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Public Support to Business R&D: A Survey and Some New Quantitative Evidence

Henri Capron and Bruno Van Pottelsberghe de la Potterie

Unité d'Economie Spatiale et de la Technologie
Université Libre de Bruxelles, CP-140
50, av. F.D. Roosevelt, B-1050, Brussels
hcapron@ulb.ac.be; bvpot@ulb.ac.be

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ABSTRACT By reference to the integrated assessment scheme suggested by Capron and van Pottelsberghe in this volume, the objective of this paper is to provide some policy implications that might be put forward from quantitative evaluations of the effectiveness of R&D subsidies. In this respect we survey the existing literature and produce some new quantitative evidence for seven major industrialized countries. Our empirical implementation comes within the scope of two categories of studies. First, we test whether R&D subsidies have a direct impact on productivity growth. Second, we evaluate the stimulation effect of these subsidies on private R&D investments. The major conclusions are that *(i)* private R&D is not associated to higher returns than government R&D; *(ii)* R&D subsidies always contribute to raise total R&D investments; *(iii)* the more unstable a subsidization rate is, the less an increase in R&D subsidies is likely to stimulate private R&D investors.

1. INTRODUCTION

The objective of this paper is to provide, by reference with the integrated assessment scheme suggested by Capron and van Pottelsberghe (1997a), some policy implications that might be put forward from quantitative evaluations of the effectiveness of R&D subsidies in seven major industrialized countries. Ultimately, we want to see whether econometric estimates would allow innovation policies to be, tomorrow, *« a little bit less a matter of faith and a little bit more a matter of understanding »*, challenging therefore the famous statement of Rothwell and Zegveld (1988).

Our empirical framework comes within the scope of two categories of studies. First, we test whether R&D subsidies have a direct impact on productivity growth. Second, we evaluate the stimulation effect of these subsidies on private R&D investments. The evaluation procedure is implemented both at the aggregate manufacturing level and for 22 disaggregate manufacturing industries.

The paper is structured as follows. The existing quantitative literature on the effectiveness of R&D subsidies is surveyed in the next section. Section 3 concentrates on the evaluation of the impact of R&D subsidies on productivity and on the private decision to invest in R&D. Finally, the conclusions and some suggestions related to the design of public investment policies are drawn in section 4.

2. IMPACT ASSESSMENT OF R&D SUBSIDIES: REVIEW OF THE LITERATURE

Empirical studies on the effects of R&D subsidies fall into two main categories. The first one estimates the direct impact of R&D subsidies on output growth. The ubiquitous and quite pessimistic finding which emerges from this literature is that privately-funded R&D contributes significantly to output growth, whereas publicly-financed R&D has little or no direct effect. The second category of studies argues that the role of R&D subsidies in the production process is rather indirect, via the stimulation of private R&D investments. However, the empirical evidence which comes from this second category of studies is far from being unambiguous, depending on the countries and/or the manufacturing industries. This stresses the need for more empirical tests and analyses concerning the interrelationship between R&D subsidies, the private decision to invest in R&D, and productivity growth; especially in other countries than the US, which have been so far the center of interest.

Consider the following production function and disaggregate the total R&D (*RT*) input into its two main components (or sources of funds): private R&D (*RP*) and government R&D (*RG*):

$$Q = A \exp(\lambda t)\, SRP^{\alpha_1}\ SRG^{\alpha_2} \prod_k X_k^{\beta_k} \tag{1}$$

Q denotes real output; *SRP* and *SRG* stand for the stock of private R&D, and the stock of government R&D, respectively. *X* characterizes the *k* traditional inputs: labor, fixed capital stock, intermediate inputs, and energy. Should we expect to find a difference between the direct effects of publicly- and privately-financed R&D? *A priori*, and within a firm, the answer is negative because *« a dollar is a dollar, irrespective of source »* [Griliches (1979), p. 110]. However, at the aggregate level one may expect some differences in the estimated rates of return to private and government R&D because a strong government support to R&D in an industry may favor externalities and limits appropriability opportunities for the companies in this industry. This may explain why most of studies which attempt to estimate a direct effect of R&D subsidies have been done at the aggregate industry level.

Table 1 summarizes the results of the empirical literature which differentiates the impact of private R&D from the impact of R&D subsidies on output growth. While there is a lack of empirical evidence for a lot of countries, the conclusions brought through the few US applications stay quite pessimistic. The three findings which emerge from the literature overview are that *(i)* private R&D has a substantial and significant direct effect on the growth of productivity which is greater than the impact of total R&D, *(ii)* whereas public R&D appears to have a much weaker direct effect, if not insignificant; and *(iii)* the rate of return to total R&D or to private R&D is lower in the industries which are relatively highly subsidized.

An hypothesis which could account for the apparent poor direct performance of R&D subsidies is that their impact on productivity growth is rather indirect, via the stimulation of the private decision to invest in R&D. According to Levy (1990), a firm could consider government R&D as a public good which can be employed without private cost. The author argues that if government R&D can be employed by the private sector at zero cost, then, in equilibrium, its marginal product must be equal to zero. Therefore the non significant impact of *RG* on output growth can not be taken as a validation for the (in)efficiency of R&D subsidies. Using the production function approach, it would not be possible to compare the levels of production with and without publicly-financed R&D.

Consequently, the question that arises is to understand the influence of R&D subsidies upon the marginal physical product of private R&D. It can be assumed that the amount of private R&D investment is an upward sloping function of its own marginal physical product. Hence, since the marginal physical product of private R&D is likely to increase with R&D subsidies, an increase of the latter should foster private R&D expenditures. Suppose that a firm's private R&D investments respond to the level of R&D subsidies according to the following formula:

$$RP = \gamma_1 + \gamma_2 \; RG \tag{2}$$

and, for simplicity, the form of total factor productivity growth equation:

$$\dot{TFP} = \alpha_0 + \alpha_1 \frac{RP}{Q} + \alpha_2 \frac{RG}{Q} \tag{3}$$

Then, the total derivative of $\dot{TFP}$ with respect to (*RG/Q)* is:

$$\frac{\partial \dot{TFP}}{\partial (RG / Q)} = \alpha_2 + \alpha_1 \gamma_2 \tag{4}$$

which is a function of the return to R&D subsidies (α_2) and of the product of the return to private R&D (α_1) by the reaction of private R&D to government support (γ_2). Therefore, the impact of publicly-funded R&D on productivity growth will be positive if $\gamma_2 > -\alpha_2 / \alpha_1$. The empirical evidence described here above shows that α_2 / α_1 is very small and most probably insignificantly different from zero. Despite their negligible rate of return, R&D subsidies may contribute to foster productivity growth if and only if they do stimulate private investments in research activities. On the other hand, if R&D subsidies have a relatively weak direct impact on output and if they deter - or are a substitute to - private R&D expenditures, then a rise in government support will slow down productivity growth.

Are publicly-funded R&D and privately-funded R&D *substitutes* or *complements*? In the case of complementarity, one would assume an indirect path of stimulus to productivity of R&D subsidies, via an inducement to perform private R&D. Most of the investigations which implicitly test this complementarity assumption between the two main sources of funds for research activities are presented in Table 2. Only a small fraction of them is based on manufacturing sectors or macro-economic data. Among the thirteen studies at the micro level, eight support the complementarity assumption, four reject it[1] and one is inconclusive.

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[1] Some studies define the dependent variable as total R&D investment, without substracting R&D subsidies. This means that the estimated coefficient associated to government R&D has to be interpreted differently. Assume that *RT=RG + RP*, then the impact of *RG* on *RT* is equal to *((ΔRP / ΔRG) + 1).* Therefore, a positive coefficient that is smaller than one would reflect an eviction effect of *RG* on *RP*, as presented by Levin and Reiss (1984) and Fölster and Trofimov (1996) in Table 2.

Table 1.
The Rates of Return (or output elasticities) to Total, Private, and Government R&D in the literature

Author(s)	Country - period	Dependent variable	R&D variable	ρ/ ε	Data	*RT*	*RP*	*RG*
Industry-level								
Leonard (1971)	USA - 16 industries 1957-63	V.A. growth; correlations	R&D/V.A.	ρ	C.S.		.75*	.04
	14 industries (no outliers)							.77*
Terleckyj (1980a, b)	USA - 20 industries 1948-66	TFP growth - sales	R&D/V.A.	ρ	C.S.	.12*		
							.27*	-.05
Griliches and Lichtenberg (1984a)	USA - 27 industries 1959-68	TFP growth - sales	R&D/sales	ρ	C.S.	.03*		
							.09*	.01
	1964-73					.01		
							.20*	-.01
	1969-76					.06*		
							.34*	.01
Levy and Terleckyj (1989)	USA - telecom industry 1958-85	Cobb-Douglas - sales	R&D stocks	ε	T.S.		.26*	.04*
Reiss (1990)	USA - 23 industries 1969-76, Deletion of 4 outliers	TFP growth - sales	R&D/sales	ρ	C.S.		.26*	.18*
Firm-level								
Griliches (1980a)	USA - 883 firms - 1957-65	Labor productivity growth - sales	growth of R&D flows	ε	C.S.			
	Pooled data						.06*	
	Chemicals & petroleum						.09*	
	Metals & machinery						.09*	
	Electric equipment						.06*	
	Motor vehicles						.14*	
	Aircraft						.03	
	Other						.05*	
Griliches (1986)	USA - 386 firms	Cobb-Douglas - V.A.	R&D stocks; premium approach	ε	C.S.	.14*	1.8*	
Lichtenberg and Siegel (1991)	USA - 2000 firms 1973-85	TFP growth - sales	R&D/sales	ρ	T.S.C.S.	.13*		
							.35*	.03
	1973-76					.10*		
							.25*	-.00
	1977-80					.19*		
							.42*	.10
	1981-85					.21*		
							.51*	-.01
	1973-85 (no outliers)					.13*		
							.29*	.07*
Crott (1995)	Belgium - 30 firms 1984-87	Labor productivity - V.A.	R&D/labor	ε	T.S.C.S.	.05*		
							.28*	.00
Country-level								
Levy and Terleckyj (1983)	USA - Private business 1949-81	Labor productivity - sales	R&D stocks	ε	T.S.			
			(Gov. R&D)				.27*	.05
			(Gov. contract R&D)				.27*	.09*
Capron (1992b)	Belgium - 1963-1985	Labor productivity growth - GNP	R&D stocks	ε	T.S.		.64*	.21*
Lichtenberg (1992)	53 countries - 1985	Labour productivity - GNP	R&D/GNP	ε	C.S.	.09*		
							.07*	.02
	1960-85	Labour productivity growth - GNP	R&D/GNP	ρ	C.S.		.10*	-.15*

1. Source: Van Pottelsberghe (1997); V.A. = added value; TFP = total factor productivity; ρ = rate of return to R&D; ε = output elasticity of R&D; T.S. = time series; C.S. = cross section; T.S.C.S. = panel data; *RT* = total R&D; *RP* = private R&D; *RG* = government R&D. * Significant at a 10% probability threshold.

Concerning the three US meso-economic studies the results are also mitigated. Nadiri (1980) and Levin and Reiss (1984) estimate that private R&D and government support are complementary. Lichtenberg (1984) fails to obtain any significant relationship. The three macro-economic estimates support the stimulation hypothesis for the US. However, Levy (1990)'s contribution shows that in Japan, Germany, Sweden and France there is a complementarity between government R&D and private R&D, while a substitution relationship appears for the UK and the Netherlands and the results are inconclusive for Italy and Switzerland.

These studies are mostly related to the US economy and the divergences between them are to a large extent due to different time periods, data sources, or regression characteristics. Most of the samples used in the micro-level regression studies are highly non-random, inducing the potential presence of a sample selection bias. Further, the fourth to the seventh columns of Table 2 clearly indicate that the empirical models differ markedly across studies. In addition, there are divergences among studies with respect to their way of controlling for firm and/or industry fixed effects. Therefore, one could wonder whether this divergence among the econometric results is consequential to the diversity of empirical models or not[2]. In this respect, five issues deserve to be discussed.

First, a large number of studies estimate an average effect of government R&D (*RG*) on private R&D (*RP*), restricting the parameter to be invariant across manufacturing industries or firms. There is, however, few evidence that the relation between government and private R&D may be different from one industry to the other, regardless the characteristics of empirical models. Nadiri (1980a) provides evidence that the growth of public R&D capital stock has a statistically significant positive effect on the private R&D capital stock of 10 manufacturing industries. When the dataset is subdivided into two groups, the estimated private R&D elasticity of government R&D stays positive for the 5 nondurables industries, while it is negative and significant for the 5 durables industries. Shrieves (1978) and Fölster and Trofimov (1996) also estimate a negative coefficient for US firms in durables industries and for Swedish firms, respectively.

2 For instance, Lichtenberg (1984) focuses only on government R&D in order to explain the evolution of private R&D investments across 12 US industries; while Switzer (1987), quite at the opposite, adds 7 other variables.

Table 2.
Estimated Marginal Impact (or elasticity- ε) of Publicly-Financed R&D on Private R&D[1].

Author(s)	Country - years - structure [1]	Sample	RP_{t-1}	Q_t	C4	other	β
Firm-level							
Rosenberg (1976)	USA - 1963 - C.S.	100 firms		+	+	+	2.35*
Shrieves (1978) ε	USA - 1965 - C.S.	411 firms		+	+	+	
		manufacturing					-.53*
		non-spec. durables					-.89*
		materials					1.26*
		spec. durab. equip.					-1.02*
		consumer goods					-.78
Carmichael (1981)	USA - 1976-77 - C.S.	46 transport firms		+			-.08*
		big firms					-.07
		small firms					-.06*
Link (1982)	USA - 1977 - C.S.	275 firms		+	+	+	.09*
Lichtenberg (1984)	USA - 1972 - C.S.	991 firms - level					.10*
	USA - 1977 - C.S.	level					-.22*
	USA - 1972 to 77 - C.S.	growth rates					-.17*
	USA - 1967 to 77 - C.S.	growth rates					-.26*
Scott (1984) ε	USA - 1974 - C.S.	3387 lines of business		+		+	.08*
Switzer (1984)	USA - 1977 - C.S.	125 firms	+	+	+	+	.08
Lichtenberg (1987)	USA - 1979-84 - T.S.C.S.	187 firms		+			.13*
						Q_g	-.00
Holemans and Sleuwagen (1988) ε	Belgium - 1980-84- T.S.C.S.	59 firms		+	+	+	.30*
Antonelli (1989) ε	Italy - 1983 - C.S.	86 firms		+		+	.37*
Leyden and Link (1992)	USA - 1987 - C.S.	137 laboratories				+	1.99*
Crott (1995) ε	Belgium - 1984-87- T.S.C.S.	30 firms		+		+	.50*
Fölster and Trofimov (1996) [4]	Sweden - 1982 - 90 T.S.C.S.	249 groups	+	+		+	.20*
Industry-level							
Nadiri (1980) ε	USA - 1969-75 - T.S.C.S.	10 industries	+	+		+	.01*
		5 durables					-.04*
		5 non durables					.02*
Levin and Reiss (1984) [4]	USA - 1967, 72, 77 - C.S.	20 industries			+	+	.12*
Lichtenberg (1984)	USA - 1963-79 - T.S.C.S.	12 industries (growth rates)					.01
Mamuneas and Nadiri (1996)	USA - 1956-88 - T.S.C.S.	15 industries		+		+	.54*
Country-level							
Lichtenberg (1987)	USA - 1956-83 - T.S.	Macro		+			.33*
						Q_g	.11
Levy and Terleckyj (1983)	USA - 1949-81 - T.S.	Private Business		+		+	.21*
Levy (1990) [3]	9 countries -1963-84 -T.S.C.S.	USA		+			.30*
		UK					-.73*
		Italy					.05
		Japan					.16*
		Germany					.23*
		Sweden					.41*
		Netherland					-.13*
		France					.33*
		Switzerland					.02

1. Source: Van Pottelsberghe (1997). **2.** T.S. = time series; C.S. = cross section; T.S.C.S. = panel data. *RP* = private R&D expenditures; *Q* = total sales; *C4* = industry concentration ratio, *Qg* = sales to government; *Other* = time dummies or industry dummies, proxy of company diversification, technological opportunity dummies, and appropriability conditions. **3.** The estimates reported for Levy (1990) are taken from Capron (1992a). **4.** The estimates by Fölster and Trofimov (1996) have to be interpreted as a negative relationship between government and private R&D (cf. footnote 2). * Significantly different from zero at a 10% probability threshold.

The second issue is related to the dynamic perspective of models to be estimated. Only three out of the nineteen studies presented in Table 3 adopt a partial adjustment mechanism for R&D investments. On a priori grounds, the inclusion of lagged R&D may be seen as an important determinant of present R&D investments. Mansfield (1964, p. 32) notices that *« First it takes time to hire people and build laboratories. Second, there are often substantial costs in expanding too rapidly because it is difficult to assimilate large percentage increases in R&D staff. ...Third, the firm may be uncertain as to how long expenditures of (desired) R&D levels can be maintained. It does not want to begin projects that will soon have to be interrupted. »*. We therefore strongly believe that the behavior of private investors can be best described in terms of a dynamic mechanism. It is worth noticing that Fölster and Trofimov (1996) at the micro level and Nadiri (1980) for Durable industries, who rely on a dynamic empirical specification, are among the few studies which estimate a negative effect of government R&D on private R&D investments. Switzer (1984) also uses a partial adjustment mechanism and does not estimate any significant relationship between government and private R&D. It seems therefore essential to test whether an adjustment process is at work and whether the introduction of the lagged endogenous variable_affects the amplitude and/or the sign of the estimated impact of R&D subsidies on private R&D.

The third issue concerns the influence of technological competition, inside a given industrial sector, on the R&D investors' behavior. In Table 3, Fölster and Trofimov (1996) is the only study which attempts to comprehend the role of R&D rivalry. Their main finding is that total R&D efforts of several competing firms in Sweden tend to decline when they receive subsidies. If only one firm benefit from subsidies, its own R&D activities increase but the total R&D by all competing firms is likely to decline. Thus, it is not surprising to evaluate a crowding-out effect at the sectoral level, even if the firms which benefit from subsidies increase their private R&D investments. The potential presence of such a negative impact of government R&D on private R&D at the aggregate (sectoral) level amplifies the requisite for empirical studies at the industry level.

The fourth issue is related to the assumption, implicitly supported by most studies on the relationship between R&D subsidies and company R&D, that the level of government support is viewed as an exogenous determinant in the company R&D expenditures models. The relevance of this assumption is rather questionable because public authorities do certainly not give R&D subsidies to randomly chosen companies. Quoting Lichtenberg (1984), « *Federal contracts do not descend upon firms like manna from heaven* » [p. 74]. Public authorities may be more inclined to support firms which do R&D and which already have good innovative ideas. The fact that private R&D intentions are perhaps among the main determinants of R&D subsidies may explain the presence of a statistical interrelationship between private R&D and R&D subsidies irrespective of the effectiveness of subsidies. This is why Kauko (1996) argues that, at the firm level, the assumption about the exogeneity of R&D subsidies is almost certainly unacceptable. Therefore, econometric estimates of the impact of publicly-financed R&D on companies' private R&D investments are likely to be subject to substantial simultaneity bias. The same argument could hold, but to a much lesser extent, for cross-industry studies if R&D subsidies were directed mainly towards R&D intensive industries. At the macro level, the exogeneity assumption is much more acceptable.

The last issue is the one introduced by Lichtenberg (1987) who provides empirical evidence, through both macro and micro US data, that most of the models which estimate regressions of private R&D expenditures on federal R&D funding and other variables give an overstatement of the federal R&D coefficient. This misspecification could be a direct implication of the failure to distinguish government sales from other sales. The econometric analysis supports the view that « *a large part of what had been interpreted as the effect of federal R&D funding on privately funded R&D expenditure is in fact attributable to variation in the government's share of output* » [p. 103]. However, these results should be taken cautiously since they mean that government purchases and government R&D are correlated. Hence, both variables could reflect the degree of government interventionism, rising again the question of whether or not such interventionism has a stimulating impact on private R&D.

In a nutshell, the two sources of funds for R&D may be either complementary or substitutable. In the first case R&D subsidies should motivate private R&D. In the opposite case private firms would decrease their own R&D expenditures as a consequence of government support to their R&D projects. Despite the heterogeneity of the empirical models referred in the literature, which makes hazardous any comparison exercise, the balance seems to tilt towards the recognition of a complementary effect between the two sources of funds. However, there are some clues that in some industries, or in some countries, government R&D is a substitute for private R&D. Further, it seems that the empirical specification may also influence the sign of the parameter of interest.

A correct answer to this debate is crucial for the R&D policy design. In what follows we attempt to better understand the interrelations between government R&D, private R&D, and productivity growth. The empirical analyses will concentrate on all the manufacturing industries of seven industrialized countries. Homogenous estimates across these countries will facilitate cross-country comparisons and should therefore give some clues towards the question of whether R&D subsidies either contribute directly to output growth and/or stimulate private R&D investments.

We first try to estimate the direct impact of R&D subsidies on productivity growth. If Levy (1990)'s argument that « *we cannot answer the question of what would be produced without R&D subsidies with this estimation strategy* » [p. 169] were right, we could have skipped that section. However, we have some reservations about the idea that government support can be employed at zero cost. In order to benefit from R&D subsidies, firms have to lobby, to prepare R&D projects, and to compete with other firms. All those activities aimed at attracting government support are associated to substantial costs. These costs are undoubtedly lower than the full private costs for the supported project and may partly explain why some studies do estimate positive direct impacts of government R&D on output growth which are much weaker than the impact of privately-funded R&D. The question about the potential « *indirect* » effectiveness of R&D subsidies, via the stimulation of private R&D investments, is then tackled.

3. SOME NEW EVIDENCE IN THE LIGHT OF THE INTEGRATED ASSESSMENT SCHEME:

3.1. The impact of R&D subsidies on the productivity growth of industries

The left-hand side variable in our empirical model is the total factor productivity growth rate. The right-hand side variables are industry dummies ($\alpha_{0,j}$) and time dummies (λ_t) and the ratio of the increment of the total R&D capital stock to value added. The parameter ρ^n in equation (5) is the net excess rate of return to total R&D. Equation (6) is similar to equation (5), with total R&D disaggregated into *SP* and *SG* which stand for the private R&D capital stock and the government R&D capital stock, respectively.

$$\dot{TFP}_{j,t} = \sum_j \alpha_{0,j} + \sum_t \lambda_t + \rho_h^n \left[\frac{\Delta\, ST_{j,t}}{Q_{j,t}} \right] + \varepsilon_{j,t} \quad (5)$$

$$\dot{TFP}_{j,t} = \sum_j \alpha_{0,j} + \sum_t \lambda_t + \rho_P^n \frac{\Delta\, SP_{j,t}}{Q_{j,t}} + \rho_G^n \frac{\Delta\, SG_{j,t}}{Q_{j,t}} + \varepsilon_{j,t} \quad (6)$$

The estimation of these models are based on balanced panels composed of about 22 industries at 3 or 4 ISIC-digits in seven industrialized countries (USA, Japan, Canada, France, Germany, Italy, and the United Kingdom). All the variables are expressed in constant 1980 US$. *Q* is the output indicator proxied by value added and is deflated by sectoral production price indices (1980=100).

The total factor productivity growth (*TFPG*) of each industry *i* at time *t* (t = 1980, ..., 1990) is computed as follows:

$$TFPG_{it} \equiv \ln V_{it} - \ln V_{it-1} - \hat{\alpha}_{it} (\ln L_{it} - \ln L_{it-1}) - (1 - \hat{\alpha}_{it}) (\ln K_{it} - \ln K_{it-1}) \qquad (7)$$

V, *L*, and *K* are respectively the value added, the number of employees, and the fixed capital stock. α is the share of total labor compensations in value added. These variables have been constructed from data drawn out from the OECD-STAN database. All the variables (except for the number of employees) are expressed in constant 1980 US $. The value added is deflated by country- and industry- specific production prices which are also available in the OECD-STAN database. *K* is the fixed capital stock generated by the perpetual inventory method. The annual flows of fixed investments are deflated by national gross fixed capital formation deflators (1980=100) as presented in the OECD's National Account Surveys. Industry- and country-specific depreciation rates come from Blades (1991). The average annual growth rate, which precedes the benchmark year, covers the period 1973-1978.

We have applied the perpetual inventory method to estimate *ST*, the total R&D capital stock, on the basis of R&D investments, deflated by the Gross Domestic Product Price Index (1980=100) of countries as established by the OECD's National Account Surveys. The R&D investment series come from the OECD-ANBERD data base. Nearly all empirical studies do not consider any lag and most of them use a 0% depreciation hypothesis or, to a lesser extent, a 10 to 20% depreciation rate common across industries, despite the fact that industries can be expected to face with different R&D depreciation rates. Consequently, we have assumed that different depreciation rates prevail in each sector. Further, industry-specific lags between R&D activities and the productivity growth they cause are taken into account. To do that, we have used the industry-specific lags and depreciation rates that have been published for the Japanese industries in 1985 by the Japan Science and Technology Agency. The same methodology has been used in order to compute the government R&D capital stock (*SG*) and the private R&D capital stock (*SP*) from the series of government R&D investments and private R&D investments respectively. [3]

[3] cf. Van Pottelsberghe and Panitch (1997) for a description of the evaluation procedure for missing data.

The impact of total R&D and the differentiated impacts of privately-funded and publicly-funded R&D on the growth of total factor productivity are displayed in Table 4. The net rates of return to total R&D range from non significant estimates for the UK, Canada, and Italy to 272% for Japan. Columns *(ii)* and *(iii)* show the estimates of the rates of return to private and government R&D, respectively. Surprisingly, neither the net private R&D intensity nor the net government R&D intensity significantly contribute to output growth. Given the existing empirical evidence of this type one would have expected the estimated rate of return to private R&D to be higher than, or at least equivalent to, the rate of return to total R&D. The estimates of the impact of private R&D, although generally insignificant, are always higher than the estimates of the impact of government R&D. These insignificant results are a very weak confirmation that the contribution of private R&D to productivity growth is more efficient than government R&D.

Table 4.

The net rates of return to total, private and government R&D (1980-1990)[1].

		(i)	*(ii)*	*(iii)*	*(iv)*
USA,	Total R&D	.275 *(.150)**			
nobs= 231	Private R&D		.428 *(.286)*		.390 *(.299)*
	Government R&D			.184 *(.216)*	.102 *(.224)*
	Adjusted R^2	.486	.483	.479	.481
Canada,	Total R&D	.214 *(.241)*			
nobs= 198	Private R&D		.068 *(.328)*		.047 *(.335)*
	Government R&D			-.321 *(.357)*	-.334 *(.371)*
	Adjusted R^2	.534	.532	.544	.542
Germany,	Total R&D	1.189 *(.334)**			
nobs= 242	Private R&D		.543 *(.337)**		-.045 *(.348)*
	Government R&D			-.704 *(.446)*	-.694 *(.453)*
	Adjusted R^2	.511	.512	.508	.506
France,	Total R&D	1.322 *(.544)**			
nobs= 220	Private R&D		.278 *(.494)*		1.360 *(.715)**
	Government R&D			-.547 *(.363)*	.210 *(.256)*
	Adjusted R^2	.383	.351	.369	.383
Italy,	Total R&D	.470 *(.322)*			
nobs= 198	Private R&D		-.286 *(.547)*		-.546 *(.587)*
	Government R&D			-.364 *(.304)*	-.391 *(.321)*
	Adjusted R^2	.415	.434	.415	.436
Japan,	Total R&D	2.720 *(.859)**			
nobs= 220	Private R&D		1.314 *(.853)*		2.839 *(.907)**
	Government R&D			.845 *(2.08)*	2.422 *(2.20)*
	Adjusted R^2	.488	.470	.455	.397
UK,	Total R&D	-.110 *(.222)*			
nobs= 231	Private R&D		-.380 *(.282)*		-.291 *(.292)*
	Government R&D			.333 *(.227)*	.272 *(.235)*
	Adjusted R^2	.489	.493	.494	.494

1. Within estimates, including time dummies. The estimated models correspond to equations (5) and (6). For each regressions, 4 to 9 outlying observations have been identified through a bounded influence procedure, their potential effect on the estimates is cancelled through an appropriate dummy variable (cf. Van Pottelsberghe (1997) for more information on this procedure). Standard errors between parentheses. * the estimated parameters are significantly different from zero at a 10% probability threshold.

When the two variables are included simultaneously into the regression equation, column *(iv)* shows that the private rate of return to R&D is high and significant only in France and Japan, whereas the return to government R&D is non significantly different from zero. For the other five countries none of the two variables is associated to a significant impact on output growth.

In short, the average estimates do not confirm the main findings which emerge from the existing literature. Indeed, we observe that private R&D has not a higher impact on productivity growth than total R&D. Yet, publicly-funded R&D, as expected, does not seem to contribute directly to the growth of output. Why are these results different from those presented in the existing literature? A first explanation might be related to the fact that the estimates presented in Table 4 are the first attempt, to our knowledge, to measure the differentiated impact of the two sources of funds on the basis of a cross-section time series database. The temporal dimension of our dataset is a potential source of multicollinearity bias between the government and private R&D variables. The literature at the industry-level has exclusively focused on cross-section estimates and is therefore less subject to these biases.

Second, disaggregating total R&D in its two main sources of funds is probably not an optimal approach when evaluating the relative efficiency of government R&D, because *« a dollar is a dollar, irrespective of source »*. Griliches (1979) suggests that at the industry level one may expect some differences in the rates of return to private and government R&D because of the more acute spillovers generated by government R&D. However, the total knowledge - rather than government knowledge - generated through the total R&D activities of a firm is more likely to spill over and benefit to other firms in highly subsidized industries. Indeed, one can hardly imagine that the innovative output of a firm, whatever the subsidization rate, can be radically splitted into 'private' knowledge and 'government' knowledge. The conceivable inefficiency of publicly-funded R&D in the production process, although much less accredited by our results than by the existing literature, still raises the question of whether or not the allowance of such subsidies is necessary. In the next subsection the hypothesis of an indirect positive effect of government R&D on output growth, through the stimulation of private R&D investments, is tested.

3.2. The impact of R&D subsidies on private R&D investments

In this subsection we analyze the econometric results obtained by Capron and Van Pottelsberghe (1997b). Three out of the five empirical issues which have been put forward in the survey summarized in Table 2 have been taken into account in the present study[4]:

1st issue: The sign of the impact of government R&D on private R&D may vary across industries.

2nd issue: Introducing a dynamic feature in the empirical model may modify substantially the sign and the significance of the estimated relationship between government and private R&D.

4th issue: There is most likely a simultaneity bias, across firms or industries, between government and private R&D.

In order to gauge empirically the link between private (*RP*) and government (*RG*) R&D, a traditional approach has been adopted. It consists in estimating the impact of R&D subsidies and other determinants on the private decision to invest in R&D activities. The main difference with the dataset used for the production function approach is that there is no need for data on gross capital formation, employment, and wage compensations. The available dataset covers an eighteen years period beginning in 1973 and ending in 1990. This higher degree of freedom allows to estimate a relationship between government and private R&D for each industry. In addition, the aggregate industrial sector is available. The regression equation has the following form for a given industry or for the aggregate industry sector over the seven countries:

Model 2: $$rp_{i,t} = c_i + \lambda \; rp_{i,t-1} + \gamma_i \; rg_{i,t} + \varphi \; q_{i,t} + \varepsilon_{i,t} \qquad (8)$$

where *c* is a constant term and ε is the error term. The lower case letters *rp*, *q*, and *rg*, are the natural logarithm of private R&D, total sales, and R&D subsidies. *t* indexes the years 1974 to 1990. The parameters λ, φ, and γ are respectively the adjustment coefficient and the private R&D elasticities with respect to the two corresponding exogenous variables. Total sales seem to be one of the main determinants of private R&D; an increase in output means that more funds may be injected in research activities. In accordance with the second issue, a dynamic specification has been adopted because R&D activities are obviously a continuous process.

[4] The third issue presented in the second section is related to the the first one in the sense that it gives one of the factors which may induce a substitution relationship between *RP* and *RG*: even if a company is stimulated by R&D subsidies, the other companies of the sector might react negatively and the aggregate industry effect of a subsidy may therefore be negative. The fifth issue is not taken into account in the present analysis because we cannot disaggregate total sales into sales to government and other sales.

Therefore, the amount invested in year t should depend, at least partly, on the amount spent the previous year RP_{t-1}. R&D projects last several years so that the inclusion of RP_{t-1} appears to be a parsimonious way to identify the feedback effect of past on current spendings. This model can be considered as a generalized version of the private R&D models in Table 3. The observations for each industry have been piled up for the 7 countries, forming a panel dataset composed of 119 observations. All the parameters, except the intercept c and γ, are constrained to be equal across countries.

How restrictive are the cross-countries equality constraints on the parameters? Concerning the parameters associated with the lagged dependent variable (λ) and total sales (φ) it can be expected that they have similar positive values across countries. However, in accordance with the first issue, the sign of the parameter associated with R&D subsidies is a priori not predictable. Concerning the intercepts, we can suspect that there is an international heterogeneity, temporally persistent, generated by country-specific features (such as appropriability conditions and technological opportunity, economic power, culture, and the national innovation system) which may act upon the investment decision. As far as these unobserved country differences are stable over time, they are taken into account by the country fixed effects.

In brief, four alternative empirical models have been used to evaluate the private R&D elasticity with respect to R&D subsidies. [5] The first one, *Model 1*, is the most often used in the literature, it does not take into account any adjustment process and is generally used to estimate long-term elasticities. The second one, *Model 2* (cf. equation (8)), includes an adjustment process and implicitly considers that government R&D has both short-term and long-term effects on private R&D. *Model 3* includes an adjustment process unrelated to R&D subsidies. It hypothesizes that the impact of government R&D is rather spontaneous and does not have any long-term effects, while the impact of output is allowed to have long-term impacts on private R&D investments. The fourth model assumes that both RG and Q have exclusively a short-run influence on RP.

The four models have been estimated with panel data techniques. We used an instrumental variable procedure that allows for *(i)* the potential autocorrelation of the error term due to the dynamic characteristic of the model; *(ii)* the potential presence of cross-sectional heteroscedasticity due to the fact that the disturbance variance might not be constant across the countries that form each panel data; and *(iii)* the potential presence of contemporaneous correlation of the disturbances across countries for a given industry. An alternative

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[5] Cf. Capron and Van Pottelsberghe (1997b) for a description of the various empirical models and their implications.

specification, which consists in adding time dummies into the regression equations, has the advantage of withdrawing the autocorrelation bias and reducing the cross-country heteroscedasticity and contemporaneous correlation of the error term. Yet, the presence of time dummies may also reduce the significance of the estimated parameters. This second econometric procedure, which incorporates time dummies, is limited two the two-stage least squares procedure that corrects for heteroskedasticity and contemporaneous correlation.

Table 5 provides a detailed summary of the econometric results estimated through *Model 3* or *Model 2*. When the parameters do not support the spontaneous hypothesis underlying *Model 3* for a given industry, the estimates obtained with *Model 2* have been preferred. This 'combined' summary of the empirical results classifies the estimates according to the countries and to four sub-aggregate groups of industries. The sub-aggregation reflects the quartile distribution of the average R&D intensity[6] of each industry across the seven countries. For instance, among the six high-tech industries in the USA, the estimated effect is positive for four industries, insignificant for one, and negative for one. Two comments may sum up these figures.

First, focusing on the last column of Table 5, a classification of the seven countries into three sub-groups emerges. The UK and Germany are the two countries in which R&D subsidies stimulate private R&D in more than half of the 22 manufacturing industries. In the two countries the effect of R&D subsidies is negative for only 20% to 27% of the industries. Then comes the group constituted by the USA and Japan, in which the impact of government R&D is insignificant for about half of the industries and positive in more than 35%. The last group, composed of Canada, Italy, and France, is characterized by a relatively high percentage (27% to 53%) of negative parameters which is larger than the percentage of positive coefficients. In the three countries, very few industries (10% to 26%) have a positive impact of R&D subsidies on private R&D.

Second, different reaction patterns also appear across the four sub-groups of industries, independently of the country of origin. In the medium-high and medium-low-tech industries, R&D subsidies have a stimulating impact in 42% to 53% of the industries, which is above the average of 38% obtained for all industries in all countries. It is worth noting that such generalization is subject to variation across countries. On average, however, one may infer

[6] The High-tech group includes Aircraft, Instruments, Office machines & computers, Electrical machinery, Electronic equipment & components, and Motor vehicles. The medium-tech-high group is composed of Chemicals, Drugs, Rubber & plastics, Machinery, and Other transports. The medium-tech-low group is composed of Petroleum refineries, Stone, clay & glass, Non-ferrous metals, Shipbuilding, and Other manufacturing. The low-tech group includes Food, drink, & tobacco, Textiles and clothing, Wood, and wood products, Paper & printing, Ferrous metals, and Fabricated metal products.

that R&D subsidies are more likely to be efficient in stimulating private R&D when they are directed towards medium-tech industries.

Do these estimates at the disaggregate industry level corroborate macroeconomic estimates? Table 6 provides some clues towards this issue. It presents the computed marginal impact of R&D subsidies on private R&D investments derived from the private R&D elasticities of R&D subsidies estimated at the aggregate manufacturing sector in Capron and Van Pottelsberghe (1997b). These values are the average amount invested by private decision-makers when they receive a $1 of R&D subsidies.

Table 5.

Number of positive, insignificant, and negative private R&D elasticities of R&D subsidies.

	High-tech.	Medium-high	Medium-low	Low-tech.	Total	%
USA +	4	2	1	2	9	43 %
USA 0	1	2	1	2	6	43 %
USA -	1	1	2	2	6	29 %
Canada +	1	0	2	0	3	17 %
Canada 0	4	3	0	3	10	56 %
Canada -	0	1	2	2	5	27 %
Germany +	1	3	5	4	13	59 %
Germany 0	1	0	0	2	3	14 %
Germany -	4	2	0	0	6	27 %
France +	0	1	1	0	2	10 %
France 0	2	3	1	4	10	50 %
France -	3	1	2	2	8	40 %
Italy +	1	1	1	2	5	26 %
Italy 0	1	1	2	0	4	21 %
Italy -	4	2	2	2	10	53 %
Japan +	0	3	3	1	7	35 %
Japan 0	5	1	1	4	11	55 %
Japan -	0	0	1	1	2	25 %
UK +	4	3	4	4	15	71 %
UK 0	0	1	0	1	2	10 %
UK -	2	0	1	1	4	19 %
TOTAL +	11	13	17	13	54	
TOTAL 0	14	11	5	16	46	
TOTAL -	14	7	10	10	41	
TOTAL +	28 %	42 %	53 %	33 %	38 %	
TOTAL 0	36 %	35 %	16 %	41 %	33 %	
TOTAL -	36 %	23 %	31 %	26 %	29 %	

Source: Derived from Capron and Van Pottelsberghe's (1997b) empirical results.

Since the private R&D elasticities of government R&D are not significantly different from zero for the US, Germany, and Japan, the marginal impacts of R&D subsidies are also assumed to be equal to zero. The first row shows that $1 of R&D subsidies yields a decrease in private R&D investments of 47 cents in Canada, of 57 cents in France, and of 69 cents in Italy. In the three countries, private R&D investors show a propensity to substitute R&D

subsidies for their own investments in R&D. Yet, these crowding-out effects are smaller than $1, which means that R&D subsidies do contribute to raise the amount of total R&D investments. In the UK, an increase in government R&D of $1 leads to an increase in private R&D investments of about 55 cents, which implies an increase of $1.55 in total R&D investments.

The complementarity between private and government R&D is a particular feature of the UK, as compared to the six other countries. This particularity might be an indication that an asymmetrical relationship, or a partial complementarity, is at work between private and government R&D. Since the early eighties, R&D subsidies in the UK have substantially decreased. Therefore, it may be that when subsidies fall, private R&D investors also decrease their investments. This positive relationship disappears, or is much less straightforward, when public support increases. This suggests that further research is needed to better understand the relationship between private and government R&D. Differentiated impacts should be tested according to the increasing or decreasing feature of R&D subsidies.

Table 6.

Marginal impact of government R&D on private R&D, at the aggregate industry level[1]

	USA	Canada	Germany	France	Italy	Japan	UK
Marginal impact (η) at the aggregate industry level	.00	**-.47**	.00	**-.57**	**-.69**	.00	.55
Weighted average of marginal impacts of the 22 industries	.22	**.04**	-.40	**-.59**	**-.27**	1.09	.94
Instability	.035	**.315**	.056	**.216**	**.329**	.186	.047

1. The marginal impacts (η) are computed from the estimated short run private R&D elasticities with respect to R&D subsidies (γ) in Capron and Van Pottelsberghe (1997b), as follows: $\eta = \gamma * (RP / RG)$. *RP / RG* is the ratio of private R&D on government R&D, averaged over the period 1973-90; the instability variable is the standard deviation of the annual growth rate of the R&D subsidization ratio (*RG / RT*) over the period 1973-90.

The second row shows the weighted average, across all industries, of the marginal impacts of R&D subsidies on private R&D. Because some industries receive much more subsidies than others, the marginal impacts are weighted by the share of each industry’ s government R&D in total government R&D to all industries. In France, Italy, and the UK the weighted averages corroborate somewhat the signs of the marginal impacts computed at the aggregate level. In Germany, only 6 out of the 22 industries have a negative reaction towards R&D subsidies. These industries account for much more than half of the total R&D subsidies granted to German industries, which explains why a $1 of government R&D yields, on average, a reduction of 40 cents in German private R&D investments. This result does not corroborate the insignificant marginal impact evaluated at the aggregate level. A similar observation holds for the US and Japan, where the average private R&D reactions towards R&D subsidies are positive, whereas the aggregate industry level estimates do not yield any significant reactions. Further, the Canadian industries seem to have a positive average answer to government R&D, although close to zero, which does not confirm the negative impact evaluated at the aggregate level.

It clearly appears from the comparison of the first two rows of Table 6 that the conclusions may substantially diverge according to the level of data aggregation considered (aggregate industrial sector *vs* weighted average of disaggregate industries). A potential explanation would be that there are important inter-industry effects. In this case, a large subsidy to a particular industry would either stimulate or inhibit private R&D investments in other industries, and particularly in those which are technologically or economically close to the subsidized industry. The results presented in Table 6 would therefore suggest that there are important inter-industry effects of R&D subsidization to industries. And these effects are negative in all countries (the weighted estimates at the disaggregate industry level are larger than the estimates at the aggregate industry level), but France and Germany. In France there is no substantial indirect impact of R&D subsidies, whereas in Germany R&D subsidies have a stimulating impact on other industries.

The last row of Table 6 gives an indication about the stability of the average subsidization rates over the period 1973-90. This indicator is relatively weak for the four countries where government R&D either stimulates or does not affect private R&D investments at the aggregate industry level. This means that the more stable a country's subsidization policy is, the less R&D subsidies are likely to supplant private R&D investments. Would this observation hold across the industries of a particular country?

Table 7 aims at further investigating the factors which may influence the response schemes of private R&D investments to R&D subsidies. For each country, it presents regression parameters estimated across the 22 industries with the estimated private R&D responses to government R&D as dependent variable (i.e., the private R&D elasticities with respect to government R&D for each industry). The three explanatory variables are the average R&D subsidization rate, the average R&D intensity, and an indicator of R&D subsidization instability. The indicator of instability for each industry is the standard deviation of the R&D subsidization ratio's annual growth rates over the period 1973-90. The regression equation for each country is expressed as follows:

$$\gamma_{0,j} = c + \beta_1\ GT_j + \beta_2\ IR_j + \beta_3\ STAB_j + \varepsilon_j\ , \qquad j = 1, ..., 22 \qquad (9)$$

where j denotes the industries, GT is the average R&D subsidization rate ($GT = RG / RT$) of each industry over the period 1973-1990, IR is the average R&D intensity ($IR = RT / Q$), and $STAB$ is an indicator of R&D subsidization (in)stability computed by taking the standard deviation of the annual growth rate of the R&D subsidization ratio over the period 1973-1990. γ_0 is the estimated private R&D elasticity of government R&D and the β's are sensitivity parameters of the response profiles to government R&D with respect to the three explanatory variables.

The R&D subsidization variable in included in order to appreciate whether there are decreasing returns associated to government R&D. A negative β_1 would mean that the more subsidized an industry is, the less it is likely to be stimulated by additional R&D subsidies. The R&D intensity variable intends to test whether high-tech industries adopt particular response schemes. Finally, we expect a negative sign for the parameter associated with the indicator of R&D subsidization stability. In order to test whether the econometric results are stable across the different specifications retained, the response schemes estimated through the different models are alternatively introduced as left-hand side variables.

The econometric results, presented in Table 7, show that the determinants of the response profiles to government R&D may vary across countries. For instance, the average R&D subsidization rate variable is associated with a significant negative coefficient in France while it is positive in the UK, with all the models. The more subsidized a French or Japanese industry is, the more the impact of R&D subsidies on private R&D is likely to be weak or negative (depending on the econometric procedure for Japan). This tends to support the view that R&D subsidies may be exposed to the law of decreasing returns (or effectiveness).

For the UK, the coefficients are positive which means that, in this country, the more subsidized an industry is, the more R&D subsidies are likely to be efficient in stimulating private R&D. In the other four countries, no inference can be made regarding the link between the response profiles and the subsidization rate. The R&D intensity variable is associated with a coefficient which is either negative like in the US and Germany, or insignificant like in the other five countries. Therefore, among the US and German industries, the more R&D intensive an industry is, the less it is likely to be stimulated by government R&D.

Turning now to the instability variable, its influence on the response profiles is more homogenous across countries. The estimated parameters are negative and significant for the USA, Canada, Italy, and the UK, which gives an additional indication that the more unstable an industry's R&D subsidization rate is, the less R&D subsidies in this industry are likely to be efficient in promoting private R&D investments. In Germany and Japan the parameters are also negative but insignificant, and in France it is insignificantly positive which does not allow for any policy prescriptions. We may infer that, on average, the more volatile a R&D subsidization rate is, the weaker the efficiency of R&D subsidies.

Table 7.
The determinants of the private R&D investments response to R&D subsidies[1]

Estimation procedure	IV-2SLS				TD-2SLS	
Model	[1]	[2]	[3]	[4]	[3]	[4]
USA, n = 21						
Instability	-.372 *	-.364 *	-.508 *	-.530 *	-.287 *	-.379 *
	(.177)	*(.148)*	*(.179)*	*(.186)*	*(.120)*	*(.165)*
RG / RT	.607 *	.473	.658	.690	.204	.029
	(.324)	*(.314)*	*(.470)*	*(.433)*	*(.173)*	*(.311)*
RT / Q	-.008	-.021 *	-.028 *	-.028 *	-.021 *	-.026 *
	(.012)	*(.009)*	*(.015)*	*(.014)*	*(.005)*	*(.011)*
Adjusted R^2	.303	.304	.335	.330	.204	.224
Canada, n = 18						
Instability	-.364 *	-.392 *	-.466 *	-.472 *	-.344	-.566 *
	(.187)	*(.147)*	*(.119)*	*(.130)*	*(.226)*	*(.167)*
RG / RT	-.350	-.524	-.386	-.424	-.590	-.115
	(.751)	*(.577)*	*(.268)*	*(.281)*	*(.811)*	*(.375)*
RT / Q	.016	.002	-.025	-.020	.004	-.036 *
	(.021)	*(.015)*	*(.015)*	*(.015)*	*(.020)*	*(.021)*
Adjusted R^2	.146	.274	.456	.415	.000	.432
Germany, n = 22						
Instability	-.051	-.373	-.379	-.351	-.268	.130
	(.355)	*(.421)*	*(.687)*	*(.679)*	*(.485)*	*(.701)*
RG / RT	-.879 *	.070	.404	.356	.488	.182
	(.457)	*(.497)*	*(.651)*	*(.653)*	*(.850)*	*(.565)*
RT / Q	-.087 *	-.054	-.049 *	-.043	-.075 *	-.043 *
	(.020)	*(.022)*	*(.027)*	*(.027)*	*(.033)*	*(.023)*
Adjusted R^2	.657	.201	.051	.015	.252	.144
France, n = 20						
Instability	.044	.027	.023	.019	.146	-.032
	(.192)	*(.110)*	*(.326)*	*(.331)*	*(.108)*	*(.365)*
RG / RT	-2.504 *	-1.464 *	-3.159 *	-3.187 *	-1.812 *	-3.016 *
	(.875)	*(.531)*	*(1.801)*	*(1.799)*	*(.825)*	*(1.758)*
RT / Q	.027	.020	.055	.055	.017	.039
	(.039)	*(.024)*	*(.085)*	*(.085)*	*(.039)*	*(.081)*
Adjusted R^2	.659	.637	.371	.379	.543	.373
Italy, n = 18						
Instability	-.296 *	-.239 *	-.172	-.192	-.208	-.153
	(.146)	*(.100)*	*(.110)*	*(.119)*	*(.143)*	*(.105)*
RG / RT	-.848	-.833	-.838	-1.133	-.377	-.869
	(.642)	*(.658)*	*(.608)*	*(.844)*	*(.805)*	*(.687)*
RT / Q	.031	.013	.039	.056	-.013	.034
	(.051)	*(.050)*	*(.051)*	*(.066)*	*(.063)*	*(.057)*
Adjusted R^2	.129	.188	.084	.099	.000	.047
Japan, n = 20						
Instability	-.040	.000	-.034	-.018	.044	-.000
	(.075)	*(.046)*	*(.032)*	*(.027)*	*(.117)*	*(.037)*
RG / RT	-1.807 *	-.755	-.232	-.220	-5.585 *	-2.056 *
	(.964)	*(.531)*	*(.284)*	*(.261)*	*(1.899)*	*(.750)*
RT / Q	-.015	-.008	-.005	-.007	.014	.001
	(.011)	*(.007)*	*(.008)*	*(.006)*	*(.022)*	*(.009)*
Adjusted R^2	.391	.190	.000	.000	.789	.720
UK, n = 21[2]						
Instability	-.613 *	-.657 *	-1.265 *	-1.379 *	-.462 *	-1.057 *
	(.218)	*(.150)*	*(.269)*	*(.312)*	*(.235)*	*(.308)*
RG / RT	-.003	.503 *	.926 *	.880 *	.951 *	.926 *
	(.997)	*(.257)*	*(.276)*	*(.388)*	*(.500)*	*(.401)*
Adjusted R^2	.049	.382	.577	.511	.152	.405

1. The dependent variables are the estimated private R&D elasticities with respect to R&D subsidies obtained by Capron and Van Pottelsberghe (1997b) for each industry ,according to four empirical models and two estimation procedures. The first estimation procedure, IV-2SLS, is an instrumental variable and two stage least squares procedure; the second procedure is 2SLS, with time dummies introduced into the model. These parameters are obtained through OLS estimates, standard errors are heteroskedastic-consistent. *RG/RT* is the average R&D subsidization rate, *RT/Q* is the average R&D intensity; the instability parameter is the standard deviation of the annual growth rate of the R&D subsidization ratio. These explanatory variables are computed over the period 1973-90 for each industry. **2.** For the UK, the R&D intensity has been removed from the regression because of a high correlation with the R&D subsidization ratio. * the estimated parameter is significantly different from zero at a 10% probability threshold.

6. POLICY RECOMMENDATIONS

The econometric analysis presented in this paper leads to four main conclusions which do not validate the suspicious stance, generally taken up in the literature, against R&D subsidies:

- We cannot reach the conclusion that the impact of privately-funded R&D on productivity growth is significantly higher than the impact of publicly-financed R&D. Further, private R&D is not associated to higher, or even equivalent, returns than total R&D. In fact, only total R&D is associated to significant rates of return. In the context of a production function framework, these results suggest that the disaggregation of total R&D into its two main sources of funds might not be an appropriate approach when panel data are used, because *a dollar is a dollar*...

- R&D subsidies may stimulate or inhibit private R&D investments depending on the countries and/or the industries considered. In any case, they always contribute to raise total R&D investments.

- The impact of R&D subsidies on private R&D investments evaluated at the aggregate level is lower than the weighted average of the impacts measured for all disaggregate industries, suggesting that important negative interindustry effects are at work.

- The cross-industry and cross-country differences in the private R&D investment response profile to R&D subsidies may be explained, at least partly, by the degree of volatility of the subsidization policy. The more unstable a subsidization rate is, the less an increase in R&D subsidies is likely to stimulate private R&D investors.

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