International and national R&D outsourcing: Complements or substitutes as determinants of innovation?

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Abstract

We study the impact of international R&D outsourcing on the probability of innovating. We find that this influence is positive, particularly for exporters. We show that international and national outsourcing are substitutes as determinants of process innovation in low-tech and medium low-tech sectors.

Keywords: international and national R&D outsourcing; innovation; complementarity; supermodularity

JEL classification: L25; O32.

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1. Introduction

Recently, some authors have raised concerns about the erosion of national competencies and high-skilled jobs due to international R&D outsourcing[1]. However, R&D outsourcing can allow companies to specialize in core knowledge-intensive tasks, thereby freeing up resources for critical research[2]. Moreover, in sectors with rapid technological change, companies may see international outsourcing as complementary to their national outsourcing in order to obtain unique knowledge in little time. A possible consequence, which we investigate in this paper, is that international R&D outsourcing increases national innovativeness. We focus on two issues: (i) the impact of international R&D outsourcing on the likelihood of innovating; and (ii) the complementarity or substitutability between international and national outsourcing to innovate[3]. We differentiate between exporters and non-exporters. This distinction is important because for exporters, international R&D outsourcing can play a crucial role in adapting their products to foreign tastes and standards (e.g. Braga and Willmore, 1991), and monitoring costs can be lower than for non-exporters[4]. Our investigation is based on a panel dataset of Spanish companies, which we describe in Section 2.

In Section 3 we present our main results. We find that the influence of a firm's international R&D outsourcing on its probability of innovating is positive but its impact differs between types of companies. Given the observed patterns between outsourcing and innovation, we find that international and national outsourcing are substitutes but only for process innovation in low-tech and medium low-tech sectors. In the concluding section we discuss this finding.

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[1] See Thursby and Thursby (2006) for references, as well as for a study of types of R&D outsourcing.

[2] For studies that analyze the importance and determinants of technology sourcing, see Cesaroni (2004), Chung and Yeaple (2008), Miozzo and Grimshaw (2005), and Ito et al. (2007). For a study on the positive relationship between outsourcing and technological change, see for example Bartel et al. (2008).

[3] We use a similar approach than Mohnen and Röller (2005).

[4] For example Lewis and Sappington (1991) emphasis the importance of a firm's monitoring capabilities in order to decide to subcontract its production.

2. Data and methodology

Our dataset comes from a survey of innovating Spanish firms (*Panel de Innovación Tecnológica, PITEC*)[5] for the years 2004, 2005 and 2006. We have information for a panel of approximately 11,600 firms every year.

The main interest of our analysis consists of testing the impact of international R&D outsourcing on a firm's likelihood of innovating, and the complementarity between outsourcing locations in low-tech or medium low-tech and high-tech or medium high-tech sectors (to classify sectors, we follow the Eurostat/OECD classification, 2007). We distinguish between exporters and non-exporters. Our dependent variables are two dummy variables: firms' *product*, and *process innovations,* denoted by y_p, and y_c, in the equations below. These variables take the value 1 if a firm reports having introduced new or significantly improved products, or production processes, respectively. In order to account for the potential correlation between disturbances of *product* and *process innovations*, we estimate (by maximum likelihood) a bivariate probit model (e.g., Greene, 1993, Chapter 21) for the following two innovation equations. We drop company and year indexes to simplify the notation.

$$y_p = 1 \quad \text{if} \quad y_p{*} = \gamma_p' x + \beta_p' z + \varepsilon_p > 0, \;\; y_p = 0 \;\; \text{otherwise,} \tag{1}$$

$$y_c = 1 \quad \text{if} \quad y_c{*} = \gamma_c' x + \beta_c' z + \varepsilon_c > 0, \;\; y_c = 0 \;\; \text{otherwise,} \tag{2}$$

$$E\left[\varepsilon_p\right] = E\left[\varepsilon_c\right] = 0, \quad \text{Var}\left[\varepsilon_p\right] = \text{Var}\left[\varepsilon_c\right] = 1, \quad \text{Cov}[\varepsilon_p, \varepsilon_c] = \rho,$$

with $x = (x^e_{0,0},\, x^e_{0,1},\, x^e_{1,0},\, x^e_{1,1},\, x^n_{0,0}, ..., x^n_{1,1})$, $\gamma_i = (\gamma^e_{i,0,0},\, \gamma^e_{i,0,1},\, \gamma^e_{i,1,0},\, \gamma^e_{i,1,1},\, \gamma^n_{i,0,0}, ..., \gamma^n_{i,1,1})$. The superindex e denotes exporters, n denotes non-exporters, and $i = p, c$. The vector x denotes dummy variables of various forms of R&D outsourcing explained below, z is a vector of control variables, γ and β are vectors of coefficients.

[5] The Spanish National Institute of Statistics constructs this database on the basis of the annual Spanish responses to the Community Innovation Survey (CIS).

Our main independent variables are measures of international and national R&D outsourcing. The company reports its *external R&D expenditures*, that is, its purchases of R&D outside the firm in Spain and abroad. With this information, we define eight dummy variables. We distinguish companies with *only national R&D outsourcing*, denoted by $x_{0,1}^{k}$, companies with *only international R&D outsourcing*, denoted by $x_{1,0}^{k}$, companies with both *national and international R&D outsourcing*, denoted by $x_{1,1}^{k}$, and companies with *no outsourcing*, denoted by $x_{0,0}^{k}$; where $k = e$ (exporters), n (non-exporters). In order to avoid simultaneity problems, we include these dummy variables with a one-period lag[6]. As controls (which we call z) we include proxies of internal R&D, and obstacles to innovating that have been shown to be important in hampering innovation (Mohnen and Röller, 2005, and Mohnen et al., 2008)[7].

We consider that two inputs are complements (substitutes) if an increase in one input increases (decreases) the returns to using more of the other (Topkis, 1998). This happens if the production function is supermodular (submodular) with respect to the inputs. Following this approach, national and international outsourcing are complements if the following restriction holds:

$$\gamma_{i,1,1}^{k} - \gamma_{i,0,1}^{k} > \gamma_{i,1,0}^{k} - \gamma_{i,0,0}^{k}, \tag{3}$$

[6] This reduces our sample to a two year panel. Note that we do not control for firm fixed effects because some of the independent variables, including national R&D outsourcing, have little variability during the two year period that we analyze given the available data.

[7] We include three types of obstacles to innovating: *Lack of funds* within the firm or from sources outside the firm or innovation costs were too high; *Lack of information* on technology or on markets; and *Lack of personnel*. For each of the factors, the company answers that its importance was high, intermediate, low, or not relevant. We assign a number that varies from zero to three for each answer. We calculate the average importance of the cost factors at the firm level minus the sector's average importance to reduce the potential bias caused if respondents give similar answers for all factors. The complete list of control variables can be seen in Table 1.

consequently, if $\gamma_{i,1,1}^{k} - \gamma_{i,0,1}^{k} < \gamma_{i,1,0}^{k} - \gamma_{i,0,0}^{k}$, then these two inputs are substitutes[8]. The left-hand side of these inequalities measures the marginal impact of international outsourcing on innovation if the firm outsources nationally, and the right-hand side measures the marginal impact of international outsourcing on innovation if the firm does not outsource nationally. If inequality (3) holds, then international R&D outsourcing reinforces the effect of national outsourcing on innovation.

We define $\Delta_i^k \equiv \gamma_{i,1,1}^{k} - \gamma_{i,0,1}^{k} - \gamma_{i,1,0}^{k} + \gamma_{i,0,0}^{k}$. We estimate Δ_i^k and its 95% confidence interval. We calculate the p-value for the null hypothesis of equality. If we reject the null hypothesis, and Δ_i^k is negative with a confidence interval *entirely* in the *negative* range, then we accept substitutability. These tests require that we estimate (1) and (2) without constant terms.

3. Results

In Table 1, we report the descriptive statistics of the main independent variables, the estimation results, and the tests. Starting with the descriptive statistics of the outsourcing activities, we find that 74.7% of the companies do not outsource R&D. National outsourcing is the most common type of outsourcing. Approximately 3% of the firms outsource internationally, but only 0.6% outsource internationally only.

In the second part of Table 1, we show the influence of international and national R&D outsourcing on the likelihood of introducing new products and new processes (estimated with a bivariate probit model): Columns (i) and (ii) show the results for the whole sample, columns (iii) and (iv) for firms in low-tech and medium low-tech sectors, and columns (v) and (vi) for high-tech and medium high-tech sectors.

[8] See, for example, Cassiman and Veugelers (2006) or Mohnen and Röller (2005). In our case, we test four equations: two for product and process innovations, for exporters and non-exporters, respectively. We also test the four equations for firms in low-tech or medium low-tech and for firms in high-tech and medium high-tech sectors.

The estimated correlation coefficient ρ is always positive and significant, which indicates that product and process innovations are influenced by a common unobservable factor, and that the bivariate model is the appropriate estimation method. Marginal effects are reported in square brackets.

Our results show that the impact of international R&D outsourcing on firms' probabilities of innovating is never negative. We find that international R&D outsourcing increases the probability of innovating by more than 30% (see, for example, the marginal effects in column (ii) for exporters). However, an inspection of the data shows that there is firm heterogeneity:

- We find that irrespective of R&D outsourcing *exporters* are more likely to innovate than the average firm. In addition, exporters that outsource R&D only internationally are approximately 18% to 37% more likely to innovate than the average firm, as shown by the marginal effects in columns (i) and (ii). R&D outsourcing increases process innovations relatively more than product innovations. The results in low and medium low-tech sectors are similar to those for the whole sample. In high-tech and medium high-tech sectors, international R&D outsourcing influences the probability of innovating positively, especially when combined with national outsourcing (columns (v) and (vi)).
- For *non-exporters*, R&D outsourcing increases process innovation relatively more than product innovation (columns (i), and (ii), respectively, with similar results in columns (iii) and (iv)). Companies with only national or only international R&D outsourcing are 22% more likely to introduce new processes than the average firm (column (ii)). As can be seen in columns (v) and (vi), the impact of only international outsourcing on the probability of innovating is negligible in high-tech and medium high-tech sectors, unless it is combined with national outsourcing. Only national

outsourcing increases the probability of introducing new products by 21% and new processes by 14%.

Finally in the bottom part of Table 1, we report the p-values for the null hypotheses of equality, Δ_i^k, and their 95% confidence intervals. For product innovation, we cannot reject the null hypothesis of equality. For the whole sample in low-tech or medium low-tech sectors, we reject the null hypothesis of equality for process innovation (p-values range from 0.036 to 0.003) and Δ_c^k is negative. In this case, international and national R&D outsourcing are substitutes. This result suggests that the marginal impact of international outsourcing on process innovation is lower when the firm is also outsourcing nationally. In high-tech and medium high-tech sectors, we cannot reject equality.

4. Concluding remarks

Our results suggest that in high-tech sectors concerns about an erosion of national competencies due to R&D outsourcing do not seem justified[9]. International R&D outsourcing can be of great importance for companies exposed to foreign markets: it increases innovation, especially when combined with national outsourcing. In low-tech and medium low-tech sectors, international and national outsourcing appear to be substitutes as determinants of process innovation. However, only a small number of companies outsource R&D internationally without outsourcing nationally, which suggests that national outsourcing can be a necessary strategy in order to outsource internationally.

[9] Griffith et al. (2006) get a conclusion similar to ours in their analysis on productivity of affiliates of UK firms in the U.S.

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Table 1: Descriptive statistics, estimation results, and tests.

	Descriptive statistics		Bivariate probit estimation																	
	All firms		All firms						Low-tech & medium low-tech sectors						High-tech & medium high-tech sectors					
	Mean	*Std. E.*	(i) Product innovation			(ii) Process innovation			(iii) Product innovation			(iv) Process innovation			(v) Product innovation			(vi) Process innovation		
R&D outsourcing:			*Coeff*	*dy/dx*	*S. E.*	*Coeff*	*dy/dx*	*S. E.*	*Coeff*	*dy/dx*	*S. E.*	*Coeff*	*dy/dx*	*S.E.*	*Coeff*	*dy/dx*	*S. E.*	*Coeff*	*dy/dx*	*S. E.*
Exporters																				
Only national (d)	8.9%	0.28	0.65	[0.24] ***	0.05	0.92	[0.32] ***	0.05	0.75	[0.29] ***	0.06	1.12	[0.37] ***	0.06	0.95	[0.24] ***	0.08	0.64	[0.22] ***	0.07
Only international (d)	0.3%	0.06	0.49	[0.18] **	0.20	1.22	[0.37] ***	0.21	0.65	[0.25] **	0.26	1.99	[0.46] ***	0.38	0.76	[0.19] **	0.29	0.65	[0.22] **	0.27
National and international (d)	1.3%	0.11	0.68	[0.25] ***	0.11	0.92	[0.31] ***	0.11	0.59	[0.23] ***	0.15	1.12	[0.36] ***	0.16	1.17	[0.25] ***	0.16	0.69	[0.23] ***	0.13
No R&D outsourcing (d)	22.1%	0.41	0.22	[0.09] ***	0.04	0.54	[0.21] ***	0.04	0.30	[0.12] ***	0.05	0.72	[0.27] ***	0.05	0.57	[0.17] ***	0.07	0.29	[0.11] ***	0.06
Non-exporters																				
Only national (d)	13.2%	0.34	0.19	[0.07] ***	0.05	0.58	[0.22] ***	0.05	0.32	[0.13] ***	0.05	0.83	[0.30] ***	0.05	0.76	[0.21] ***	0.07	0.38	[0.14] ***	0.07
Only international (d)	0.3%	0.06	-0.06	[-0.02]	0.17	0.61	[0.22] ***	0.16	0.12	[0.04]	0.19	0.87	[0.30] ***	0.19	0.43	[0.12]	0.27	0.37	[0.13]	0.26
National and international (d)	1.2%	0.11	0.07	[0.03]	0.09	0.49	[0.18] ***	0.08	0.34	[0.13] ***	0.10	0.80	[0.28] ***	0.10	0.50	[0.14] ***	0.13	0.25	[0.09] *	0.12
No R&D outsourcing (d)	52.6%	0.50	-0.15	[-0.06] ***	0.04	0.27	[0.11] ***	0.04	-0.01	[-0.01]	0.04	0.45	[0.18] ***	0.04	0.44	[0.15] ***	0.07	0.20	[0.07] ***	0.06
R&D expenditures/ sales	0.09	0.34	0.55	[0.22] ***	0.05	0.11	[0.04] **	0.05	0.78	[0.30] ***	0.08	0.13	[0.05] *	0.07	0.26	[0.09] ***	0.06	0.03	[0.01]	0.05
(R&D expenditures/ sales)[2]			-0.05	[-0.02] ***	0.01	-0.01	[0.01] **	0.01	-0.09	[-0.03] ***	0.01	-0.02	[-0.07] *	0.01	-0.02	[-0.01] ***	0.08	-0.01	[-0.01]	0.01
Obstacles to innovate:																				
Lack of finance	0.67	0.47	-0.13	[-0.05] ***	0.02	-0.12	[-0.05] ***	0.02	-0.14	[-0.05] ***	0.02	-0.12	[-0.05] ***	0.02	-0.10	[-0.03] ***	0.03	-0.09	[-0.03] **	0.03
Lack of personnel	0.68	0.46	-0.12	[-0.05] ***	0.02	-0.08	[-0.03] ***	0.02	-0.14	[-0.05] ***	0.03	-0.12	[-0.05] ***	0.03	-0.09	[-0.03] **	0.04	0.01	[0.01]	0.03
Lack of information	0.61	0.49	-0.24	[-0.10] ***	0.02	-0.24	[-0.09] ***	0.02	-0.24	[0.09] ***	0.03	-0.03	[-0.12] ***	0.03	-0.23	[-0.07] ***	0.04	-0.08	[-0.03] **	0.03
Not needed	0.78	0.42	-0.07	[-0.03] ***	0.02	-0.10	[-0.04] ***	0.02	-0.05	[-0.02] **	0.03	-0.15	[-0.06] ***	0.03	-0.09	[-0.03] **	0.04	0.01	[0.01]	0.04
Rho			0.44	***	0.01				0.48	***	0.01				0.33	***	0.01			
Observations			20,673						13,606						7,067					

Tests:	*Coeff*	*Conf. Interval*	*Coeff*	*Conf. Interval*	*Coeff*	*Conf. Interval*	*Coeff*	*Conf Interval*	*Coeff*	*Conf. Interval*	*Coeff*	*Conf. Interval*
Exporters												
Null hypothesis of equality	p-value=0.307		p-value=0.003		p-value=0.085		p-value=0.004		p-value=0.906		p-value=0.285	
$\Delta_i^e \equiv \gamma_{i,1,1}^e - \gamma_{i,0,1}^e - \gamma_{i,1,0}^e + \gamma_{i,0,0}^e$	-0.22	[-0.66,0.21]	-0.67	[-1.13,-0.22]	-0.51	[-1.11, 0.07]	-1.17	[-1.98, -0.37]	0.04	[-0.60, 0.68]	-0.32	[-0.91, 0.27]
Non-exporters												
Null hypothesis of equality	p-value=0.243		p-value=0.013		p-value=0.605		p-value=0.036		p-value=0.411		p-value=0.289	
$\Delta_i^n \equiv \gamma_{i,1,1}^n - \gamma_{i,0,1}^n - \gamma_{i,1,0}^n + \gamma_{i,0,0}^n$	-0.20	[-0.53,0.14]	-0.42	[-0.76,-0.08]	-0.11	[-0.52, 0.30]	-0.45	[-0.87, -0.03]	-0.24	[-0.82, 0.34]	-0.30	[-0.86, 0.25]

Note: Estimations without constant. All regressions include size, regional, and time dummies. Industry dummies are included in columns (i) and (ii). Marginal effects (*dy/dx*) from the bivariate probit model (at sample means) are reported in square brackets. S. E.: Estimated standard error. * Significant at 10%, ** significant at 5%, *** significant at 1%. The symbol (d) denotes dummy variable. The classification of sectors follows the Eurostat/OECD (2007) classification. *Interval* is the 95% confidence interval for Δ_i^k. National and international outsourcing are complements if $\gamma_{i,1,1}^n - \gamma_{i,0,1}^n > \gamma_{i,1,0}^n - \gamma_{i,0,0}^n$. If $\gamma_{i,1,1}^n - \gamma_{i,0,1}^n < \gamma_{i,1,0}^n - \gamma_{i,0,0}^n$, then they are substitutes.