Discussion Paper

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The impact of public funding for innovation on firms' R&D investments: Do R&D cooperation and appropriability matter?

Abstract

This paper provides a theoretical and empirical framework to explore how public funding affects firms' R&D investments depending on their engagement in horizontal R&D cooperations and different levels of appropriability conditions within the economy.

It assumes firms' Cournot-Nash behavior in the choice of the optimal R&D investment level and provides empirical evidence in support of the theoretical findings using data on Spain and Germany from the Third Community Innovation Survey. Theoretical and empirical results suggest that firms' cooperative behaviour and the appropriability conditions affect the relationship between public funding for innovation and R&D investments.

Classificazione JEL: O32; H20; L10; D43; D78.

Keywords: R&D cooperatives; subsidies;knowledge spillovers; innovation

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I. Introduction

This paper provides a theoretical and empirical framework to explore how public funding affects firms' R&D investments depending on their engagement in horizontal R&D cooperations and different levels of appropriability conditions within the economy.
The empirical relationship between R&D subsidies and R&D expenditures has been recently analyzed by Gonzáles and Pazó, (2008) and Czarnitzski and Fier, (2002) which focus on crowding-out effects, i.e. the analysis of the complementarity or substitutability between public funding and private R&D expenditures. On this point, David *et al.* (2000) review the empirical studies and find that substitutability is a frequent event.
On the contrary, theoretical literature generally find a positive impact of R&D subsidies on R&D investments for a total-cost-reduction effect (see among others Hinloopen, 1997). While most theoretical models deal with horizontal cooperation, the empirical literature does not analyze this topic in great detail (Czarnitzki *et. al.*, 2007, pp. 1352). One of the objective of this paper is to fill this gap, at least partially.
In line with previous studies, we first develop a theoretical model that explores the relationship between public subsidies and R&D expenditures allowing for two spillover effects: the first decreases the firm's marginal cost and the second increases total costs (see Amir, 2000 and Lambertini *et al.*, 2004). Second, we empirically analyze our theoretical findings using Community Innovation Survey (CIS) data on R&D investments, public subsidies, firms' engagements in horizontal cooperation agreements and Intellectual Property Rights use. The analysis of firms' cooperation strategies is an important guide for regulating the incentives for innovation and avoiding harming market competition (Lopez, 2008). In addition, R&D cooperation is useful tool to avoid the negative effects of bad appropriability conditions, which could lead firms to abandon the desired R&D projects. In this circumstance, cooperation facilitates the appropriation of benefits deriving from innovation and may in-

crease R&D investments of cooperating firms.
At the same time, another policy may foster R&D investments: granting a patent to successful innovators, although this may imply a non-optimal dissemination of research outcomes (Arrow, 1962).
Policy makers expect that incentives to cooperation, patents and public subsidies stimulate private R&D investments and use these policies extensively (European Commission, 1995, 1997); this paper contributes to the development of a theoretical and empirical framework integrating the impact of these policies on R&D investments.

The results show that public funding for innovation positively affects R&D investments in different ways depending on firms' cooperative behavior and on the appropriability conditions within the economy. In particular, in line with Hinloopen (1997), a government can increase private R&D investments through the provision of subsidies; in addition this paper finds that subsidizing cooperative R&D is more effective in rising private innovation efforts than subsidizing non-cooperating firms only if the spillovers are high (e.g. case of bad appropriability conditions)[1].

The next section builds the theoretical framework and Section 3 describes the empirical methodology. The results are shown in Section 4, while Section 5 presents the conclusive remarks and policy implications.

II. Theoretical Framework

Assume a two-stage symmetric duopoly with homogeneous products. In the first stage both firms simultaneously determine their R&D investment while the second stage entails Cournot competition in the product market. The firm's amount of research (x_i, $i = 1, 2$)[2] is oriented in cost reducing activities. There are two scenarios: 1) no cooperation takes place in either the first and the second stage;

[1]In Hinloopen (2001) the effect of subsidies on innovation effort is not affected by collaboration activities.

[2]This is the terminology of D'Aspremont and Jacquemin (1988)

2) firms cooperate in the first stage by forming R&D cartels[3], while compete in the output in the second stage. In both the scenarios a public R&D subsidy s_i is granted. In line with the main studies on this theme(Hinloopen, 1997, 2001), the subsidy is assumed to reduce firms' total costs and to be an increasing function of firms' amount of R&D: $s_i = sx_i$, with $0 \leq s \leq 1$. In other words, each firm receives the same per-unit R&D subsidy s[4].

In order to formulate testable predictions, the inverse demand function is $p = a - bQ$, where $Q = q_1 + q_2$ is the total quantity produced. Each firm faces a marginal production cost, given by:

$$C_i(q_i, x_i, x_j) = [A - x_i - \beta x_j]$$

$$i = 1, 2$$

Following D'Aspremont and Jacquemin (1988) we assume that:
$0 < A < a \quad 0 < \beta < 1 \quad x_i - \beta x_j \leq A \quad Q \leq a/b$

β is the amount of knowledge of firm j which spills over firm i and reduces its costs of production. As in D'Aspremont and Jacquemin's (1988) model, β is exogenous and represents the constant amount of not appropriable knowledge that each firm produces. The cost of R&D is $\gamma(1 + \beta)x_i^2/2$ and it is assumed to be quadratic, reflecting diminishing returns to R&D expenditure (D'Aspremont and Jacquemin, 1988; Kamien *et al.*, 1992), and increasing in the level of spillovers (Amir, 2000; Lambertini *et al.*, 2004).

Firms choose the level of research and a subsequent production strategy based on their R&D choice. Proceeding by backward induction, the market stage is solved first for given values of x_i. In the second stage the firm i's profit is:

$$\Pi_i = [a - bQ]q_i - [A - x_i - \beta x_j]q_i - \gamma(1 + \beta)x_i^2/2 + sx_i$$

[3]R&D cartels are agreements to coordinate R&D activities so as to maximize the sum of overall profits (Kamien *et al.*, 1992). The cartel does not necessarily imply that participating firms share the outcomes of their R&D efforts (Hinloopen, 1997)

[4]Spencer and Brander (1983) assume a government's subsidy s per unit of R&D

The first order condition leads to the Nash-Cournot equilibrium quantity of firm i:

$$q_i = \frac{(a-A) + x_i(2-\beta) + x_j(2\beta-1)}{3b} \tag{1}$$

At the first stage firms choose the amount of R&D and the symmetric and unique solution satisfying $\delta\Pi_i^*/\delta x_i = 0$ is:

$$x^{NC*} = \frac{(2-\beta)(a-A) + 4.5bs}{4.5\gamma b(\beta+1) + \beta^2 - \beta - 2} \tag{2}$$

Hereafter, the variations of the optimal value of research x^{C*} and x^{NC*} are calculated for given values of the parameters A, a, b and γ (Fig.1 and Fig.2).

In case of noncooperative R&D (x^{NC*}) the firms' investments in R&D decrease in the level of spillovers whatever the subsidy level s, and increase in the level of subsidy whatever the spillovers level β (Fig. 1).

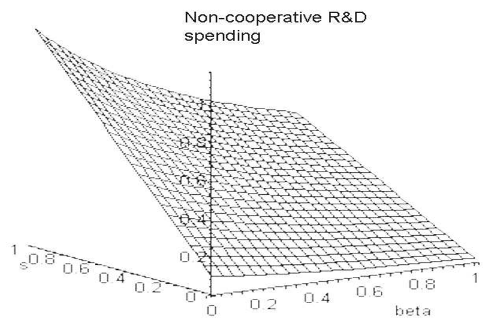

Figure 1: Relationship between the investment in R&D, subsidy level s and the level of spillover *beta* in case of noncooperative R&D (A=2; a=4; b=10; γ=1).

In the second scenario, firms maximize the first-stage joint profit $\Pi = \Pi_i^* + \Pi_j^*$. Considering the symmetric solution $x_i = x_j = x$ the unique solution for x^* is:

$$x^{C*} = \frac{(a-A)(\beta+1) + 4.5bs}{4.5b\gamma(\beta+1) - (\beta+1)^2} \tag{3}$$

On the one hand, if the firm does not receive any subsidy, the amount of R&D increases in R&D spillovers in line with D'Aspremont and Jacquemin's (1988) findings. On the other hand, for positive levels of subsidy, R&D spending decreases in the level of spillovers as in the noncooperative case.

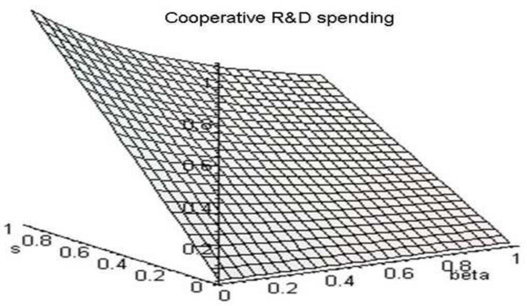

Figure 2: Relationship between the investment in R&D, the subsidy level s and the level of spillover *beta* in the case of cooperative R&D (A=2; a=4; b=10; γ=1).

The results of the theoretical model can be summarized as follows:

$$x_i^{NC*} > x^{C*} \quad for \quad \beta < 1/2 \tag{4}$$

$$x_i^{NC*} < x^{C*} \quad for \quad \beta > 1/2 \tag{5}$$

$$\begin{gathered} \frac{\delta x_i^{NC*}}{\delta s} > 0 \quad \forall s \in [0,1] \quad \forall \beta \in [0,1] \quad and \\ \frac{\delta x_i^{C*}}{\delta s} > 0 \quad \forall s \in [0,1] \quad \forall \beta \in [0,1] \end{gathered} \tag{6}$$

$$\begin{gathered} \frac{\delta x_i^{NC*}}{\delta \beta} < 0 \quad \forall s = [0,1] \quad \forall \beta = [0,1] \quad and \\ \frac{\delta x_i^{C*}}{\delta \beta} < 0 \quad for s > 0 \quad and \quad \forall \beta \in [0,1] \end{gathered} \tag{7}$$

$$\left|\frac{\delta x_i^{NC*}}{\delta \beta}\right| > \left|\frac{\delta x^{C*}}{\delta \beta}\right| \quad \forall s \in [0,1] \quad \mathit{and} \quad \forall \beta \in [0,1] \tag{8}$$

$$\frac{\delta x_i^{NC*}}{\delta s} > \frac{\delta x^{C*}}{\delta s} \quad for \quad \beta < 1/2 \tag{9}$$

$$\frac{\delta x_i^{NC*}}{\delta s} < \frac{\delta x^{C*}}{\delta s} \quad for \quad \beta > 1/2 \tag{10}$$

These results derive from a simple model which considers only two scenarios; however, they provide a base for the empirical analysis.
Expressions 6-10 lead to the following hypothesis:

Hp1: Public funding for innovation have a positive impact on R&D investments.

Hp2: Knowledge spillovers decrease firms' R&D investments, both of cooperating and noncooperating firms.

Hp3: The absolute value of the marginal effect of knowledge spillovers on firms' R&D investments is higher for non-cooperative firms.

Hp4: For low levels of spillovers, the marginal effect of subsidies on firms' R&D investments is higher for non-cooperative firms.

Hp5: For high levels of spillovers, the marginal effect of subsidies on firms' R&D investments is higher for cooperative firms.

These hypothesis resemble the results of previous studies, in particular Hinloopen's (1997, 2001). The theoretical model and the empirical predictions do not address the social welfare issues since the main objective is to provide testable predictions and explore the impact of public support to business R&D under different conditions[5].

In the remainder of the paper the hypothesis will be tested on the German and Spanish samples of firms drawn from the Third Community Innovation surveys (CIS).

III. Empirical Framework

III.A. Data and Variables

This paper uses micro-data dealing with the German and Spanish 'pseudofirms' resulting from an Eurostat standardized micro-aggregation procedure applied to the Third CIS (1998-2000). The sample includes only the innovative firms[6] because these have to fill out all the questionnaire; the Spanish and German datasets because they are the larger ones. These restrictions lead to 3481 innovative firms in Spain (43% of total firms) and 1666 firms in Germany (57% of total firms). However, due to missing values, the sample is further reduced to 1786 firms for Spain and 1073 for Germany. The dataset allows the construction of the following variables[7].

Dependent Variable

R&D spending - The firms' total innovation expenditure in 2000 is measured by the sum of expenditures in intramural research, acquisition of R&D, machinery, equipment for innovation activities or other external knowledge, training, market introduction of innovations and designs.

[5] "Although the ultimate objective underlying such policies is to maximize social welfare, policy evaluations generally focus on whether they stimulate private R&D investments" (Guellec and De la Potterie, 1997, pp. 96).

[6] Innovative firms are those which have introduced onto the market new or significantly improved product or process during the period 1998-2000.

[7] See Table 2 for some descriptive statistics.

Independent Variables

Subsidy - This paper considers only government-funded subsidies for R&D, hereafter referred to as subsidies or public funding interchangeably[8].
In the CIS, firms declared whether or not they had three different sources of public support for innovation during the period 1998-2000: 1) local or regional authorities; 2)the central government; 3) the European Union. The public funding may include grants, loans, subsidies, and loan guarantees. This paper sums 1-point for each yes-answer of these questions and rescaled the total score to a number between 0 and 1.

Horizontal R&D cooperation (horcoop) - It is a dummy variable equal to 1 if the firms declared that between 1998 and 2000, they actively participated in joint R&D and/or other innovation projects with competitors or firms in the same industry; 0 otherwise. In addition, a specular dummy variable (*nocoop*) equal to 1 if the firm does not cooperate in R&D, and 0 otherwise. This variable will be useful for construction the interaction terms in Tables 4, 5 and 6.

Industry level of spillovers - Spillovers are measured by the amount of knowledge not protected by firms through strategic or legal methods. In the spirit of Levin *et al.* (1987), Cassiman and Veugelers (2002) and Colombo *et al.* (2006), appropriability is a qualitative measure that inversely captures the extent of technological spillovers. In the CIS questionnaire firms were asked information about the degree by which they appropriate the returns of their innovative activity, and to reveal if they have used one or more methods to protect their innovations: registration of design patterns, trademarks, copyright, secrecy, complexity of design, lead-time advantage on competitors. The firm-level of appropriability

[8] The two most innovation-focused subsidy policies are government-funded R&D and fiscal incentives. Fiscal incentives are available to all firms according to precise criteria while government-funded R&D is selective, targeting specific projects evaluated useful, for example, to support the whole industry (Guellec and De la Potterie, 1997).

sums 1-point for each yes-answer of these questions and rescaled the total score to a number between 0 and 1; outgoing spillovers at the firm-level are measured as the quote of knowledge not protected by the firm (1 - appropriability score). Within the same industry, defined at two-digit NACE code, we compute the mean value of spillovers (e.g. at the industry level) averaging the firm-level outgoing spillovers. The result captures the exogenous nature of spillovers that derives from to technology and market characteristics; moreover, the use of industry spilovers reduces measurement errors connected to the use of survey data (Cassiman and Veugelers, 2002).

We also distinguished between *low-spillovers*=1 if the $industry\_spillovers < 0.5$ and 0 otherwise; and *high-spillovers*=1 if the $industry\_spillovers \geq 0.5$, 0 otherwise. Then we construct four interaction terms:
(a) *horcoop*low-spillovers*subsidy* and *nocoop*low-spillovers*subsidy*; these variables estimate the impact of subsidies on R&D investments of, respectively, cooperating and noncooperating firms, when the industry level of spillovers in the economy is low (good appropriability conditions);
(b)*horcoop*high-spillovers*subsidy* and *nocoop*low-spillovers*subsidy*; these variables estimate the impact of subsidies on R&D investments of cooperating and noncooperating firms, when the level of spillovers in the economy is high (bad appropriability conditions).

Control Variables

Control variables are drawn from previous theoretical and empirical studies on the theme: 1) the orderliness of R&D activities (Cassiman and Veugelers, 2002 called this variable *permanent R&D*); 2) firms' size, measured by the total turnover in 2000; 3) firms' size squared, to allow for non linear effects; 4) export intensity, to control for the competition inside the market (Cassiman and Veugelers, 2002); 5) other industry-level variables as the average amount of

R&D and of permanent R&D at 2-digit NACE code, which controls for technology oriented sectors.

III.B. Estimation Method

Public subsidies for innovation are usually distributed to innovative firms and may be affected by firms' R&D spending which is the variable they should explain. Horizontal cooperation, as well, may be affected by the innovative activities of the firms [9].
To tackle these potential endogeneity problems we use a two stage least squares method (2SLS)[10]; however, the Hausman test never rejects the null hypothesis on consistency of the OLS estimator.

Therefore, in order to test Hp 1 and Hp 2, we run the following OLS regression both on the Spanish and German samples (see Table 3):

$$\begin{aligned} R\&Dspending_i = a + b_1\ horcoop_i + b_2\ subsidy_i \\ +b_3\ industry\_spillovers_i + \sum_n b_n X_{i,n} + e_i \end{aligned} \tag{11}$$

We expect a positive sign for b_2 (Hp1) and a negative one for b_3 (Hp2).
In order to test Hp 3, we construct two interaction terms multiplying the dummy variables *nocoop* and *horcoop* for the industry level of knowledge spillovers and we run the following OLS regression (See Table 4):

$$\begin{aligned} R\&Dspending_i = a + b_1\ subsidy_i + b_2\ nocoop_i * industry\_spillovers_i + \\ b_3\ horcoop_i * industry\_spillovers_i + \sum_n b_n X_{i,n} + e_i \end{aligned} \tag{12}$$

[9] Veugelers and Cassiman (1999) did not found any cooperating firms which was not performing any in-house R&D. As regards, see also Piga and Vivarelli (2004).

[10] We control the relevance of the instruments performing an F-test of excluded instruments, and the validity of the instruments performing a Sargan test.

According to Hp3, we expect negative signs for the coefficients b_2 and b_3, but with an absolute value of b_2 significantly higher than the absolute value of b_3.

Finally, to test Hp 4 and Hp 5, we estimate the following regression through OLS (See Tables 5 and 6):

$$\begin{aligned} R\&Dspending_i = a + b_1\ & horcoop_i * low\_spillovers_i * subsidy_i + \\ b_2\ & nocoop_i * low\_spillovers_i * subsidy_i + \\ b_3\ & horcoop_i * high\_spillovers_i * subsidy_i + \\ b_4\ & nocoop_i * high\_spillovers_i * subsidy_i + \\ & \sum_n b_n X_{i,n} + e_i \end{aligned} \tag{13}$$

According to H4 and H5, we expect positive signs of the coefficients but, respectively, $b_2 > b_1$ and $b_3 > b_4$.

IV. Results

Table 3 in appendix shows the results of OLS regressions performed to test Hp1 and Hp2.
On the one hand, subsidies for cooperation significantly increase R&D investments of firms in both countries analyzed, supporting Hp1; on the other hand, Hp2 is not supported by data since the industry level of spillovers has an impact on R&D investments not significantly different from zero[11].

Table 4 does not provide evidence in support of Hypothesis 3 for which the marginal effect of knowledge spillovers on firm's R&D investments is higher, in absolute value, for non-cooperating firms. In fact, as in Table 3, the knowledge spillovers variable has an impact not significantly different from zero even distinguishing between co-

[11] Firms cooperating in R&D activities invest the 23% more than the non-cooperating firms in Spain while in Germany the 28%.

operating and non-cooperating firms.

In Table 5, we test Hp4 and Hp5. For low levels of spillovers, the marginal effect of subsidies on R&D investments of noncooperating firms is not significantly higher in both the countries (Hp4). On the one hand, the coefficients *b1* and *b2* in the first column have been dropped because the Spanish industry-level spillovers are never *low*, as defined in section 4, and become a zero vector. In Germany, on the other hand, the coefficients *b1* and *b2* are not significant.
In order to check these results, the variable *low_spillovers* is redefined in Table 6: the industry_spillovers are low in the first two quartiles of their distribution, and the other way round for the variable *high_spillovers*. Table 6 shows that the coefficients *b1* and *b2* are positive and highly significant in both countries; however they are very similar in Spain and not significantly different in Germany (see the F test on H_0: b1=b2). Therefore, we can reasonably conclude that subsidizing firms in industries with good appropriability conditions has a positive impact on their R&D investments but this impact is not significantly affected by firms' cooperative behaviour.

Hypothesis 5 stated that for high levels of spillovers, the marginal effect of subsidies on firms' R&D investments is higher for cooperating firms. This hypothesis is tested in Tables 5 and 6. The coefficients *b3* and *b4* in Table 5 are positive and significant in both countries, with *b3* always greater than *b4* as expected in Hp5. However, the F test in Table 5 cannot reject the null hypothesis on the equality between the two coefficients for Spain. Broadly speaking, for any definition of the variable *High_spillovers* and *low_spillovers*, Hp5 is supported, excluding the regression in Table 5 regarding Spain. Table 6 suggests that subsidies given to firms in industry with bad appropriability conditions have an higher impact on R&D investments when firms cooperate.

V. Conclusions

This paper assumes firms' Cournot-Nash behavior in the choice of the optimal R&D investment level and provides empirical evidence in support of the theoretical findings using data from the Third Community Innovation Survey for Spain and Germany. Theoretical and empirical findings suggest that public funding for innovation positively affect R&D investments but in different ways depending on firms' cooperative behavior and on the appropriability conditions within the economy.

Public funding for innovation, as financial support in terms of grants and loans, subsidy, and loan guarantees from local or regional authorities, central government and the European Union, fosters firms' R&D investments in both the countries analyzed supporting the hypothesis of complementarity between public and private R&D. On the one hand, when the appropriability conditions within the economy are bad, public funding is much more effective if it is given to cooperatives. On the other hand, in case of good appropriability conditions, the subsidies' impact on firms' R&D investments is not significantly different between cooperating and non-cooperating firms. However, this last result is not perfectly consistent with theoretical hypothesis which predict, for low levels of spillovers, a higher marginal effect of subsidies on R&D investments in case of non-cooperating firms.

The main limitation of the study lies in the construction of the appropriability indicator, because it: 1) It assigns to all the methods of protection the same effectiveness in preventing involuntary leakages of knowledge; 2) It assumes that a firm that uses all these methods of protection is able to fully appropriate of its knowledge. Contrary to this last point, Mansfield (1985) showed that high levels of appropriability could coexist with high levels of knowledge spillovers.

Moreover, although we control for potential simultaneity bias during the analysis, the cross section data-set could lead to this kind of problem. Therefore, a possible extension of the study consists of estimating the model using two linked waves of CIS and introducing other proxies for the appropriability conditions of the economy.

However, the paper's findings leave room for some policy implications. Policy-makers should address public funding for innovation paying a greater attention to both the firms' use of legal methods of protection and cooperative behaviours. This would increase the effectiveness of subsidies in enhancing private R&D investments and the knowledge circulation. Current policy objectives are more articulated than in the past but are still quite general and not broken down into sub-segment of specific, measurable and quantitative indicators (see INNO-Policy TrendCharts[12]). This paper contributes to this theme suggesting that public funding aimed to foster R&D investments should be addressed taking into account the appropriability conditions of the economy and the cooperative behaviours of the recipients. Therefore an increasing "vertical" coordination among policy-makers at the European, national and regional levels is necessary in order to achieve the maximum possible benefit.

[12]See www.proinno-europe.eu.

Appendix

Description of the Variables

Horcoop = 1 if firms reveal to have at least one co-operative agreement with external competitors , and 0 otherwise.

Nocoop = 1 if firms reveal not to have at least one co-operative agreement with external competitors , and 0 otherwise.

R&D spending = natural logarithm of total expenditure for innovation activities during the year 2000

Subsidy = sum of 1-point for each firm's yes-answer to the firms'receipt of the following types of public funding: funding from local or regional authorities, funding from central government and from the European Union; rescaled between 0 and 1.

Appropriability = sum of 1-point for each firm's yes-answer to the use of the following methods to protect product and processes: Registration of design patterns, trademarks, copyright, secrecy, complexity of design, lead-time advantage on competitors;(rescaled between 0 and 1).

Industry_spillovers = Mean of spillovers at industry level. Spillovers is defined as (1- appropriability) and industry level is defined at two-digit NACE.

Low_spillovers = 1 if $Industry\_spillovers < 0.5$, 0 otherwise. (In Table 5 Low_spillovers=1 for the 1st or 2nd quartile of the Industry_spillovers variable distribution; 0 otherwise)

High_spillovers = 1 if $Industry\_spillovers \geq 0.5$, 0 otherwise.(In Table 5 High_spillovers=1 for the 3rd or 4th quartile of the Industry_spillovers variable distribution; 0 otherwise)

Permanent R&D = 1 if the firms' R&D activities have a permanent character (is performed systematically), 0 otherwise.

Size = natural logarithm of total turnover during the year 2000

Size squared =the square of Size.

Export Intensity Export share in total firm sales.

Industry level of R&D = Mean of R&D spending at industry level. Industry level is defined at two-digit NACE).

Industry level of permanent R&D = Mean of orderliness of R&D at industry level. Industry level is defined at two-digit NACE).

Table 1: **Hypothesis supported by data**

Hypothesis	Supported= Yes, No
Hp1	Yes
Hp2	No
Hp3	No
Hp4	No
Hp5	Yes

Table 2: **DESCRIPTIVE STATISTICS**

Spain	Sample mean N: 1786	Mean Cooperating firms N: 220	Mean Noncooperating firms N: 1566
R&D spending	12.79	14.00	12.62***
	(1.77)	(1.72)	(1.72)
Subsidy	0.23	0.44	0.19***
	(0.24)	(0.37)	(0.27)
Appropriability	0.28	0.38	0.27***
	(0.30)	(0.31)	(0.29)
Germany	Sample mean N:1073	Cooperating firms N:149	Noncooperating firms N:924
R&D spending	13.44	14.54	13.27***
	(2.30)	(2.77)	(2.17)
Subsidy	0.21	0.40	0.17***
	(0.29)	(0.37)	(0.27)
Appropriability	0.34	0.44	0.33***
	(0.26)	(0.27)	(0.26)

Note: Standard deviations are in parenthesis
* Difference in mean between cooperating and noncooperating firms significant at the 10-percent level.
** Significant ate the 5-percent level
*** Significant at the 1-percent level

Table 3: **OLS regressions to test Hp1 and Hp2**

Variables	**SPAIN**	**GERMANY**
Dependent Var: R&D spending	Coefficient	Coefficient
	(Std. Err.)	(Std. Err.)
Horcoop	0.238***	0.288**
	(0.086)	(0.130)
Subsidy	1.199***	1.030***
	(0.099)	(0.136)
Industry_spillovers	-0.633	-0.940
	(0.453)	(0.628)
Permanent R&D	1.037***	0.737***
	(0.070)	(0.098)
Size	-0.340	-0.155
	(0.253)	(0.242)
Size squared	0.023***	0.024***
	(0.007)	(0.006)
Export Intensity	0.205*	0.733***
	(0.114)	(0.177)
Industry level of permanent R&D	-0.631**	-0.016
	(0.300)	(0.468)
Industry level of R&D	0.469***	0.142**
	(0.072)	(0.062)
Constant	5.637**	6.626***
	(2.293)	(2.150)
Nobs:	1786	1073
R^2:	0.59	0.67
F:	235.17***	214.69***

Notes: Robust Standard errors in parenthesis
* Significant ate the 10-percent level
** Significant ate the 5-percent level
*** Significant at the 1-percent level

Table 4: **OLS regressions to test Hp3**

Variables	**SPAIN**	**GERMANY**
Dependent Var: R&D spending	Coefficient (Std. Err.)	Coefficient (Std. Err.)
Subsidy	1.198***	1.024***
	(0.099)	(0.136)
Nocoop*Industry_spillovers (b2)	-0.674	-1.021
	(0.453)	(0.625)
Horcoop*Industry_spillovers (b3)	-0.332	-0.533
	(0.464)	(0.643)
Permanent R&D	1.037***	0.736***
	(0.070)	(0.098)
Size	-0.0339	-0.157
	(0.252)	(0.242)
Size squared	0.023***	0.024***
	(0.007)	(0.006)
Export Intensity	0.205*	0.732***
	(0.114)	(0.177)
Industry level of permanent R&D	-0.631**	-0.025
	(0.300)	(0.466)
Industry level of R&D	0.470***	0.141**
	(0.072)	(0.062)
Constant	5.672**	6.733***
	(2.291)	(2.150)
Nobs:	1786	1073
R^2:	0.59	0.67
F:	235.34***	216.04***
F test on H_0: b2=b3	-	-

Notes: Robust Standard errors in parenthesis
* Significant at the 10-percent level
** Significant at the 5-percent level
*** Significant at the 1-percent level

Table 5: **OLS regressions to test Hp4 and Hp5**

Variables	**SPAIN**	**GERMANY**
Dependent Var: R&D spending	Coefficient (Std. Err.)	Coefficient (Std. Err.)
Horcoop*low_spillovers*subsidy (b1)	-	0.311
		(0.741)
Nocoop*low_spillovers*subsidy (b2)	-	-0.058
		(0.890)
Horcoop*high_spillovers*subsidy (b3)	1.441***	1.601***
	(0.143)	(0.198)
Nocoop*high_spillovers*subsidy (b4)	1.178***	0.916***
	(0.110)	(0.150)
Permanent R&D	1.045***	0.733***
	(0.070)	(0.097)
Size	-0.321	-0.175
	(0.252)	(0.243)
Size squared	-0.023***	0.024***
	(0.007)	(0.006)
Export Intensity	0.239**	0.734***
	(0.112)	(0.177)
Industry level of permanent R&D	-0.477	0.375
	(0.291)	(0.400)
Industry level of R&D	0.451***	0.181***
	(0.072)	(0.064)
Constant	5.178**	5.452**
	(2.255)	(2.122)
Nobs:	1786	1073
R^2:	0.59	0.67
F:	259.68***	198.30***
F test on H_0: b1=b2	-	-
F test on H_0: b3=b4	2.67	9.59***
F test on H_0: b1=b3	100.61***	2.93*
F test on H_0: b2=b4	114.64***	1.20

Notes: Robust Standard errors in parenthesis
* Significant ate the 10-percent level
** Significant ate the 5-percent level
*** Significant at the 1-percent level

Table 6: **Robustness Checks for OLS regressions testing Hp4 and Hp5 in Table 5**

Variables	**SPAIN**	**GERMANY**
Dependent Var: R&D spending	Coefficient	Coefficient
	(Std. Err.)	(Std. Err.)
Horcoop*low_spillovers*subsidy (b1)	1.086***	1.525***
	(0.230)	(0.289)
Nocoop*low_spillovers*subsidy (b2)	1.087***	1.050***
	(0.121)	(0.175)
Horcoop*high_spillovers*subsidy (b3)	1.623***	1.550***
	(0.166)	(0.229)
Nocoop*high_spillovers*subsidy (b4)	1.250***	0.666***
	(0.160)	(0.223)
Permanent R&D	1.040***	0.733***
	(0.070)	(0.097)
Size	-0.347	-0.153
	(0.254)	(0.244)
Size squared	0.024***	0.024***
	(0.007)	(0.007)
Export Intensity	0.269**	0.727***
	(0.113)	(0.177)
Industry level of permanent R&D	-0.372	0.335
	(0.298)	(0.412)
Industry level of R&D	0.430***	0.150**
	(0.072)	(0.062)
Constant	5.561**	5.724***
	(2.263)	(2.150)
Nobs:	1786	1703
R^2:	0.59	0.67
F:	212.26***	196.18
F test on H_0: b1=b2	0.00	2.33
F test on H_0: b3=b4	2.98*	8.87***
F test on H_0: b1=b3	3.90**	0.00
F test on H_0: b2=b4	0.82	2.14

Notes: Robust Standard errors in parenthesis
Low_spillovers=1 if the firm belong to the 1st or the 2nd quartile of the distribution of the Industry_level spillovers variable, 0 otherwise. The other way around for High_spillovers.
* Significant ate the 10-percent level
** Significant ate the 5-percent level
*** Significant at the 1-percent level

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