing	Only national	Only international	National & international
Non-outsourcing	92.0%	7.2%	0.3%	0.5%
Only national	31.4%	65.1%	0.3%	3.1%
Only international	37.1%	14.2%	38.8%	9.9%
National & international	13.4%	23.3%	2.6%	60.7%

Table OA2: Balancing tests and number of observations after matching corresponding to Table 4, 6, 8 and AO5

			Balancing tests			Number of observations		
Case	**Treatment**	**Control**	**Ps R2**	**LR Chi2**	**p>Chi2**	**Total**	**Treated**	**Control**
1	Only national	Non-outsourcing	0.003	28.05	0.667	5,973	2,997	2,976
2	Only international	Non-outsourcing	0.026	19.40	0.931	511	258	253
3	National & international	Non-outsourcing	0.030	35.10	0.324	815	407	408
Cross-effects								
4	National & international	Only national	0.010	18.79	0.969	1,286	648	630
5	National & international	Only international	0.132	34.40	0.308	132	66	66

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 5, 7 and 9

		Balancing tests			Number of observations	
Treatment	**Control**	**Ps R2**	**LR Chi2**	**p>Chi2**	**Treated**	**Control**
National & international *with organizational changes*	Only national	0.011	24.86	0.812	641	618
National & international *without organizational changes*	Only national	0.023	16.71	0.988	244	239

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: The effect of R&D outsourcing on innovative outputs dissaggregating by national and international R&D outsourcing expenditures. OLS estimations for the matched samples

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 international	-0.0083	-0.0071	-0.0016	-0.0011
		(0.026)	(0.006)	(0.008)	(0.007)
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 international	-0.0002	-0.0029	0.0112	0.0044
		(0.007)	(0.007)	(0.007)	(0.008)
Reported independent variable: Ln(national R&D outsourcing)					

Notes: Explanation of variables in Table 1. We present OLS estimators for the matched samples. In all regressions, we control for contemporaneous international R&D outsourcing and internal R&D expenditures. All regressions include year and industry dummies. Estimated standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.

Table OA5: Balancing tests and number of observations after matching with longer pre-trends corresponding to Tables OA6 to OA8

		Balancing tests			**Number of observations**	
Treatment	**Control**	**Ps R2**	**LR Chi2**	**p>Chi2**	**Treated**	**Control**
National & international *with organizational changes*	Only national	0.010	14.87	0.990	426	416
National & international *without organizational changes*	Only national	0.032	16.63	0.977	179	171

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 OA6: The effect of R&D outsourcing on innovative outputs and organizational changes, controlling for longer pre-treatment trends.

PANEL A: Product innovation		**Dependent variable:**			
		Product Innovation	**New to the market**	**New to the firm**	**Innovative sales**
Treatment	**Control**	**(1a)**	**(1b)**	**(1c)**	**(1d)**
National & international *with organizational changes*	Only national	0.042	0.101**	0.038	-0.004
		(0.032)	(0.043)	(0.044)	(0.004)
National & international *without organizational changes*	Only national	-0.113	-0.073	-0.079	-0.009
		(0.066)	(0.068)	(0.068)	(0.017)
PANEL B: Process innovation		**Dependent variable:**			
		Process innovation	**New production process**	**New logistic process**	**New support process**
Treatment	**Control**	**(2a)**	**(2b)**	**(2c)**	**(2d)**
National & international *with organizational changes*	Only national	0.024	-0.017	0.052	0.092*
		(0.044)	(0.046)	(0.037)	(0.050)
National & international *without organizational changes*	Only national	-0.113*	-0.119*	-0.102**	-0.175**
		(0.069)	(0.071)	(0.045)	(0.072)

Notes: Explanation of variables in Table 1. We present OLS estimators for the matched samples. The reported independent variable is the natural logarithm of R&D outsourcing expenditures. We control for internal R&D expenditures. All regressions include year and industry dummies. Estimated standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.

Table OA7: The effect of R&D outsourcing on innovative outputs and organizational changes, controlling for longer pre-treatment trends. OLS estimations for the matched sample

PANEL A: Product innovation		**Dependent variable:**			
		Product Innovation	**New to the market**	**New to the firm**	**Innovative sales**
Treatment	**Control**	**(1a)**	**(1b)**	**(1c)**	**(1d)**
National & international *with organizational changes*	Only national	0.0088	0.0201*	-0.0052	0.0045***
		(0.008)	(0.010)	(0.010)	(0.001)
National & international *without organizational changes*	Only national	-0.0117	0.0021	0.0152	0.0016
		(0.018)	(0.019)	(0.019)	(0.003)
PANEL B: Process innovation		**Dependent variable:**			
		Process innovation	**New production process**	**New logistic process**	**New support process**
Treatment	**Control**	**(2a)**	**(2b)**	**(2c)**	**(2d)**
National & international *with organizational changes*	Only national	0.0168*	0.0186*	0.0321***	0.0357***
		(0.009)	(0.010)	(0.009)	(0.011)
National & international *without organizational changes*	Only national	-0.0145	-0.0215	0.0077	0.0239
		(0.019)	(0.019)	(0.012)	(0.016)

Notes: Explanation of variables in Table 1. We present OLS estimators for the matched samples. The reported independent variable is the natural logarithm of R&D outsourcing expenditures. We control for internal R&D expenditures. All regressions include year and industry dummies. Estimated standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.

Table OA8: The effect of R&D outsourcing on innovative outputs and organizational changes, controlling for longer pre-treatment trends, disaggregating by national and international R&D outsourcing. OLS estimations for the matched sample

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 *with organizational changes*	Only national	0.0027	0.0073**	0.0026	0.0004
		(0.002)	(0.003)	(0.003)	(0.000)
National & international *without organizational changes*	Only national	-0.0134***	-0.0103**	-0.0091*	-0.0020***
		(0.005)	(0.005)	(0.005)	(0.001)
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 *with organizational changes*	Only national	0.0015	-0.0023	0.0048*	0.0068**
		(0.003)	(0.003)	(0.003)	(0.003)
National & international *without organizational changes*	Only national	-0.0093*	-0.0097**	-0.0081**	-0.0143***
		(0.005)	(0.005)	(0.003)	(0.004)
Reported independent variable: Ln(international R&D outsourcing)					

Notes: Explanation of variables in Table 1. We present OLS estimators for the matched samples. The reported independent variable is the natural logarithm of R&D international outsourcing expenditures. We control for contemporaneous national R&D outsourcing and internal R&D expenditures. All regressions include year and industry dummies. Estimated standard errors between parentheses. ***, **, * indicate a 1%, 5%, and 10% significance level, respectively.