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

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Preliminary and incomplete

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 innovation mostly in low-tech and medium low-tech sectors.

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

JEL classification: L25; O31; O32.

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1. Introduction

Recently, some authors have raised concerns about the erosion of national competencies and losses of high-skilled jobs due to international outsourcing, of which R&D is an important case.[1] For example, in the pharmaceutical industry, a large part of the clinical tests are subcontracted, manufacturers of semiconductors acquire designs from foreign suppliers, software is imported … (The Economist Intelligent Unit, 2007). 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, through two mechanisms: a direct effect for the firm that acquires R&D, and an indirect effect through the interrelation with domestic providers of R&D services. 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). Our investigation is based on a panel dataset of Spanish companies, which we describe in Section 2.

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[1] See Blinder (2006), Head et al. (2009), and 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). Grossman et al. (2005) analyze circumstances that influence firms' decision to outsource locally or abroad.

[3] We use a discrete test of supermodularity (Cassiman and Veugelers, 2006; Mohnen and Röller, 2005).

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. For exporters, international R&D outsourcing seems the most innovative strategy, while national outsourcing seems the most relevant for non-exporters. Given the observed patterns between outsourcing and innovation, we find that international and national outsourcing are substitutes mostly in low-tech and medium low-tech sectors. In the concluding section we discuss this finding.

2. Data and methodology

Our dataset comes from a yearly survey of innovating Spanish firms (*Panel de Innovación Tecnológica, PITEC*) from 2004 to 2008. The Spanish National Institute of Statistics constructs this database on the basis of the annual Spanish responses to the Community Innovation Survey (CIS).[4] From this panel, we exclude companies that do not report any R&D expenditure (neither internal nor external), so that our data refer to all companies that are trying to innovate during this period. Therefore, our analysis focuses on whether outsourcing increases the probability of innovation success of R&D projects.[5] We have information for a panel of approximately 9,500 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

[4] The survey is targeted to manufacturing and services companies whose main economic activity corresponds to sections C,D, and E of NACE 93, except nonindustrial companies because of the imprecision of methodological marking in the international context by other branches of activity.All data are freely downloadable in the PITEC website.
[5] R&D services are defined in the survey as: "Creative work to increase the volume of knowledge and to create new or improved products and processes (including the development of software)".

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.

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

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

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

with $x = (x^e_{0,0},\, x^e_{0,1},\, x^e_{1,0},\, x^e_{1,1},\, x^n_{0,0},\ldots,x^n_{1,1})$, $\gamma_i = (\gamma^e_{i,0,0},\, \gamma^e_{i,0,1},\, \gamma^e_{i,1,0},\, \gamma^e_{i,1,1},\, \gamma^n_{i,0,0},\ldots,\gamma^n_{i,1,1})$. 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.

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 $x^k_{0,1}$, companies with *only international R&D outsourcing*, denoted by $x^k_{1,0}$, companies with both *national and international R&D outsourcing*, denoted by $x^k_{1,1}$, and companies with *no outsourcing*, denoted by $x^k_{0,0}$; where $k = e$ (exporters), n (non-exporters).

As controls (which we call *z*) we include firm-level variables, and obstacles to innovating that have been shown to be important for innovation (Mohnen and Röller, 2005, and Mohnen et al., 2008). We include four 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; *Lack of personnel*; and innovation *not needed*. 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. We include in the regressions the logarithm of total R&D per sales ratio and its squared.[6] This allow us to analyse the effect of outsourcing through international and national R&D dummies controlling by the total amount invested in innovation. We add firm size dummies (measured through employment). Under the existence of economies of scale, we expect that firm size affects innovation positively. We also include industry and geographical fixed-effects. The reason for including geographical dummies is that firms can learn from the innovative activities implemented by geographically close companies, given the importance of agglomeration effects to induce spillovers. In order to avoid simultaneity problems, we include all independent with a one-period lag.

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:

[6] The variable total R&D includes internal and acquired R&D services.

$$\gamma^k_{i,1,1} - \gamma^k_{i,0,1} > \gamma^k_{i,1,0} - \gamma^k_{i,0,0}, \quad (3)$$

consequently, if $\gamma^k_{i,1,1} - \gamma^k_{i,0,1} < \gamma^k_{i,1,0} - \gamma^k_{i,0,0}$, then these two inputs are substitutes (see, for example, Cassiman and Veugelers, 2006, or Mohnen and Röller, 2005). 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 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.

We define $\Delta^k_i \equiv \gamma^k_{i,1,1} - \gamma^k_{i,0,1} - \gamma^k_{i,1,0} + \gamma^k_{i,0,0}$. We estimate Δ^k_i and its 90% confidence interval. We calculate the p-value for the null hypothesis of equality. If we reject the null hypothesis, and Δ^k_i 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.

As a robustness tests, first, we estimate a random effects probit model in order to control by unobserved firm-specific effects. This model requires that latent heterogeneity and included observed characteristics have zero correlation and also that disturbances between product and process innovation are uncorrelated (Greene, 1993). Given these restrictive assumptions, we do not consider the random effects model necessarily better than the bivariate probit. Moreover, the results are not significantly different from those from the bivariate probit.[7] We do not use a fixed-effect model because the outsourcing variables do not vary much over this period of time and the

[7] The results are reported in an Appendix.

panel is very short, which can lead to imprecise estimates (Wooldridge, 2001). Furthermore, in order to construct the complementarity tests, we need to estimate the model without constants which is not possible with a fixed-effects model.

As a second robustness test we use an instrumental variable (IV) approach. In the IV estimation, we use the one-period lag of the outsourcing variables and a dummy variable that takes the value one if the company belongs to a foreign business group as instruments for the outsourcing decisions.

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 69.6% of the companies do not outsource R&D. National outsourcing is the most common type of outsourcing. Approximately 3.8% of the firms outsource internationally, but just 0.8% outsource internationally only.

In Table 2, 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. 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 can increase 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 23% to 31% 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 for process innovation (column (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 24% 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 11% and new processes by 17%.

In the bottom part of Table 2, we report the p-values for the null hypotheses of equality, Δ_i^k, and their 90% confidence intervals. For the whole sample, we reject the null hypothesis of equality for both types of innovation and for exporters and non-exporters (p-values range from 0.038 to 0.000) and Δ_i^k is negative. These results suggest that international and national R&D outsourcing are substitutes. These findings are mostly due to low-tech and medium low-tech sectors, where we always reject the null hypothesis of equality (p-values range from 0.074 to 0.000) and Δ_i^k is always negative. This implies that in low-tech and medium low-tech sectors the marginal impact of international outsourcing on innovation is lower when the firm is also outsourcing nationally. In high-tech and medium high-tech sectors, we can only reject equality for exporters and process innovation.

In Table A in the Appendix, we report the random effects specification. As in the previous estimations, we find that international outsourcing is more relevant for exporters than for non-exporters. We find again national and international outsourcing seem to be substitutes, especially in low-tech or medium low-tech sectors.

Finally in Table B in the Appendix, we show the complementarity test for the IV specification. The results are again consistent with previous estimations.

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.[8] International R&D outsourcing can be of great importance for companies exposed to foreign markets: it increases innovation, and also when combined with national outsourcing. A possible interpretation for these findings is that international outsourcing reduces market uncertainties for internationalized firms, but also that exporters face lower costs from international outsourcing than non-exporters.[9] In low-tech and medium low-tech sectors, international and national outsourcing appear to be substitutes as determinants of innovation. However, only a small number of companies outsource R&D

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

[9] This would be in line with Grossman and Rossi-Hansberg (2008) who point out that the costs from service offshoring derive from instructing and monitoring.

internationally without outsourcing nationally, which suggests that national outsourcing can be a necessary strategy in order to outsource internationally.

Acknowledgements

This research has been partially funded by projects SEJ2007-65520/ECON and ECO2010-18947/ECON of the Spanish Ministry of Science and Innovation. We are especially grateful to Pierre Mohnen for his very detailed comments. We also thank Saul Lach, Lourdes Moreno, Diego Rodríguez, and participants at seminars in Bocconi University for their helpful comments.

References

Bartel, A., Lach, S., and N. Sicherman (2008), "Outsourcing and technological innovations: A firm-level analysis" CEPR Discussion paper no. 6731.

Blinder, A. (2006), "Offshoring: The Next Industrial Revolution?" *Foreign Affairs* March/April 2006, pp. 113-128.

Braga, H., and L. Willmore (1991), "Technological imports and technological effort: An analysis of their determinants in Brazilian firms", *The Journal of Industrial Economics* 34(4), pp. 421–432.

Cassiman, B., and R. Veugelers (2006), "In Search of Complementarity in Innovation Strategy: Internal R&D and External Technology Acquisition", *Management Science* 52(1), pp. 68–82.

Cesaroni, F. (2004), "Technological outsourcing and product diversification: do markets for technology affect firms' strategies?", *Research Policy* 33(10), pp. 1547–1564.

Chung, W., and S. Yeaple (2008), "International Knowledge Sourcing: Evidence from US Firms Expanding Abroad", *Strategic Management Journal* 29(11), pp. 1207-1224.

Eurostat (2007), *High-tech industry and knowledge-intensive services*, available at http://europa.eu.int/estatref/info/sdds/en/htec/htec_agg_nace.pdf

Greene, W. (1993), *Econometric Analysis*, Prentice Hall, New Jersey.

Grossman, G. and E. Rossi-Hansberg (2008), "Trading tasks: A simple theory of offshoring", *American Economic Review* 98(5), pp. 1978-97.

Griffith, R., Harrison, R., and J. Van Reenen (2006), "How special is the special relationship? Using the impact of U.S. R&D spillovers on U.K. firms as a test of technology sourcing", *American Economic Review* 96(5), pp. 1859-1875.

Head, K., Mayer, T., and J. Ries (2009), "How remote is the offshoring threat?", *European Economic Review* 53(4), pp. 429-444.

Ito, B., Tomiura, E., and R. Wakasugi (2007), "Dissecting Offshore Outsourcing and R&D: A Survey of Japanese Manufacturing Firms", RIETI Discussion Paper Series 07-E -060.

Miozzo, M., and D. Grimshaw (2005), "Modularity and Innovation in Knowledge-Intensive Business Services: IT outsourcing in Germany and the UK", *Research Policy* 34(9), pp. 1419-1439.

Mohnen, P., and L. Röller (2005), "Complementarities in Innovation Policy", *European Economic Review* 49(6), pp. 1431 – 1450.

Mohnen, P., Palm, F., Schim van der Loeff, S., and A. Tiwari (2008), "Financial Constraints and Other Obstacles: are they a Threat to Innovation Activity?", *De Economist* 156(2), pp. 201-214.

Panel de Innovación Tecnológica (PITEC). Source: FECYT Spanish Ministry of Science and Innovation. Available at http://icono.fecyt.es/contenido.asp?dir=05)Publi/AA)panel

The Economist Intelligent Unit (2007), “Sharing the Idea. The emergence of global innovation networks”, *The Economist*.

Thursby J. and M. Thursby (2006), “Where Is the New Science in Corporate R&D?”, *Science* 314, pp. 1547-1548.

Topkis D. (1998), *Supermodularity and Complementarity*, Princeton University Press.

Wooldridge J. (2001), *Econometric Analysis of Cross Section and Panel Data*, MIT Press.

Table 1: Descriptive statistics

	All firms		Low-tech & medium low-tech sectors		High-tech & medium high-tech sectors	
	Mean	*Std. E.*	*Mean*	*Std. E.*	*Mean*	*Std. E.*
R&D outsourcing:						
Exporters						
Only national (d)	11.8%	0.32	10.1%	0.30	14.7%	0.35
Only international (d)	0.4%	0.06	0.4%	0.06	0.5%	0.07
National and international (d)	2.0%	0.14	1.2%	0.11	3.3%	0.18
No R&D outsourcing (d)	25.3%	0.43	23.3%	0.42	28.5%	0.45
Non-exporters						
Only national (d)	14.6%	0.35	15.2%	0.36	13.6%	0.34
Only international (d)	0.4%	0.06	0.4%	0.06	0.4%	0.06
National and international (d)	1.1%	0.10	0.9%	0.09	1.4%	0.12
No R&D outsourcing (d)	44.4%	0.50	48.6%	0.50	37.7%	0.48
Log(R&D expenditures/ sales)	0.11	0.35	0.07	0.28	0.17	0.44
Obstacles to innovate:						
Lack of finance	0.65	0.48	0.65	0.48	0.65	0.48
Lack of personnel	0.66	0.48	0.66	0.47	0.64	0.48
Lack of information	0.57	0.49	0.58	0.49	0.56	0.50
Not needed	0.76	0.43	0.75	0.43	0.77	0.42
Observations	35,925		22,180		13,745	

Note: The symbol (d) denotes dummy variable.

Table 2: Estimation results, and tests.

	Bivariate probit estimation																							
	All firms								Low-tech & medium low-tech sectors								High-tech & medium high-tech sectors							
	(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)	0.70	[0.23]	***	0.03	0.94	[0.29]	***	0.03	0.77	[0.27]	***	0.04	1.06	[0.30]	***	0.04	0.74	[0.19]	***	0.08	0.67	[0.23]	***	0.07
Only international (d)	0.73	[0.23]	***	0.12	1.28	[0.31]	***	0.13	0.88	[0.29]	***	0.16	1.33	[0.31]	***	0.18	0.68	[0.16]	***	0.19	0.97	[0.29]	**	0.20
National and international (d)	0.86	[0.26]	***	0.06	1.05	[0.29]	***	0.06	0.99	[0.32]	***	0.10	1.26	[0.31]	***	0.20	0.87	[0.20]	***	0.10	0.73	[0.24]	***	0.09
No R&D outsourcing (d)	0.29	[0.11]	***	0.03	0.64	[0.22]	***	0.03	0.33	[0.13]	***	0.04	0.72	[0.24]	***	0.04	0.39	[0.12]	***	0.07	0.40	[0.15]	***	0.07
Non-exporters																								
Only national (d)	0.32	[0.12]	***	0.03	0.75	[0.24]	***	0.03	0.37	[0.14]	***	0.04	0.84	[0.26]	***	0.04	0.40	[0.11]	***	0.08	0.47	[0.17]	***	0.07
Only international (d)	0.28	[0.10]	**	0.12	0.79	[0.24]	***	0.12	0.42	[0.16]	**	0.15	1.05	[0.27]	***	0.16	0.21	[0.06]		0.21	0.25	[0.09]		0.20
National and international (d)	0.22	[0.08]	***	0.07	0.55	[0.18]	***	0.07	0.21	[0.08]		0.10	0.65	[0.20]	***	0.10	0.35	[0.10]	***	0.12	0.28	[0.10]	**	0.12
No R&D outsourcing (d)	-0.03	[-0.01]		0.03	0.38	[0.14]	***	0.03	0.02	[0.01]	***	0.04	0.45	[0.16]	***	0.04	0.04	[0.01]		0.07	0.16	[0.06]	**	0.07
Log(R&D expenditures/ sales)	0.37	[0.14]	***	0.05	0.01	[0.01]		0.03	0.56	[0.22]	***	0.05	-0.02	[-0.01]		0.05	0.22	[0.07]	***	0.05	0.04	[0.02]		0.05
Log(R&D expenditures/ sales)^2	-0.03	[-0.01]	***	0.01	-0.01	[-0.01]		0.01	-0.04	[-0.02]	***	0.01	0.01	[-0.01]	*	0.01	-0.03	[-0.01]	***	0.01	-0.01	[-0.01]		0.01
Obstacles to innovate:																								
Lack of finance	-0.06	[-0.02]	***	0.02	-0.07	[-0.02]	***	0.01	-0.06	[-0.02]		0.02	-0.06	[-0.02]	***	0.02	-0.06	[-0.02]	**	0.03	-0.06	[-0.03]	***	0.02
Lack of personnel	-0.08	[-0.03]	***	0.02	-0.01	[-0.01]		0.02	-0.13	[-0.05]	***	0.02	-0.05	[-0.02]	***	0.02	0.01	[0.01]		0.03	0.05	[0.02]	**	0.03
Lack of information	-0.13	[-0.05]	***	0.02	-0.08	[-0.03]	***	0.02	-0.13	[-0.05]	***	0.02	-0.11	[-0.04]	***	0.09	-0.13	[-0.04]	***	0.03	-0.03	[-0.01]		0.02
Not needed	-0.01	[-0.03]		0.02	-0.05	[-0.02]	***	0.02	-0.01	[-0.01]		0.02	-0.09	[-0.03]	***	0.02	-0.01	[-0.01]		0.03	0.02	[0.01]		0.02
Rho	0.28		***	0.01					0.28		***	0.01					0.27		***	0.01				
Observations	35,925								22,180								13,745							

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=0.038		p-value=0.001		p-value=0.074		p-value=0.050		p-value=0.417		p-value=0.010	
$\Delta_i^e \equiv \gamma_{i,1,1}^e - \gamma_{i,0,1}^e - \gamma_{i,1,0}^e + \gamma_{i,0,0}^e$	-0.27	[-0.50,-0.05]	-0.48	[-0.70,-0.25]	-0.33	[-0.63, -0.03]	-0.40	[-0.73, -0.06]	-0.16	[-0.50, 0.16]	-0.50	[-0.81, -0.18]
Non-exporters												
Null hypothesis of equality	p-value=0.002		p-value=0.000		p-value=0.002		p-value=0.000		p-value=0.330		p-value=0.179	
$\Delta_i^n \equiv \gamma_{i,1,1}^n - \gamma_{i,0,1}^n - \gamma_{i,1,0}^n + \gamma_{i,0,0}^n$	-0.41	[-0.64,-0.19]	-0.60	[-0.82,-0.36]	-0.55	[-0.84, -0.26]	-0.80	[-1.10, -0.48]	-0.22	[-0.58, 0.15]	-0.28	[-0.63, 0.06]

Note: Estimations without constant. All regressions include size, regional, industry and time dummies. 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 90% 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.

Appendix

Table A: Robustness check. Results, and tests estimated with a random effects probit model.

	Random effects probit estimation																	
	All firms						Low-tech & medium low-tech sectors						High-tech & medium high-tech sectors					
	(i) Product innovation			(ii) Process innovation			(iii) Product innovation			(iv) Process innovation			(v) Product innovation			(vi) Process innovation		
R&D outsourcing:	*Coeff*		*S. E.*	*Coeff*		*S. E.*	*Coeff*		*S. E.*	*Coeff*		*S.E.*	*Coeff*		*S. E.*	*Coeff*		*S. E.*
Exporters																		
Only national (d)	1.18	***	0.08	1.60	***	0.08	1.23	***	0.11	1.79	***	0.09	1.47	***	0.02	1.15	***	0.19
Only international (d)	1.14	***	0.24	1.68	***	0.22	1.20	***	0.31	1.66	***	0.28	1.46	***	0.40	1.62	***	0.40
National and international (d)	1.22	***	0.14	1.70	***	0.12	1.21	***	0.20	1.98	***	0.18	1.58	***	0.25	1.24	***	0.22
No R&D outsourcing (d)	0.67	***	0.08	1.17	***	0.07	0.62	***	0.10	1.27	***	0.08	1.14	***	0.20	0.83	***	0.18
Non-exporters																		
Only national (d)	0.28	***	0.08	1.10	***	0.07	0.34	***	0.10	1.27	***	0.08	0.60	***	0.20	0.63	***	0.18
Only international (d)	0.15		0.22	1.10	***	0.22	0.18		0.27	1.40	***	0.27	0.57		0.40	0.55		0.41
National and international (d)	0.21		0.15	0.97	***	0.14	0.16		0.20	1.15	***	0.19	0.68	**	0.28	0.54	**	0.26
No R&D outsourcing (d)	-0.21	***	0.07	0.60	***	0.06	-0.18	**	0.09	0.71	***	0.08	0.17		0.19	0.26		0.17
Log(R&D expenditures/ sales)	0.56	***	0.7	0.05		0.06	0.77	***	0.11	-0.08		0.09	0.42	***	0.11	0.18	*	0.10
Log(R&D expenditures/ sales)^2	-0.05	***	0.01	-0.01		0.01	-0.06	***	0.01	0.01		0.01	-0.05	***	0.01	-0.02	*	0.01
Obstacles to innovate:																		
Lack of finance	-0.04		0.03	-0.12	***	0.03	-0.02		0.04	-0.10	***	0.03	-0.08	**	0.05	-0.15	***	0.05
Lack of personnel	-0.08	**	0.03	0.01		0.03	-0.15	***	0.04	-0.03		0.04	0.04		0.05	0.08	*	0.05
Lack of information	-0.10	***	0.03	-0.10	***	0.03	-0.09	**	0.04	-0.13	***	0.03	-0.09	***	0.05	-0.01		0.05
Not needed	-0.01		0.03	-0.04		0.06	-0.01		0.04	-0.10	***	0.04	-0.03		0.05	0.08	*	0.05
Observations	35,925						22,180						13,745					
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=0.091			p-value=0.084			p-value=0.080			p-value=0.530			p-value=0.584			p-value=0.066		
$\Delta_i^e \equiv \gamma_{i,1,1}^e - \gamma_{i,0,1}^e - \gamma_{i,1,0}^e + \gamma_{i,0,0}^e$	-0.43		[-0.85,-0.01]	-0.40		[-0.79,-0.02]	-0.60		[-1.16, -0.03]	-0.19		[-0.72, 0.33]	-0.21		[-0.85, 0.42]	-0.70		[-1.32, -0.07]
Non-exporters																		
Null hypothesis of equality	p-value=0.084			p-value=0.009			p-value=0.084			p-value=0.008			p-value=0.426			p-value=0.364		
$\Delta_i^n \equiv \gamma_{i,1,1}^n - \gamma_{i,0,1}^n - \gamma_{i,1,0}^n + \gamma_{i,0,0}^n$	-0.41		[-0.81,-0.02]	-0.63		[-1.03,-0.23]	-0.54		[-1.06, -0.03]	-0.80		[-1.31, -0.30]	-0.32		[-0.98, 0.34]	-0.37		[-1.06, 0.31]

Note: Estimations without constant. All regressions include size, regional, industry and time dummies. 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 90% 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.

Table B: Robustness check. Tests estimated with an instrumental variable estimation.

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=0.049		p-value=0.005		p-value=0.055		p-value=0.036		p-value=0.806		p-value=0.095	
$\Delta_i^e \equiv \gamma_{i,1,1}^e - \gamma_{i,0,1}^e - \gamma_{i,1,0}^e + \gamma_{i,0,0}^e$	-0.38	[-0.77,-0.01]	-0.56	[-0.95,-0.17]	-0.59	[-1.20, -0.03]	-0.63	[-1.22, 0.33]	-0.06	[-0.54, 0.42]	-0.45	[-0.99, -0.07]
Non-exporters												
Null hypothesis of equality	p-value=0.003		p-value=0.029		p-value=0.003		p-value=0.059		p-value=0.740		p-value=0.286	
$\Delta_i^n \equiv \gamma_{i,1,1}^n - \gamma_{i,0,1}^n - \gamma_{i,1,0}^n + \gamma_{i,0,0}^n$	-0.72	[-1.20,-0.25]	-0.54	[-1.02,-0.05]	-1.07	[-1.79, -0.36]	-0.67	[-1.37, -0.30]	-0.10	[-0.70, 0.49]	-0.36	[-1.02, 0.31]
Sargan test (p-value)	0.696		0.328		0.169		0.515		0.002		0.99	