DOES GOVERNMENT SUPPORT STIMULATE PRIVATE R&D?

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The authors are grateful for comments and suggestions from Thomas Andersson, Dirk Pilat and Dave Turner. We are indebted to Jacek Warda who kindly provided the B-indexes and to Hélène Dernis and Brigitte van Beuzekom for their assistance.

INTRODUCTION

The economic justification for government support to business-funded research and development (R&D) is linked to the presence of "market failures" associated with R&D activities.[1] Two important market failures are imperfect appropriability conditions and risk. Imperfect appropriability, or the diffusion of knowledge, implies that the private rate of return to R&D is lower than its social return. Therefore, the amount invested by firms in research activities is likely to be below the socially optimal level. Risk associated with research requires a high risk premium. Consequently, external investors are reluctant to fund R&D projects, which is especially detrimental to new entrants and to small firms that face financial constraints. Public support to R&D aims to reduce these market failures.

Public authorities can support the innovative process in various ways. Framework conditions such as the educational and training system, infrastructure, the legal environment, and macroeconomic policies are important to support innovation. However, the two most focused policy instruments are government-funded R&D and fiscal incentives. Fiscal incentives are "horizontal" because they are available to all firms according to precise criteria. Government-funded R&D is rather "vertical" since it is selective, targeting projects which are selected by governments, either for their own needs or to support industry.

This paper investigates whether fiscal incentives and direct subsidies stimulated business-funded R&D in 17 OECD countries over the period 1981-1996. Several criteria can be used to measure the efficiency of government support to business R&D. Although the ultimate objective underlying such policies is to maximise social welfare, policy evaluations generally focuses on whether they stimulate private R&D investment.[2] The evaluation of the efficiency of the two main policy tools can thus be based on one main criterion: does government support induce an increase in total R&D activity beyond its cost, without generating other distortive impacts or new types of market failure?

The present investigation has four distinctive features compared with the existing literature. First, it is a multi-country and time series analysis, whereas most studies are based on cross sections of firms or industries within a particular country. Second, it incorporates simultaneously direct subsidies and fiscal incentives amongst the determinants of private R&D investment. Third, the empirical analysis tests for various specifications and econometric models. Fourth, several extensions of the basic model allow the elasticity of private R&D with respect to financial incentives to vary across countries according to the stability of their policies, their rate of subsidisation, the complementarity between the two policy tools, and the role of defence-oriented R&D subsidies.

The paper is structured as follows. The next section reports stylised facts of OECD governments' support to R&D in the business sector. It is followed by a short survey of the existing literature. The fourth section presents the empirical analysis, in three parts: the basic results, three sources of cross-country differences in the effectiveness of government support to business R&D, and the effect of defence-oriented government R&D. The final section draws some conclusions and policy implications.

COUNTRY PATTERNS

Government-funded R&D performed by business firms primarily consists of contracts and regular grants.[3] Other forms of support are loan guarantees, conditional loans, and convertible loans. However, as shown by Young (1998), government contracts and grants, and fiscal incentives, account for the bulk of government support to business R&D.

Fiscal incentives may take various forms, which make an international comparison problematic (see OECD (1998*a*) for a detailed examination). Most OECD countries allow for a full write-off of current R&D expenditures (depreciation allowances are deducted from taxable income). Amongst the 17 countries included in the present study, about one third also provide R&D tax credits. These are deducted from the corporate income tax and are applicable either to the level of R&D expenditures - flat rates - or to the increase in these expenditures with respect to a given base - incremental rates. In addition, some countries allow for the accelerated depreciation of investment in machinery, equipment, and buildings devoted to R&D activities.

The so-called "B-index", as defined by Warda (1996), gives a synthetic view of tax generosity. It is a composite index computed as the present value of before-tax income necessary to cover the initial cost of R&D investment and to pay the corporate income tax, so that it becomes profitable to perform research activities. Algebraically, the B-index is equal to the after-tax cost of a $1 expenditure on R&D divided by one less the corporate income tax rate. The after-tax cost is the net cost of investing in R&D, taking account of all available tax incentives:

$$\text{B-index} = \frac{(1-A)}{(1-\tau)},$$

where τ is the statutory corporate income tax rate (CITR) and A is the net present discounted value of depreciation allowances, tax credits, and special allowances on R&D assets (Annex 1 provides a complete description of the B-index). The underlying methodology is highly flexible and enables various types of tax treatment to be modelled in a comparable manner. The more generous a country's tax treatment of R&D outlays, the lower its B-index. A B-index equal to one means that, on average, R&D is neither taxed, nor explicitly subsidised through taxes. Projects with benefit-cost ratios higher (lower) than B are (not) profitable for the firm and are therefore (not) undertaken. The B-index is calculated at the economy-wide level, and therefore does not allow to distinguish the diversity of tax treatment for various types of firms (*e.g.* by size or by region). In the present investigation it has been assumed that the "representative firm'' is large and enjoys the full benefits from tax allowances or credits.

OECD countries' tax treatments and B-indexes are reported in Table 1 for the years 1981 and 1996. The most generous countries in 1996 are (in descending order) Spain, Australia, Canada, Denmark, the Netherlands, France, and the United States. The least favourable tax treatments are found in Germany, Norway and Italy, where the B-indexes range from 1.02 to 1.05. Large swings in the B-index have occurred in some countries over the last 16 years. Spain, the Netherlands, Australia, France, and Denmark substantially increased their tax concessions. At the opposite extreme, business firms in the United States, Sweden and, to a lesser extent, Italy (for large firms), have experienced a substantial deterioration in the fiscal treatment of their R&D activities. Although the increase of the B-index in the United States is quite significant, the fiscal treatment of R&D still ranks among the most generous. Finally, there have been drastic reductions in the corporate income tax rate (CITR) in most OECD countries over this period (only three countries raised it). In countries with relatively weak fiscal incentives for R&D investments, this fall in the CITR contributed in making the fiscal treatment of R&D activities more generous.

The share of government-funded R&D in the total funding of R&D performed by business firms has constantly decreased during the 1980s and early 1990s. The most drastic declines in the rates of subsidisation occurred in large countries with a long tradition of high government support for R&D, such as the United States, the United Kingdom, and France, especially during the late 1980s and early 1990s. Young (1998) shows that the drop in defence R&D largely explains the decline in these three countries. Some small countries have also markedly reduced government funding, such as Belgium, Denmark, and Norway. In these countries, the diminishing share of government R&D is more likely due to a decline in R&D for energy, agriculture, forestry, and fisheries.

Fiscal incentives and direct subsidies can be used as complements or as substitutes. There is no clear cross country pattern, however. Table 1 shows that

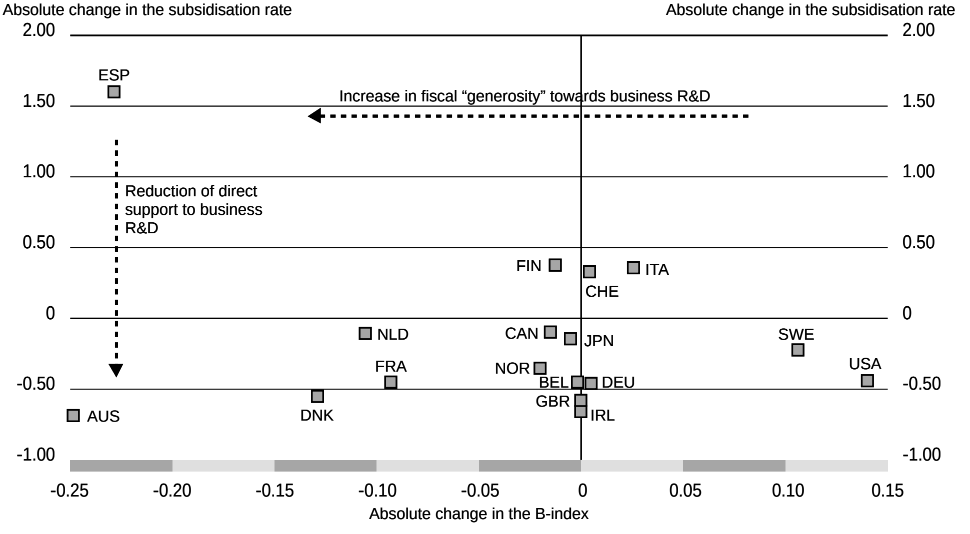
Table 1. **R&D tax treatment and subsidisation in OECD countries, 1996**

	R&D depreciation rate (%)			Tax credit base		Flexibility		Corporate income tax	B-Index	Subsidisation rate
	Current exp.	Machin. and equip.	Buildings	Level	Increm.	Special allowances	Credit taxable	1981-96 (%)	1981-96	1981-96 (%)
Australia	150	3 ys, SL	40 ys, SL					46-36	1.01-0.76	8-3
Belgium	100	3 ys, SL	20 ys, SL			13.5% (M)		48-40	1.01-1.01	8-4
Canada	100	100	4, DB	20%		(C, M, B)	yes	42-32	0.84-0.83	11-10
Denmark	100	100	100			25%		40-34	1.00-0.87	12-5
Finland	100	30, DB	20, DB					49-28	1.02-1.01	4-6
France	100	5 ys, SL or 40, DB	20 ys, SL		50%		no	50-33	1.02-0.92	25-13
Germany	100	30, DB	25 ys, SL					63-57	1.04-1.05	17-9
Ireland	100	100	100					10-10	1.00-1.00	14-5
Italy	100	10 ys, SL	33 ys, SL					36-53	1.03-1.05	9-12
Japan	100	18, DB	2, DB		20%	7% for high-tech (M)	no	55-51	1.02-1.02	2-2
Netherlands	100	5 ys, SL	25 YS, SL	12.5%		2% (M, B)	no	48-37	1.01-0.90	7-7
Norway	100	20, DB	5, DB					51-28	1.04-1.02	25-16
Spain	100	100	10 ys, SL	20%	40%		no	33-35	0.86-0.66	4-11
Sweden	100	30, DB	25 ys, SL					52-28	0.92-1.02	14-10
Switzerland	100	40, DB	8, DB					28-34	1.01-1.02	1-2
United Kingdom	100	100	100					52-33	1.00-1.00	30-12
United States	100	5 ys, DB	39 ys, SL		20%		yes	46-35	0.82-0.93	32-17

Note: These figures concern the tax treatment of large firms, which account for the bulk of total R&D investment in OECD countries. "ys" indicates the approximate number of years needed for a full depreciation of investment in machinery, equipment and buildings devoted to R&D activities. A level of 100 implies that the related expenditures can be fully depreciated during the year incurred. SL indicates a straight-line depreciation scheme, and DB a declining balance scheme. C, M, and B, are abbreviations for current expenditures, machinery, and buildings, respectively. The subsidisation rate is the share of government financed R&D in total business performed R&D.

Source: OECD, *Technology, Productivity and Job Creation-Best Policy Practices*, 1998.

Figure 1. ***Changes in fiscal and subsidisation policies, 1981-1996 (absolute changes)***



Source: OECD Secretariat.

some countries favour fiscal incentives, with relatively weak subsidisation rates (*e.g.*, Australia, Denmark, and the Netherlands), whereas others focus more on direct financial support than on tax concessions (like Norway, the United Kingdom, Italy, Sweden, and Germany). Among the remaining countries two groups can be distinguished. A first group made up of Canada, Spain, the United States and France, provides both high fiscal incentives and government funding. A second group of five countries, which includes Japan and Switzerland, has a low level of generosity for both policy tools.

An analysis of these two policy instruments in growth rates provides different insights. As shown in Figure 1 most OECD countries have substituted one tool for the other. Indeed, most countries have simultaneously reduced the B-index - *i.e.*, increased the level of tax concessions - and the subsidisation rate, thus substituting tax allowances for direct subsidies. Switzerland and Italy have substituted direct support to R&D for tax concessions. In a small number of countries, both types of incentives have evolved in the same direction (including Spain, Sweden, and the United States).

THE STATE OF THE ART

There has been no attempt thus far to test simultaneously for the effectiveness of both fiscal incentives and publicly funded R&D in stimulating business R&D. Rather, previous studies have focused either on the relationship between government R&D and business-funded R&D (see the survey by Capron and van Pottelsberghe, 1997), or the effect of fiscal incentives (see the survey by Mohnen, 1997). There appears to be a lack of empirical work at the macroeconomic level; most studies having been implemented at the firm or industry level.

The empirical evidence regarding the link between government and privately-funded R&D suggests that the two sources of funds are complementary. Guellec and Ioannidis (1998) find a positive and significant long-term effect of government R&D on private R&D, and most of the studies surveyed by Capron and van Pottelsberghe (1997) also estimate a positive impact of R&D subsidies. However, some studies suggest that the impact of government-funded R&D on privately-funded R&D might be negative in particular industries or countries.[4] These substitution effects are partial, however, as government funding always contributes to higher total R&D investment.

Government-funded R&D appears to be characterised by a negative inter (or intra) industry effect. Subsidies to a particular industry (or firm) may be stimulating in that particular industry, but may also crowd out business R&D investments in other, closely related, industries (or firms). Such negative spillover effects have been underlined by Mamuneas and Nadiri (1996), using a panel data set of US industries. One advantage of a macroeconomic analysis is that it implicitly takes these - negative or positive - spillover effects into account. Nevertheless, an aggregate approach does not provide any assessment of the efficiency of the cross industry allocation profiles adopted by public authorities. For instance, poorly directed government R&D outlays may crowd out business-funded R&D with a potentially greater economic or social impact.

Quantitative analyses of the effectiveness of R&D tax credits involves estimating a relationship between the volume of R&D and tax incentives. In these investigations, the elasticity of R&D with respect to tax incentives fluctuates between 0.07 and 2.7, the estimates being most frequently under unity. In general, it appears that tax incentives do not generate much R&D beyond the tax expenditures incurred by government. Quantitative analyses at the macroeconomic level might be better suited than micro-level ones to provide an insight into the economy-wide efficiency of fiscal policies. Such studies take account of the indirect effects that occur between firms or industries, although they miss firm-specific aspects. Based on a study for 8 OECD countries, Bloom *et al.* (1997) find a long-run elasticity of industry-funded and performed R&D with respect to the price of R&D of about - 1.0.[5]

EMPIRICAL EVIDENCE

This section provides empirical evidence on the stimulating effect of the two main policy instruments for government support to business R&D. The present work can be seen as an extension of Bloom *et al.* (1997), in four directions. First, it incorporates more countries (17 OECD countries, instead of 8). Second, the empirical exercise relies on more general empirical models and econometric methods. Third, government-funded R&D and fiscal incentives are included simultaneously amongst the determinants of privately-funded R&D. Fourth, more detailed policy aspects, including the interaction of the two policy tools and the effect of defence spending, are analysed.

Basic results

We rely on a simple R&D investment model that considers business-funded R&D as a function of output, government-funded R&D, tax incentives (summarised by the B-index), time dummies, and country-specific fixed effects.[6] Since research activities are subject to high adjustment costs, a dynamic specification that distinguishes short-run from long-run elasticities is required.[7] For this purpose, the basic model adopted here is similar to the one used by Guellec and Ioannidis (1998). It allows for an error correction mechanism by introducing the lagged dependent variable and the lagged exogenous variables. The generalised error correction model is written as follows:

$$\begin{aligned}\Delta RP_{i,t} = {} & \lambda\,\Delta RP_{i,t-1} + \beta\,\Delta VA_{i,t} + \beta_1\,\Delta VA_{i,t-1} + \gamma\,\Delta RG_{i,t} + \gamma_1\,\Delta RG_{i,t-1} + \alpha\,\Delta B_{i,t} + \alpha_1\,\Delta B_{i,t-1} \\ & \lambda_2 \ln RP_{i,t-2} + \beta_2 \ln VA_{i,t-2} + \gamma_2 \ln RG_{i,t-2} + \alpha_2 \ln B_{i,t-2} \\ & + \varsigma_i + \tau_t + e_{i,t} \qquad [1]\end{aligned}$$

where RP, VA, RG, and B, are respectively business-funded and -conducted R&D, business sector value added, government-funded R&D implemented in business firms, and the B-index as defined in Annex 1. The first three variables are expressed in US PPP$ and deflated with the business sector's GDP price index. The countries are indexed by i (=1, ..., 17), and the years 1983 to 1996 by t (= 1 ..., 14). Δ is the first (logarithmic) difference operator, and "*ln*" stands for natural logarithm. ζ and τ are country and time dummies, respectively. The country dummies control for the fixed effects included in the "*level*" variables. Time dummies are included to take account of common technology shocks among the OECD countries that are not controlled by the exogenous variables, such as the increasing use of information technology.

From the parameters included in specification [1], it is possible to derive a dynamic adjustment mechanism specific to each exogenous variable. For instance, the effects of government-funded R&D on business-funded R&D are $[\gamma + \gamma_1]$ or γ in the short-term (depending on whether "short-term" definition covers two or one year) and is [$-\gamma_2/\lambda_2$] in the long-term. The data on value added is derived from OECD (1997). Privately-funded R&D and direct R&D subsidies to business firms are taken from OECD (1998*b*). The B-index has been computed by the OECD secretariat from national sources.

Table 2 presents the panel data estimates of equation [1], alternatively with and without time dummies and correcting for the potential contemporaneous correlation of the error term across countries with the SURE method. All parameters are stable with respect to the introduction of time dummies into the equation (compare column 1 and 2). The Breush-Pagan test indicates that the error term of the OLS estimates is subject to significant contemporaneous correlation across countries.[8] As illustrated in column 2, value added, government R&D and tax incentives have significant short-term effects on business-funded R&D. The short-term private R&D elasticities with respect to these three variables are equal to 1.26, 0.06, and - 0.18, respectively. The long-term elasticities are 2.4 for value added, 0.22 for government R&D, and zero for the B-index.

The effect of fiscal incentives and direct subsidies are significant only with a one year lag. This indicates that policies aimed at fostering private R&D should not be expected to be effective in the year incurred. The reverse is true with the growth of value added, which has a contemporaneous effect, confirming that R&D is pro-cyclical. The relatively weak impact of fiscal incentives in the long run may mean that firms are not very sensitive in the long run to R&D price changes. Other factors, such as the overall strategy of the firm or financial constraints could have a larger impact. For instance, a reduction in prices may not be very stimulating if financial constraints persist. Finally, some countries have an incremental tax credit, which implicitly has short-term effects.[9]

In contrast, the effect of direct subsidies is rather weak in the short run and mainly occurs in the long run. The different time patterns of these two policies reflect two distinct mechanisms. Tax concessions may induce firms to enhance or to accelerate their current projects, while direct subsidies are generally focused on projects selected by government. Such new projects create new opportunities that may induce firms to start further research projects with their own money. This result is in line with Mansfield and Switzer (1984), who notice that performing companies have learned to form realistic expectations about future government support. As a result, they develop R&D proposals for the government in a way that takes account of their own R&D planning.

Subsidisation rates, stability, and substitutability

This section tests whether the estimated private R&D elasticity with respect to direct subsidies varies across countries according to their rate of subsidisation. It also evaluates the extent to which the impact of the two policy tools depends on

Table 2. **The impact of R&D tax credits and government-funded R&D on privately-funded R&D – Main results**

Regression #	Error Correction model, dependent variable is ΔRP_t	
	1	2
ΔRP_{t-1}	0.068*	0.073
	(1.66)	*(1.47)*
ΔVA_t	1.177***	1.259***
	(24.9)	*(19.9)*
ΔVA_{t-1}	0.110*	0.011
	(1.68)	*(0.13)*
ΔRG_t	0.004	–0.005
	(0.93)	*(–0.96)*
ΔRG_{t-1}	0.061***	0.059***
	(11.1)	*(10.1)*
ΔB_t	–0.034	0.011
	(–1.43)	*(0.43)*
ΔB_{t-1}	–0.171***	–0.183***
	(–5.02)	*(–5.47)*
$\ln RP_{t-2}$	–0.098***	–0.083***
	(–6.75)	*(–6.13)*
$\ln VA_{t-2}$	0.109***	0.200***
	(3.66)	*(4.87)*
$\ln RG_{t-2}$	0.016**	0.019***
	(2.91)	*(3.87)*
$\ln B_{t-2}$	0.038	0.040
	(1.07)	*(1.10)*
Country dummies	yes	yes
Time dummies	no	yes
B-P chi2 test	231.5	238.8
Adj-R2	0.444	0.477
Durbin-Watson	1.95	1.97

Note: The estimates cover 17 countries for the period 1981-1996 (233 observations), RP denotes business-funded R&D investment, VA value added, B the B-index, l*n* a natural logarithm, and Δ the first-log difference operator. All regressions are estimated with the SURE method (seemingly unrelated regression equation) that corrects for contemporaneous correlation of the error terms. B-P is the Breush-Pagan chi-squared test statistic which tests for the presence of contemporaneous correlation. T-statistics are shown in parentheses; *** indicates the parameters that are significantly different from zero at a 1 per cent probability threshold; ** at 5 per cent; and * at 10 per cent.

Source: OECD, *Economic Outlook 60* and *MSTI databases, 1998.*

their relative stability over time, and we investigate whether the effects of the two policy tools are complementary or substitute. These modifications of the basic model make it difficult to estimate a proper generalised ECM.[10] The following dynamic model (2) is therefore used. It is a simplified form of the ECM (1) where the adjustment mechanism is identical for all exogenous variables. It has the advantage of being more flexible with respect to slight changes of the private R&D equation:

$$\Delta RP_{i,t} = \lambda\, \Delta RP_{i,t-1} + \beta\, \Delta VA_{i,t} + \gamma_1\, \Delta RG_{i,t-1} + \alpha_1\, \Delta B_{i,t-1} + \tau_t + e_{i,t} \qquad [2]$$

This equation is a traditional first-difference autoregressive model.[11] The short and long-term effects of government-funded R&D are now [γ_1] and [$\gamma_1/(1-\lambda)$], respectively. The first column of Table 3 presents similar results to those in the last column of Table 2, except that the adjustment parameter, and hence the long-term effect, is constrained to be similar for all variables. As before, the Breush-Pagan test shows that the SURE method has to be used. In comparison with the error correction model of the second column of Table 2, the short-term elasticities are broadly similar. In contrast, the long-term elasticities are different from those estimated with the previous model (corresponding elasticities shown in brackets): 1.54 [2.40] for value added, 0.09 [0.22] for government R&D and - 0.36 [0.00] for the B-index. The constrained dynamic model seems to provide reliable estimates of short-term effects but is apparently less reliable for deriving long-run elasticities - *i.e.* the adjustment process varies across the exogenous variables.

The second column of Table 3 differentiates the impact of government R&D for four subgroups of countries with respect to their average rate of subsidisation. It appears that the highly subsidised countries have an insignificant elasticity of R&D with respect to government-funded R&D. The countries in an intermediate position have the highest elasticity (about 0.06), whereas it is slightly lower (0.05) for the countries with a low subsidisation rate. These results suggest that the impact of direct subsidies is first stable or slightly increasing with the subsidisation rate, and falls when it reaches a certain threshold. In order to test for this inverted U-curve describing the relationship between government and privately financed R&D, the estimated private R&D elasticity of government R&D is allowed to vary across countries, depending non-linearly on the subsidisation rate, α_1 and α_2 being the parameters of interest:

$$\gamma_{i,t} = \alpha_1\, x_{i,t} + \alpha_2\, x_{i,t}^2, \qquad [3]$$

where $$x_{i,t} = \frac{RG_{i,t}}{RT_{i,t}}.$$

The results of this quadratic specification are reported in the third column of Table 3. They suggest that the private R&D elasticity with respect to government support increases with the subsidisation rate up to a maximum threshold of 15 per

Table 3. **Subsidisation rates, stability of the schemes, and substitutability**

Regression #	Error Correction model, dependent variable is ΔRP_t						
	Subsidisation rate			Instability	Substitutability		
	1	2	3	4	5	6	7
ΔRP_{t-1}	0.327***	0.330***	0.320***	0.316***	0.303***	0.297***	0.305***
	(9.29)	*(9.16)*	*(9.48)*	*(8.96)*	*(9.30)*	*(8.63)*	*(8.84)*
ΔVA_t	1.036***	1.053***	1.003***	1.053***	1.016***	0.985***	1.038***
	(16.71)	*(16.11)*	*(17.65)*	*(16.51)*	*(17.15)*	*(17.63)*	*(17.2)*
ΔRG_{t-1}	0.056***			0.068***	0.058***		0.056***
	(9.00)			*(7.70)*	*(11.51)*		*(9.32)*
ΔB_{t-1}	–0.242***	–0.244***	–0.247***	–0.902***		–0.194***	–0.172***
	(–5.25)	*(–5.33)*	*(–4.87)*	*(–4.120)*		*(–4.067)*	*(–4.37)*
ΔRG_{t-1}* DGT-*high*		–0.037					
		(–1.62)					
ΔRG_{t-1}* DGT-*medium high*		0.059**					
		(2.62)					
ΔRG_{t-1}* DGT-*medium low*		0.063***					
		(8.15)					
ΔRG_{t-1}* DGT-*low*		0.047**					
		(2.47)					
ΔRG_{t-1}* (GT_{t-1})			1.053***				
			(6.66)				
ΔRG_{t-1}* $(GT_{t-1})^2$			–3.425***				
			(–3.48)				
ΔRG_{t-1}* GT-				–7.748**			
				(–2.00)			
ΔB_{t-1}* B-				4.029***			
				(3.248)			
ΔRG_{t-1}* ΔB_{t-1}					1.312***	0.879***	0.941***
					(7.86)	*(3.80)*	*(5.33)*
Adj-R2	0.416	0.410	0.414	0.412	0.414	0.395	0.423
Durbin-Watson	2.08	2.08	2.08	2.05	1.97	1.94	1.97

Note: The estimates cover 17 countries for the 1981-1996 period (216 observations). The variables are expressed in first differences of logarithms (growth rates). RP denotes business-funded R&D investment, VA value added, B the B-index, and GT the subsidisation rate. DGT-*high* = a dummy variable that takes the value of one for the countries whose average subsidisation rate is over 19 per cent and 0 otherwise, DGT-*medium high* [11-19 per cent], DGT-*medium low* [6-11 per cent], DGT-*low* [0-6 per cent[(see Table 4). All regressions are estimated with the SURE method and include an intercept and time dummies. T-statistics are shown between parentheses; *** indicates the parameters that are significantly different from zero at a 1 per cent probability threshold; ** at 5 per cent; and * at 10 per cent.

Source: OECD, *Economic Outlook 60* and *MSTI databases, 1998.*

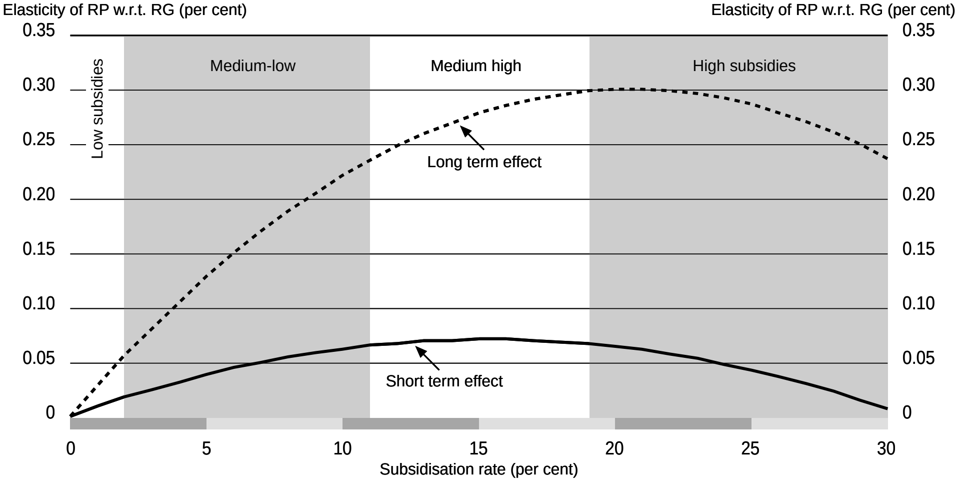
cent, then decreases with the subsidisation rate, and becomes negative after a threshold of 30 per cent. Two concerns can be raised with respect to this non-linearity. First, is it an artefact of the particular specification adopted? Second, is it also robust in the longer run?

Regarding the first point, it can be argued that the variation across countries of the private R&D elasticities with respect to government R&D simply reflects a constant marginal effect (or return) of R&D subsidies across countries. Indeed, a constant elasticity implies that the additional dollar stimulus to private R&D for each additional dollar spent - *i.e.* the marginal effect of R&D subsidies - decreases with the rate of subsidisation. By the same token, an elasticity varying across countries could translate into constant marginal effects.[12] The product of the estimated elasticities (columns 1 and 2 in Table 3) and the ratio of private R&D to government R&D shows that one dollar of R&D subsidies induces an average increase of 45 cents in private R&D investment. This marginal effect varies across countries, from a negative marginal effect of 16 cents amongst the highly subsidised countries, to a positive 39 cents and 58 cents for "medium-high" and "medium-low" subsidised countries, respectively, to no effect for the lowly subsidised countries. The validity of these estimates is confirmed by columns 1 to 3 of Annex Table A1, which present estimates of marginal impacts.[13] These results are qualitatively similar to those obtained from the estimation of elasticities in Table 3, and confirm the non-linearity of the stimulation effect of government R&D. In particular, the inverted-U shape (column 3 in Annex Table A1) denotes a maximum return at a 14 per cent subsidisation rate and negative returns over a threshold of 27 per cent.

To investigate the second concern, the validity of these findings is tested for the long-term. Two different types of specification are estimated within an ECM framework: one identical to the basic specification [1], where the parameters are elasticities; and a second one where the parameters are marginal effects. The results are presented in Annex Table A1, columns 4 to 7. The first specification, where the ECM is applied to the basic specification [1], with both the short-term and long-term coefficients differentiated across four subgroups, confirms (columns 4 and 5 in Annex Table A1) that the lowly subsidised countries are characterised by a zero impact of government R&D, and that the highly subsidised countries are characterised by a weaker effect than those that provide a medium level of subsidies.

The second test applies an ECM where both the right-hand side and left-hand side variables of equation [1] - except the B-index - have been divided by value added. The results, presented in columns 6 and 7 of Table 3, are qualitatively similar in nature to the previous ones: R&D subsidies have a non-linear effect on private R&D investment, that is much weaker when the subsidisation rate is too low or

Figure 2. ***Estimated elasticity of private R&D with respect to government subsidies and its dependence on the initial level of subsidy***

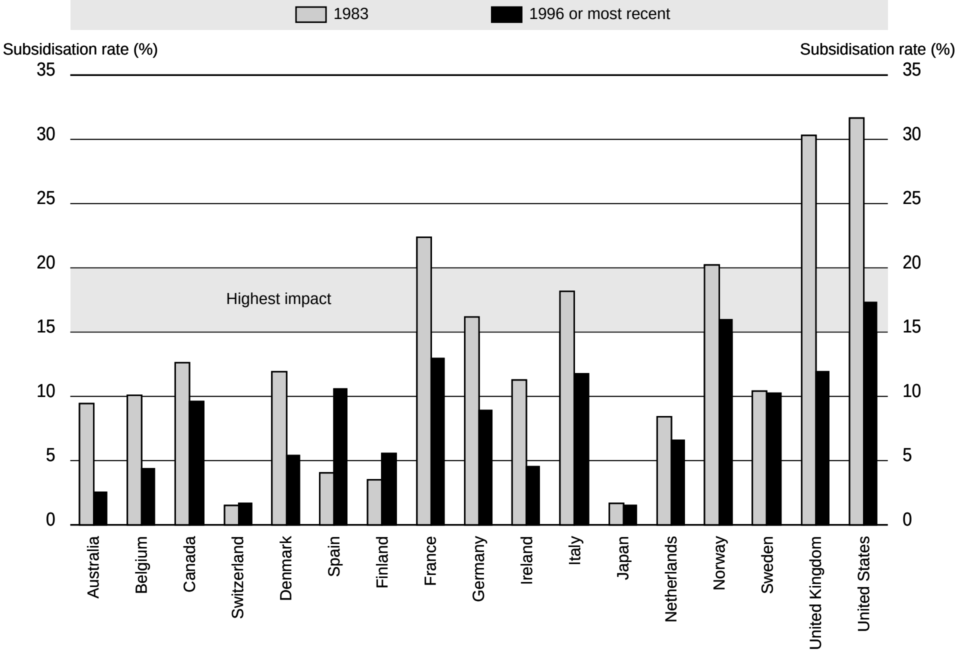


Note: The two curves depict the elasticities of private R&D with respect to government R&D estimated through the quadratic model (see equation 3). The parameters in column 8 of Annex Table A1 provide the long-term impact, while column 3 of Table 3 provides the parameters for the short-term impact.

too high. The group of countries with the highest long-term impact is those that provide a medium-high level of subsidies; comprising countries with an average subsidisation rate of 15 per cent and ranging from 11 per cent to 19 per cent. Finally, the parameters estimated through the quadratic specification, displayed in column 8 of Annex Table A1, suggest that the highest long-term impact of government R&D on private R&D is reached at a subsidisation rate of about 20 per cent.

Figure 2 illustrates the inverted-U shape of the elasticity of private R&D with respect to government R&D in the short-term and the long-term. It appears that the highest impact is reached for the countries that are in the medium-high class - *i.e.* with an average subsidisation rate ranging from 11 to 19 per cent. Figure 3 provides the position of each individual country regarding their subsidisation rates in 1983 and in 1996 (or the most recent available year). In 1996, the countries that might expect the highest stimulating effects of their subsidies are the United States, the United Kingdom, France, Italy, and Norway. In Switzerland and Japan, the R&D subsidisation rates are so low (under two per cent over the whole period) that no significant impact of government-financed R&D on private R&D investments can be expected. In the early eighties, business firms in the United States and the United Kingdom were so highly subsidised that they may have substituted

Figure 3. ***Subsidisation rates in 1983 and 1996***
Per cent



Source: *Cf.* Table 1.

government R&D for private funds. Alternative empirical results, presented in Annex Table A1, show that this non-linear relationship is robust to the specification used - *i.e.* to the estimate of elasticities or marginal impacts - and holds in both the short-term and long-term.

The effect of the time stability of these two policies on their effectiveness is investigated by combining the direct subsidies and the B-index with proxies for their respective stability. The two variables that reflect the stability of the schemes for each country are GT-*instability* and B-*instability*, which are respectively the standard deviation of the subsidisation rate (GT) and of the B-index over the period 1983-1996. For both policy tools, the estimates presented in column 4 of Table 3 show that the more volatile a policy, the less likely it is to have a positive effect. The rationale for this sensitiveness is straightforward. R&D investment involves a long-term commitment, which translates instantaneously into a sunk cost. Such investment is therefore likely to be sensitive to uncertainty, including uncertainty arising from fiscal or government funding. These results confirm Hall's (1992) result that the impact of US R&D tax incentives grew over time, after it appeared that the schemes were to be maintained in the future. Similar evidence concerning R&D subsidies is reported in Capron and van Pottelsberghe's (1997) empirical analysis at the industry level. They find for the G7 countries that those industries that benefit from stable subsidisation rates are most likely to be stimulated by government-funded R&D.

The interaction between the two policy tools is also important. The question is whether they are mutually reinforcing, complementary, or substitutes in stimulating business-funded R&D. The results (reported in columns 5 to 7) clearly highlight that a substitution effect is at work. In column 5, one sees that an increase in tax incentives would reduce the stimulating effect of direct subsidies to R&D. Similarly, column 6 shows that the higher the growth of subsidies, the weaker is the impact of additional R&D tax concessions. The two results are confirmed in column 7, where both variables are simultaneously combined with each other. This implies that the design and implementation of both instruments are more likely to be effective when performed in a co-ordinated manner, where substitution effects are taken into account.

The effects of defence oriented R&D

The previous subsection underlines the fact that too high a level of subsidies may not stimulate private R&D investment. In this final part of the empirical analysis, we investigate whether defence R&D provides an additional explanation for the behaviour of private R&D investors. According to the Frascati Manual (OECD, 1993) two categories of government funds can be identified: *i)* those which are specifically for the procurement of R&D (the results of the R&D belong to a recipient which is not necessarily the direct funder or the performer) and *ii)* those which are provided to the performers of R&D in the form of grants or subsidies (the results belong to the R&D performer). It is not possible to make an empirical distinction between these two components of government support to business R&D. However, defence-related subsidies are more likely to belong to the first category. The results of R&D procurement may not necessarily be used by the R&D performer, which could imply that firms will not provide their own financial contributions to such R&D, leading to a low leveraging effect.

Data on defence-related government support to business R&D are scarce. Table 4 summarises OECD estimates of the share of defence related R&D subsidies in the total direct R&D subsidies of the 17 countries included in our analysis. It suggests a non-monotonic relationship between the subsidisation rate and the share

Table 4. **Defence-related R&D support and the level of overall subsidisation**

	Lowly subsidised [0-6 per cent]	Medium-low [6-11 per cent]	Medium-high [11-19 per cent]	Highly subsidised [19-100 per cent]
High defence [60-100 per cent]			Sweden (65%)	United States (74%) France (67%) United Kingdom (70%)
Medium-high [30-60 per cent]	Switzerland (50%)	Canada (45%)	Italy (40%) Germany (40%)	
Medium-low [2-30 per cent]	Japan (n.a.) Finland (2%) Australia (5%)	Spain (21%)		Norway (16%)
Low defence [0-2 per cent]		The Netherlands (1%) Belgium (n.a.) Denmark (n.a.) Ireland (0%)		

Source: OECD estimates, the figures in parentheses are approximations of the share of defence-related subsidies in total subsidies to business firms. Subsidisation rates are from Table 1.

of defence-related subsidies (only six countries are positioned in the diagonal cells from high defence/high subsidies to low defence/low subsidies). The main exception are the most subsidised countries; among the four countries with the highest subsidisation rates, three are also the most defence oriented, namely France, the United States, and the United Kingdom.

Column 1 in Table 5 presents the estimated private R&D elasticities with respect to total government-funded R&D differentiated for four subgroups of countries: high defence-oriented R&D subsidies, medium-high, medium-low, and low. The countries with the highest share of defence objectives associated with direct subsidies are characterised by a crowding out effect of direct subsidies. The other three sub-groups are associated with positive or zero impacts. The zero impact of the countries characterised by the medium-low share of defence-related subsidies in total subsidies is related to the diversity of the subsidisation share in total R&D amongst these countries (*i.e.*, low or high levels of subsidies).

Another way of investigating the "defence" issue is to disaggregate total government support into its civilian and defence components. Unfortunately, due to strong data limitations, this was feasible for only five countries: Sweden, the United States, France, the United Kingdom, and Germany - which are the countries with the highest share of defence in their R&D. Columns 2 to 5 of Table 5 display various estimates with government-funded R&D adjusted for defence-related R&D subsidies for the five countries. The basic specification (column 2) yields an impact of non-defence government R&D similar to the one of total government R&D

Table 5. **Defence-oriented subsidies to business R&D**

Regression #	RG not adjusted for defence	RG adjusted for defence subsidies in five countries			
	Error Correction model, dependent variable is ΔRP_t				
	1	2	3	4	5
ΔRP_{t-1}	0.336***	0.334***	0.333***	0.335***	0.330***
	(9.89)	*(9.60)*	*(9.52)*	*(9.82)*	*(9.21)*
ΔVA_t	1.073***	1.028***	1.025***	1.040***	1.049***
	(16.21)	*(17.4)*	*(17.3)*	*(17.9)*	*(16.3)*
ΔB_{t-1}	–0.239***	–0.247***	–0.241***	–0.243***	–0.243***
	(–6.317)	*(–5.26)*	*(–5.14)*	*(–5.45)*	*(–5.43)*
ΔRG_{-t}		0.052***	0.052***	0.052***	
		(8.39)	(8.38)	(8.41)	
ΔRG-DEF$_{t-1}$ *(5 countries)*			0.001		
			(0.06)		
ΔRG-DEF$_{t-1}$ * DGT-*high* *(3 countries)*				–0.058**	
				(–2.89)	
ΔRG_{t-1} * D*def-high*	–0.039*				
	(–1.76)				
ΔRG_{t-1} * D*def-medium high*	0.036*				
	(1.64)				
ΔRG_{t-1} * D*def-medium low*	0.017				
	(1.26)				
ΔRG_{t-1} * D*def-low*	0.080***				
	(10.4)				
ΔRG_{t-1} * DGT-*high*					0.014
					(0.98)
ΔRG_{t-1} * DGT-*medium high*					0.041*
					(1.90)
ΔRG_{t-1} * DGT-*medium low*					0.062***
					(8.05)
ΔRG_{t-1} * DGT-*low*					0.050**
					(2.54)
Adj-R2	0.417	0.415	0.412	0.412	0.408
Durbin-Watson	2.04	2.09	2.09	2.10	2.09

Note: Estimates cover 17 countries over the 1981-1996 period (216 observations). The variables are expressed in first differences of logarithms (growth rates). RP denotes business-funded R&D investment, VA value added, B the B-index, GT the subsidisation rate, RG-DEF defence-oriented R&D subsidies for the United States, the United Kingdom, France, Germany, and Sweden. DGT-*high* = a dummy variable that takes the value of one for countries whose average subsidisation rate is over 19 per cent and 0 otherwise, DGT-*medium high* [11-19 per cent], DGT-*medium low* [6-11 per cent], DGT-*low* [0-6 per cent]. D*def-high* = a dummy variable that takes the value of one for the countries whose average subsidisation rate is over 60 per cent and 0 otherwise, D*def-medium high* [30-60 per cent], D*def-medium low* [2-30 per cent], D*def-low* [0-2 per cent] (see Table 4). All regressions are estimated with the SURE method and include an intercept and time dummies. T-statistics are shown between parentheses; *** indicates the parameters that are significantly different from zero at a 1 per cent probability threshold; ** at 5 per cent; and * at 10 per cent.

Source: OECD, *Economic Outlook 60* and *MSTI databases, 1998.*

reported in Table 2 (0.052 instead of 0.056). The estimated impact of defence-related R&D subsidies in the five countries is presented in column 3. The non-significant parameter provides some support for the idea that defence related R&D subsidies do not stimulate private R&D.

When the focus is shifted to the three countries characterised by both the highest subsidisation rate and the highest share of defence in government-funded R&D (France, the United States and the United Kingdom have a share of defence-related R&D in total R&D subsidies of about 70 per cent), a negative and significant impact on business-funded R&D appears (column 4). A one per cent rise in defence-related R&D subsidies seems to induce a 0.06 per cent fall in privately-financed R&D. Therefore, the negative or much lower impact of government financed R&D in highly subsidised countries may be attributed, at least partly, to defence-related subsidies. The objective underlying these subsidies is the fulfilment of public needs, however, which are not met - or governed - by market funding. In this case, government support to business firms induces firms to enter into projects that would not have been carried out otherwise. These results have to be interpreted with caution for two reasons. First, they concern only five countries. Second, private R&D investment is not adjusted for its defence component, which makes the estimates less reliable with respect to the effect of defence-oriented R&D subsidies. Indeed, a considerable share of business-funded R&D may also be directed towards defence objectives in these countries.

CONCLUDING REMARKS AND POLICY IMPLICATIONS

Both fiscal incentives and direct subsidies stimulate private R&D investments, at least in the short run. In the longer run, direct subsidies are more effective than fiscal incentives. This is probably so because direct subsidies lead firms to launch new projects, whereas fiscal incentives mainly induce firms to accelerate ongoing projects.

Apart from this principal result, three features seem to differentiate the effectiveness of these policies across countries. First, countries that provide a level of subsidies that is too low or too high stimulate private R&D less than countries with an intermediate level of subsidisation. Indeed, the returns to government financed R&D seem to have an inverted-U shape, increasing up to a subsidisation rate of about 15 per cent, and decreasing afterwards. Over a level of 30 per cent, additional public money is likely to be substituted for private R&D. Second, countries with more stable fiscal and subsidisation policies are more likely to be effective than countries with less stable policies. Third, the two policy tools are substitutes, which implies that the increased use of one of them reduces the effectiveness of the other. Finally, defence-related R&D subsidies seem to reduce private R&D investment - although it is not their official goal to stimulate them at all.

These results suggest that governments, by attempting to correct for market failures, might also be subject to some kind of failures. Three policy recommendations could reduce the extent of such government failures. First, any type of government support to business R&D is more likely to be effective if it is integrated within a long-term framework, thus reducing to some extent the uncertainty facing investors. Second, the simultaneous use of both policies - fiscal incentives and direct subsidies - requires co-ordination between the authorities involved, since they are substitutes. Third, if government want to stimulate private R&D, providing too low or too high a level of subsidies is not likely to be effective.

NOTES

1. See Arrow (1962). Bernstein (1989) and van Pottelsberghe (1997) provide empirical evidence of the extent to which knowledge diffuses across firms and industries, respectively.

2. The empirical literature on the effectiveness of R&D subsidies to the business sector measures either their impact on output growth or their stimulation effect on privately financed R&D. According to Levy (1990), the former approach is not reliable because government funds are available at zero or low costs. The profit maximising firm would use R&D subsidies up to a level where their marginal product is equal to their marginal cost, *i.e.* zero. One should therefore not expect the estimated impact of government-funded R&D on output growth to be significant. Another argument put forward by Griliches (1979) is that there is no reason to dissociate private from government funds, because "*a dollar is a dollar*", whatever the source of funding (see Capron and Van Pottelsberghe, 1997). Even if more important spillovers might be associated with government-funded R&D, it is conceptually not feasible to distinguish publicly-funded spillovers from privately-funded spillovers emanating from a given project.

3. According to the Frascati Manual, the figures on government-funded R&D performed by business firms also include loans which may (and are likely to) be forgiven (OECD, 1993).

4. For instance, Carmichael (1981) for transport firms, Nadiri (1980) at the US industry level, and Levy (1990) obtain negative impact of government R&D on private R&D in particular industries and/or countries.

5. The index of fiscal incentives in this study is composed of a tax component and a purely economic component which is equal to the sum of the firm's discount rate and R&D depreciation rate, less the inflation rate that prevails in the economy. The empirical results show that the tax component significantly affects business-funded R&D expenditure, whereas the economic component has no significant impact.

6. These should take account of stable country characteristics that may influence the private decision to invest in R&D, especially in the long run, such as culture, tax policies, and institutional differences.

7. Hall (1992) argues that R&D investments are subject to important adjustment costs, for three reasons. First, R&D expenditures tend to have a low variance relative to ordinary investment. Second, at least half of R&D investment consists of payments to scientists and engineers who embody the firm's stock of knowledge and contribute to its increase. Third, R&D investment usually takes several years before being profitable, which makes it costly to stop.

8. This test has to be interpreted cautiously. If it globally rejects the hypothesis of cross-sectional correlation for all pairs of countries, there may still be a strong correlation between some countries. In this case, the correction for contemporaneous correlation has to be made, even if the null hypothesis is not rejected. In our case, the test always rejects the hypothesis of no contemporaneous correlation of the error terms. The pairs of countries that are associated with the highest values of correlation between their error terms are often characterized by a cultural and geographical proximity, or size similarity.

9. If the reference base is the previous year, which is the case in France, the tax credit might lead to lumpy investment behaviour - *i.e.* more concentrated research efforts.

10. This is mainly because any attempt to interact variables in growth rates (approximating the short run elasticities) has to be associated with a similar transformation of the variables in levels (approximating the long run effects) and of *lnRP*t-2.

11. The conventional econometric technique is to compute the within transformation by cross section unit to eliminate the fixed effects (which is similar to the inclusion of country dummies). However, in a dynamic context, this procedure would yield inconsistent estimates because there are lagged endogenous variables among the right-hand side variables. Indeed, Nickell (1981) and Keane and Runkle (1992) show that the within transformation introduces, by construction, a correlation between the lagged endogenous variable and the error term. Therefore, the country dummies are not included into equation (2). However, if they had been introduced into the regression equation, the results would have been qualitatively similar.

12. With a constant elasticity, $\gamma = [(\partial RP/\partial RG) * (RG/RP)]$, the marginal effect $\rho = (\partial RP/\partial RG) = \gamma * (RP/RG)$ decreases when the rate of subsidisation increases.

13. The marginal effects are estimated directly by replacing the first (logarithmic) difference of government R&D by the ratio of the increment of government R&D to the level of private R&D.

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Annex

THE B-INDEX

The B-index is defined as the present value of before-tax income that is necessary to cover the initial cost of R&D investment and to pay the corporate income taxes, so that it becomes profitable to perform research activities. Algebraically, the B-index is equal to the after-tax cost of a $1 expenditure on R&D divided by one less the corporate income tax rate. The after-tax cost is the net cost of investing in R&D, taking into account all available tax incentives:

$$\text{B-index} = \frac{(1-A)}{(1-\tau)},$$

where τ = statutory corporate income tax rate; A = the net present discounted value of depreciation allowances, tax credits, and special allowances on the R&D assets. In a country with full write-off and no other scheme, $A = \tau$, and consequently B = 1. The more favourable a country's tax treatment of R&D, the lower its B-index. The value for A may take three forms: *i)* the net present value (NPV) of depreciation allowances A_d, *ii)* the NPV of special R&D allowances A_s, and *iii)* the NPV of R&D tax credits A_c. The proportions of the R&D costs that are entitled to standard depreciation allowances are, respectively, D_d, D_s, D_c. The net present value of all depreciation allowances and tax credit is:

$$A = D_d \, \tau \, A_d + D_c \, \tau^c + D_s \, A_s$$

If the depreciation allowance is granted at an exponential rate of d and with standard depreciation allowance - DB - *Declining balance*:

$$A_d = \frac{\delta}{\delta + r}$$

or with *straight line* - SL:

$$A_d = \frac{(1-e^{-rL})}{r\,L},$$

For a tax credit that applies on incremental expenditures, it depends on how the base is defined: *i)* last years expenditures; *ii)* the previous largest expenditures, as in Japan; *iii)* a fixed year in the past; *iv)* an average of the past two years' expenditures as in France and

Spain; *v)* an average of the past three years' expenditures. Following Bloom *et al.* (1997), the assumptions *i)* = *ii)*, and for *iv)* and *v)*:

$$A_c = \tau^c \left[1 - \frac{1}{k} (\textstyle\sum_{k=1}^{K} (1+r)^{-k} \right]$$

If ,the credit is on real expenditures, then A_c is divided by $(1 + \pi)$. In the three years case *iv*), the term between brackets is equal to .171; in the two-years case it is .132; and in the 1 year case it is .091. For example, the United States has a incremental tax credit of 20 per cent of the amount by which R&D outlays of a fiscal year exceed a base amount. The base amount is the product of the "fixed-base percentage" and the average of the gross receipts for the 4 preceding years. The fixed-base percentage is the R&D intensity during the 1984-88 period (*i.e.* the share of R&D investments in gross receipts), which should not exceed 16 per cent. The base amount is therefore varying with the growth of output; the higher the output growth, the higher the base amount. The US treatment aims apparently at fostering the propensity to invest in R&D rather than the increase of R&D as such. The base amount cannot be less than 50 per cent of the tax payer's current-year qualified research expenditures. Calculation of the B-index has been made under the assumption that the "representative firm" is taxable, so that it realises the full gain from the tax deduction. For incremental tax credits, calculation of the B-index implicitly assumes that R&D investment is fully eligible to the credit, and does not exceed the ceiling when there is one. Therefore, the flexibility of the policies according to refunding, carryback and carryforward of unused tax credit, and flowthrough mechanisms are not taken into account by the B-index. Practically, the B-index of a country that would apply both types of tax credits (level and incremental), depreciation allowances, and taxable credits, is computed as follows:

$$B = \frac{1 - \tau A_d - D^{cL}\ \tau^{cL}\ (1-\tau) - D^{cI}\ \tau^{cI}\ (1-\tau)}{(1-\tau)}$$

Table A1. **The marginal and long-term effect of R&D subsidies**

Dependent variable =>	ΔRP_t					$\Delta(RP/VA)$		
Regression #	1	2	3	4	5	6	7	8
ΔRP_{t-1}	0.323***	0.327***	0.327***	0.051	0.042	0.257***	0.254***	0.254***
	(9.84)	*(9.72)*	*(9.66)*	*(1.20)*	*(0.98)*	*(6.40)*	*(6.25)*	*(6.68)*
ΔVA_t	0.977***	1.044***	0.983***	1.238***	1.243***			
	(18.49)	*(18.48)*	*(18.19)*	*(17.91)*	*(17.87)*			
ΔB_{t-1}	–0.251***	–0.252***	–0.239***	–0.208***	–0.207***	–0.002***	–0.002***	–0.002***
	(–4.73)	*(–4.90)*	*(–4.50)*	*(–7.13)*	*(–7.10)*	*(–5.48)*	*(–5.91)*	*(–5.07)*
DRG_{t-1} / RP_t	0.351***							
	(6.22)							
ΔRG_{t-1} * DGT-*high*				–0.053**	–0.049**	–0.155***	–0.101*	–0.020
				(–2.58)	*(–2.29)*	*(–2.80)*	*(–1.86)*	*(–0.404)*
ΔRG_{t-1} * DGT-*medium high*				0.117***	0.117***	0.392***	0.427***	0.319***
				(4.84)	*(4.80)*	*(3.53)*	*(4.00)*	*(3.16)*
ΔRG_{t-1} * DGT-*medium low*				0.073***	0.071***	1.115***	1.127***	1.152***
				(11.68)	*(10.98)*	*(18.06)*	*(17.80)*	*(20.19)*
ΔRG_{t-1} * DGT-*low*				0.028*	0.026*	1.627***	1.698***	1.388***
				(1.79)	*(1.70)*	*(3.91)*	*(3.97)*	*(3.12)*
$[DRG_{t-1} / RP_t]$ * DGT-*high*		–0.209**						
		(–2.63)						
$[DRG_{t-1} / RP_t]$ * DGT-*medium high*		0.426***						
		(3.19)						
$[DRG_{t-1} / RP_t]$ * DGT-*medium low*		0.770***						
		(7.36)						
$[DRG_{t-1} / RP_t]$ * DGT-*low*		–1.966						
		(–0.94)						
$[DRG_{t-1} / RP_t] * (GT_{t-1})$			6.283***					
			(5.81)					
$[DRG_{t-1} / RP_t] * (GT_{t-1})^2$			–22.75***					
			(–4.95)					
$\ln RP_{t-2}$				–0.074***	–0.074***	–0.181***	–0.189***	–0.183***
				(–4.68)	*(–4.70)*	*(–13.40)*	*(–13.12)*	*(–14.38)*
$\ln VA_{t-1}$				0.170***	0.183***			
				(3.68)	*(3.83)*			

Table A1. **The marginal and long-term effect of R&D subsidies** *(cont.)*

Dependent variable =>	ΔRP_t					$\Delta(RP/VA)$		
Regression #	1	2	3	4	5	6	7	8
ln B_{t-2}				0.012	0.019	–0.001***	–0.001***	–0.001***
				(0.33)	*(0.52)*	*(–3.66)*	*(–4.03)*	*(–3.47)*
ln RG_{t-2} * DGT-USA					0.048**		0.055	
					(2.20)		*(1.50)*	
ln RG_{t-2} * DGT-*high*				0.063***	0.076***	0.129***	0.232***	
				(5.27)	*(4.17)*	*(5.60)*	*(6.43)*	
ln RG_{t-2} * DGT-*medium high*				0.115***	0.116***	0.579***	0.576***	
				(6.04)	*(6.09)*	*(7.16)*	*(7.06)*	
ln RG_{t-2} * DGT-*medium low*				0.013**	0.009	0.287***	0.303***	
				(2.10)	*(1.22)*	*(3.32)*	*(3.20)*	
ln RG_{t-2} * DGT-*low*				–0.010	–0.013	0.060	0.068	
				(–0.92)	*(–1.13)*	*(0.31)*	*(0.28)*	
ln $RG_{t-2}]$ * (GT_{t-2})								3.342***
								(8.05)
ln RG_{t-2} * $(GT_{t-2})^2$								–8.129***
								(–7.13)
Adj-R2	0.400	0.404	0.397	0.492	0.488	0.348	0.349	0.352
Durbin-Watson	2.03	2.09	2.09	1.99	1.97	2.26	2.26	2.22

Note: The estimates cover 17 countries over the 1981-1996 period (216 observations). The variables are expressed in first differences of logarithms (Δ = growth rates). RP denotes business-funded R&D investment, VA value added, B the B-index, RG government-funded R&D and DRG its first difference, while GT is the subsidisation rate. DGT-high = a dummy variable that takes the value of one for countries whose average subsidisation rate is over 19 per cent and 0 otherwise, DGT-*medium high* [11-19 per cent], DGT-*medium low* [2-11 per cent], DGT-*low* [0-2 per cent[(see Table 4). All regressions are estimated with the SURE method and include an intercept and time dummies. T-statistics are shown between parentheses; *** indicates the parameters that are significantly different from zero at a 1 per cent probability threshold; ** at 5 per cent; and * at 10 per cent.

Source: OECD, *Economic Outlook 60* and *MSTI databases, 1998.*