OECD Science, Technology and Industry Working Papers
2000/04

The Impact of Public R&D Expenditure on Business R&D

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https://dx.doi.org/10.1787/670385851815

Unclassified **DSTI/DOC(2000)4**

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development

OLIS : 14-Jun-2000
Dist. : 15-Jun-2000

English text only

DIRECTORATE FOR SCIENCE, TECHNOLOGY AND INDUSTRY

STI WORKING PAPERS 2000/4

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THE IMPACT OF PUBLIC R&D EXPENDITURE ON BUSINESS R&D

Dominique Guellec and Bruno van Pottelsberghe

This document attempts to quantify the aggregate net effect of government funding on business R&D in 17 OECD Member countries over the past two decades. Grants, procurement, tax incentives and direct performance of research (in public laboratories or universities) are the major policy tools in the field. The major results of the study are the following:

- Direct government funding of R&D performed by firms (either grants or procurement) has a positive effect on business financed R&D (one dollar given to firms results in 1.70 dollars of research on average).
- Tax incentives have a positive (although rather short-lived) effect on business-financed R&D.
- Direct funding as well as tax incentives are more effective when they are stable over time: firms do not invest in additional R&D if they are uncertain of the durability of the government support.
- Direct government funding and R&D tax incentives are substitutes: increased intensity of one reduces the effect of the other on business R&D.
- The stimulating effect of government funding varies with respect to its generosity: it increases up to a certain threshold (about 13% of business R&D) and then decreases beyond.
- Defence research performed in public labs and universities crowds out private R&D; Civilian public research is neutral for business R&D.

Ce document vise à quantifier l’effet des financements gouvernementaux sur la dépense de R-D des entreprises au niveau agrégé, pour 17 pays Membres de l’OCDE sur les deux dernières décennies. Les dons, les achats publics, les incitations fiscales et la réalisation directe de la recherche (dans les laboratoires publics ou les universités) sont les principaux outils de la politique dans ce domaine. Les principaux résultats de l’étude sont les suivants :

- Le financement direct par le gouvernement de la recherche réalisée par les entreprises (dons ou achats publics) a un effet positif sur le financement de la recherche par les entreprises (un dollar versé aux firmes se traduit en moyenne par 1.70 dollars de recherche).
- Les incitations fiscales ont un effet positif (bien de court terme) sur le financement de la recherche par les entreprises.
- Le financement direct comme les incitations fiscales sont plus efficaces lorsqu’ils sont stables dans le temps : les firmes n’effectuent pas de dépenses supplémentaires en recherche si elles ne sont pas assurées de la durabilité du soutien gouvernemental.
- Le financement direct et les incitations fiscales sont substituables : une intensité plus élevée de l’un réduit l’effet de l’autre sur la recherche des entreprises.
- L’effet stimulant du financement public varie selon sa générosité : il augmente jusqu’à un certain niveau (environ 13 % de la recherche des entreprises) puis diminue au-delà.
- La recherche liée à la défense réalisée dans les laboratoires publics et les universités évince la recherche sur fonds privés.
- La recherche publique à finalité civile n’a pas d’effet sur la dépense de recherche des entreprises.

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EXECUTIVE SUMMARY

The share of government in the funding of R&D in 1998 was 30% in the OECD, 31% in the United States, 36% in Europe and 19% in Japan. Such an effort may have various effects on the dynamics of technology, including contributing to basic knowledge, to the government's own missions, and to economic growth. One possible channel for the latter effect is a leverage effect by government funding on business funding: thanks to government support, or to the basic knowledge produced on government funds, the private return on investment in R&D is improved, triggering higher expenditure on R&D by companies. However, it is also possible that government funding crowds out business, either directly (government pre–empts a technological opportunity or gives money to firms for projects that they would have carried out anyway), or indirectly (by increasing demand, hence the market price of resources needed for research). It is uncertain whether, economy-wide, the leverage effect dominates the crowding out effect or not. This document attempts to quantify the aggregate net effect of government funding on business R&D in 17 OECD Member countries over the past two decades.

Government funding of R&D is extremely variegated across countries and tends to change over time. Government can directly fund business for carrying out research, either under procurement programmes (the result is government property) or as a grant (the result belongs to the recipient). The bulk of the former is made up of defence contracts.

A second way for government to support R&D is through tax incentives, notably R&D tax credits (now used in ten OECD countries).

A third way is for government to perform R&D itself, in public laboratories. Such research generally serves the government's own needs, in the defence, energy or public health areas for instance, but it may have broader uses. Finally, the government funds university research, generally with the objective of generating basic knowledge. Contributing to industrial technology is not the direct purpose of these last two instruments, but they may have such an impact through "technology spillovers".

The major results of the study are the following:

- Direct government funding of R&D performed by firms has a positive effect on business financed R&D. One dollar given to firms results in 1.70 dollars of research.

- Tax incentives have a positive effect on business-financed R&D.

- These two policy instruments are more effective when they are stable over time: firms do not invest in additional R&D if they are uncertain of the durability of the government support.

- Direct government funding and R&D tax incentives are substitutes: increased intensity of one reduces the effect of the other on business R&D.

- The impact of direct government funding on business R&D is more long-lived than that of tax incentives, reflecting the fact that government programmes target research projects with a longer time horizon than those on the agenda of business.

- The stimulating effect of government funding varies with respect to its generosity: it increases up to a certain threshold and then decreases beyond. On average for the 17 countries and the time period under study, this threshold is about 13% of business R&D. It may, of course, differ across countries and evolve over time. Too much or too little funding is less effective that being somewhere in the middle.

- Defence research performed in public labs and universities crowds out private R&D. This is due partly to the increase in cost of research generated by government outlays (which boosts the demand for researchers and other resources, hence their market price). Civilian public research is neutral for business R&D. The impact of knowledge spillovers coming out of university (mainly basic) research takes too long a lag to be seen in the data.

- The negative effect of university research is mitigated when government funding of business R&D increases. Targeted government programmes probably help firms to digest the knowledge generated by universities.

These results are averages over many countries. As the economic structure and design of policies differ widely across countries, such conclusions may apply to various extents to each individual country. However, they point to lessons that may be useful to policy makers. First, well-designed government programmes have a leverage effect on business R&D – this is not wasted money. Second, frequently redesigning a policy instrument, *e.g.* the rules and generosity of R&D tax credit or government programmes – reduces its effectiveness. Third, a piecemeal approach to technology policy is detrimental to its effectiveness: tax breaks and direct funding of business are substitutes, while direct funding and university research are complements. Hence, the various policy instruments should be consistent with each other, which implies that the various administrative departments involved in their design and management need to be co–ordinated. Fourth, if government is willing to stimulate business R&D, providing too low or too high a level of funding is not effective. Fifth, although defence-related R&D funding does not aim at stimulating private R&D expenditure, its crowding-out effect on business, civilian R&D, has to be taken into account. Sixth, research performed in universities presents a potential usefulness for business that can be improved through targeted government funding enhancing the transfer of technology.

1. INTRODUCTION

OECD governments spent around USD 150 billion in research and development (R&D) activities in 1998, almost one-third of total R&D expenditure in the concerned countries. Beside fulfilling public needs (such as defence), the economic rationale for government involvement in this area is the existence of market failures associated with R&D. Imperfect appropriability, or the diffusion of knowledge uncontrolled by the inventor, implies that the private rate of return to R&D is lower than its social return. In addition, high risk for research implies extremely high hurdles, discouraging firms from engaging in such activities. This is especially detrimental to small firms for which access to funding is more difficult. Therefore, the amount invested by firms in research activities in a competitive framework is likely to be below the socially optimal level (Arrow, 1962). In this line of argument, the wedge between private and social return is likely to be higher in basic research, requiring a stronger involvement of government in this area. Government can commit funds for stimulating business-performed research. This may aim at reducing the private cost of R&D (*e.g.* grants) or at working out technological opportunities available to firms (which reduces both the cost and uncertainty of research). If this policy works, public and private funding will be complementary (increasing the former enhances the latter). However, the effectiveness of the policies aiming at stimulating private R&D outlays can be challenged on three main grounds: crowding out through prices, substitution effects and allocative distortions.

First, government spending may crowd out private money, by increasing the demand, hence the cost, of R&D. Goolsbee (1998) and David and Hall (1999) argue that the major effect of government funding is to raise the wage of researchers. Faced with higher research costs, firms will allocate money to other activities so that, even if the total amount of R&D is higher due to government funding, its “real amount” (*e.g.* measured by the number of researchers) will be lower and of lesser economic efficiency.

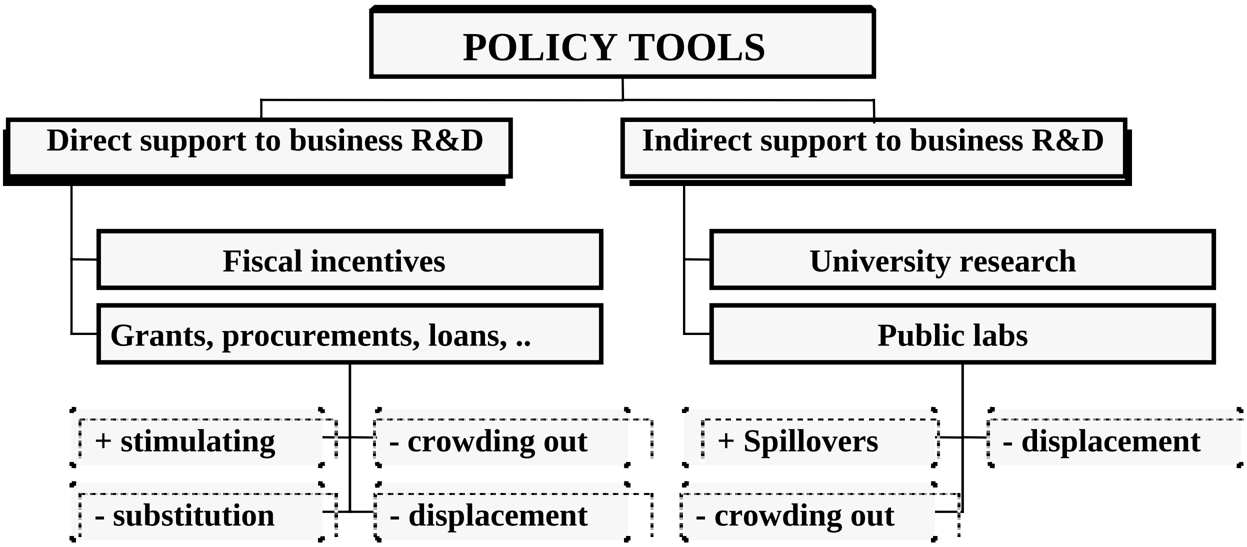
A second argument is that public money directly displaces private funding, as firms simply substitute public money for their own, while undertaking the same amount of research as originally planned. Therefore, the government supports projects that would have been implemented anyway.

Third, government funds, being allocated to projects in a less efficient way than market forces would do, generate distortions in the allocation of resources between the various fields of research (*e.g.* areas with lower opportunities would be favoured). It may also distort competition between firms, by helping some of them at the expense of others.

The purpose of this document is to assess the effect of government spending on R&D funded and performed by business. Does the externality effect dominate the crowding-out effect? Is there complementarity or substitutability between various policy instruments and business R&D? How do the various policy instruments interact with each other?

In order to assess the effect of government spending, it is necessary to identify the various channels taken by money flows: where and how public money is spent. The effect of public spending may differ depending on the policy instrument used. There are three main policy instruments (Figure 1) used by government: public (government or university) research, government funding of business-performed R&D, and fiscal incentives. Public research, carried out in public laboratories or universities, and funded by government, is exemplified by National laboratories in the United States or the CNRS (Centre National de la Recherche Scientifique) in France. The goal of these bodies is to satisfy public needs and to provide the basic knowledge that may be used downstream by firms in their own, applied, research. Government laboratories are more concerned with the former, universities and similar institutions are more concerned with the latter. Universities are usually endowed with much more independence with regards their research agenda than government laboratories, making them a less responsive instrument for policy. However, as the government controls much of the research budget of these institutions (through grants, contracts or fellowships), it is relevant to include them in the list of policy instruments. Some argue that the kind of science produced by public research facilities is irrelevant to the business sector (Kealey, 1996), with the idea that if it were useful, business would do it itself. However, weak appropriability of basic knowledge makes it difficult for firms to reap its rewards: as a contribution to this ongoing discussion, the effect of public spending in this area is tested in this document.

Figure 1. **Policy tools and their potential effects (dotted line) on private R&D outlays**



A second policy instrument is public funding of research performed by the business sector. According to the *Frascati Manual* (OECD, 1994) used by statisticians of R&D, two categories of government funds to business 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 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). In all cases, subsidies are targeted to specific goals chosen by the funder: government gives money to firms for particular technological projects that are seen as having a high social return (*e.g.* "generic technologies" or "pre-competitive research") or that are useful to the government's own objectives (*e.g.* health, defence). As government funds help the recipient (technology or firm) even if it is initially inferior to alternatives, such support gives rise to the criticism that government, rather than the market, is "picking winners". Moreover, grants are often conditional on some aspect of firm strategy: they may require for instance that the recipients set up research alliances with other firms (co-operation), or that they collaborate with universities.

Third, government can help firms indirectly, through tax breaks. Most OECD countries allow for a full write-off of current R&D expenditures (depreciation allowances are deducted from taxable income). Among the 17 countries included in the present study, about one-third also provide R&D tax credits (see Annex Table A1). These are deducted directly from the corporate income tax and are based either on the level of R&D expenditures – flat rate – or on the increase in these expenditures with respect to a given base

– incremental rate. In addition, some countries allow for an accelerated depreciation of investment in machinery, equipment and buildings devoted to R&D activities. In some countries, there are special tax breaks related to R&D for small firms. The main criticism of this instrument is that it is windfall money for firms: they do not change their R&D strategy (which is what the government is expecting), but are refunded for it. In a way, this argument contradicts the one opposed to targeted funding: tax breaks are not sufficiently discriminatory, so that firms may use public money for any goal that suits their own strategy, whatever the social return. Non-discrimination may be viewed as an advantage, since the government does not distort the research agenda as shaped by market forces. However, tax incentives are in fact somewhat discriminatory, as they are not accessible to non-taxable firms (*e.g.* new firms with investment higher than sales). This is unfortunate, since such companies may be among the most innovative and short of cash. In some countries, special provisions in the tax law allow refunding in cash of the credit for certain categories non-taxable firms.

Among these three policy instruments, only the last two have been the subject of distinct quantitative evaluation. This is unfortunate, since the three policy tools have partly similar, partly complementary objectives that make it difficult to analyse the effectiveness of one instrument independent of the others. Public research, whether performed in government labs or universities, provides basic knowledge that is especially helpful for firms in the most advanced technology areas (close to basic research). Grants help firms in the applied research stage and encourage co-operation (another way of internalising externalities). R&D tax breaks, since they are non- or weakly-discriminatory, help all R&D-performing firms, especially those that do not have not access to grants (small companies) or do research that is not basic enough to benefit from other policy instruments. Moreover, there are interactions between these instruments, as the downstream ones (related to applied research) may enhance the efficiency of upstream ones (basic research) by supporting the absorptive capacity of recipient firms. Hence, these tools constitute a system whose efficiency can be best captured as a whole. It is the purpose of this study to do so.

This document investigates whether publicly performed research, direct funding and fiscal incentives stimulated business-funded R&D in 17 OECD countries over the period 1981-96. This integrated (three policy instruments) macroeconomic and international approach makes this study distinct from previous work in this field. The main results are that:

- Direct government funding of business R&D and tax breaks has a positive impact on business spending in R&D.
- The effect of public funding is more long-lived than that of tax incentives.
- The impact of direct support varies with respect to the funding rate: it increases up to a threshold (which average is estimated at about 13% for the period of time and set of countries considered here) and decreases beyond that threshold.
- These two policy tools are more effective when stable over time.
- Direct support and tax breaks are substitutes (increasing the use of one of them reduces the impact of the other – this finding contradicts the “complementarity thesis” mentioned above, while supporting the integrated approach taken in this study).
- Public research and university intramural research exert a negative impact on business-funded R&D: the crowding-out effect seems to dominate the spillover effect (alternatively, it can be argued that the latter takes indirect channels or that the lag is too long for it to be captured by econometric techniques).

- However, the negative effect of university research is mitigated when government funding of business research is increased: the knowledge generated by academic research is better transferred to firms when targeted funding is implemented.

- Finally, defence-oriented public funding seems to be the main factor underlying the crowding-out effect of government intramural R&D outlays.

These results should be interpreted with some caution. The precise design of policies varies substantially across countries and has evolved over time in a way that is not totally reflected in the financial flows used here. The estimates herein capture an average that may hide differences in the effectiveness of public policies across countries and changes over time. However, such an average is useful by itself, as a reference for individual countries to benchmark their policies. It gives a hint of the policy tools that are better managed in most countries and of those that should be improved. Finally, this global approach allows the interactions between the various policy tools to be identified.

2. THE MODEL AND DATA

Previous studies attempting to evaluate the effectiveness of government support to business R&D have focused either on the relationship between R&D subsidies and business-funded R&D (see the survey by Capron and van Pottelsberghe, 1997), or on the effect of fiscal incentives (see the survey by Mohnen, 1997).[1] A comparison of these studies is made difficult by the heterogeneity of the empirical models used, *e.g.* different time periods, data sources, aggregation levels and regression techniques. On average, however, the balance tilts towards the recognition of a positive effect of government funding and tax incentives on privately financed R&D. This is even more so for studies at the aggregate, macroeconomic level: among seven such studies referenced by David *et al.* (1999), six find complementarity between public and private expenditure, while the seventh finds no significant relationship. Nevertheless, the existing literature has disregarded two important dimensions. There has been no attempt so far to test simultaneously for the effectiveness of all instruments, and there are few macroeconomic studies [of the 33 studies referenced by David *et al.* (1999), seven are macroeconomic], most empirical analyses being at the firm or industry level.

As compared to the firm level approach that is more common in the field, the macroeconomic approach allows the indirect effects of policies to be captured – negative as well as positive spillovers. A firm benefiting from subsidies is likely to boost its own R&D activity but the R&D activity of competing firms might decline, for instance because they see their chances of having a competitive edge waning due to the financial advantage given to the recipient. Negative externalities can also take place between industries, as shown by Mamuneas and Nadiri (1996) with US manufacturing industries. On the other hand, the recipient firm’s research may generate knowledge spillovers that will flow to its competitors as well. The potential presence of these effects makes the case for empirical studies at an aggregate level, which implicitly take them into account (be they positive or negative). A second advantage of working at the macroeconomic level is that government funding of R&D can be considered as exogenous with respect to privately funded R&D. Indeed, at the firm level, the relevance of the assumption of exogeneity is questionable because public authorities do not provide R&D subsidies to randomly chosen companies; “Federal contracts do not descend upon firms like manna from heaven” (Lichtenberg, 1984, p. 74). Public authorities may be more inclined to support firms which do R&D and which already have good innovative records. In other words, a positive and significant relationship between a firm's R&D and the government funds it received cannot be taken as an evidence of the efficiency of government support. The same argument holds, although to a lesser extent, for cross-industry studies since R&D subsidies are directed mainly towards R&D-intensive industries. At the macro level, the exogeneity assumption is much more acceptable, as it is clearly argued in David *et al.* (1999). An issue at this level may be the presence of a common latent variable influencing both business and government expenditure, which would bias the estimates. There are two candidates : the business cycle is one, since it eases at the same time financial conditions for government and for business. For dealing with this issue, we have GDP growth as an explanatory variable for business-funded R&D. A second potential latent variable is the cost of R&D: the price of specialised inputs or the wages of researchers may increase when government expands its spending, triggering a growth in business spending that is only nominal. We will examine the potential influence of this factor on our estimates by taking into account the reaction of R&D prices to demand as estimated by Goolsbee (1998).

Each of the policy tools raises specific measurement issues. Public research is broken down into two components, government research and university research. Government funding of business R&D is composed of procurement and grants or subsidies, the latter being of special interest here. However, even if the explicit goal of procurement is not to trigger a rise in business-funded R&D, such an effect is often called upon to justify government spending (the "leverage effect"). Due to data availability constraints, these two components of direct government funding of business R&D are aggregated herein. If government-funded R&D performed by firms primarily consists of procurement and regular grants, it should be noted that there are other forms of support, such as loan guarantees, conditional loans and convertible loans. However, as shown by Young (1998), government procurements and grants, and fiscal incentives, account for the bulk of government support to business R&D.

The data on value added is taken from OECD (1999a). Privately funded R&D, direct R&D subsidies to business, and R&D outlays by public labs and universities are taken from OECD (1999b). All the variables except the B-index are expressed in constant USD PPP and deflated with the business sector's GDP price index (base year 1990). The B-index has been computed by the OECD Secretariat from national sources (see Annex Table A1).

OECD countries performed about 500 billion USD PPP of R&D outlays in 1998. The lion's share of these activities (70%) was performed by firms, followed by higher education institutions (*i.e.* universities: 17%) and government intramural research (or public labs: 11%). Government is by far the major source of funding for these two public institutions, whereas it contributes only 10% to the R&D performed by private firms. Over the past 20 years, this distribution of R&D outlays by sources of fund and institutions of performance has substantially changed, witnessing a gradual reduction of the government share, both in financing and performance. In the early 1980s as compared with the late 1990s, the share of government in the funding of business R&D expenditure (23%) was more than twice as large, and research performed in public labs accounted for 17% of total R&D activities.

Beside these OECD-wide averages, important differences occur between countries. Public labs in the United States and Japan account for about 8% of domestic research activities, compared with 15% in the European Union.[2] A similar difference appears across the Triad with respect to the share of research performed by universities: it is 21% in the European Union, compared with 14% in the United States and Japan. Smaller countries seem to rely much more on university research than do larger ones (more than 25% in Australia, Norway, Spain, Belgium and the Netherlands). The business sector in Japan and the United States performs more than 73% of total research activities (about 63% in the European Union), and the funding structure differs significantly. In the United States and the European Union, the share of business-performed R&D that is financed by government is 15 and 10%, respectively. In Japan, it represents about 1%.

Fiscal incentives may take various forms, making international comparisons problematic. The so-called “B-index”, designed by Warda (1996), gives a synthetic view of tax generosity (Annex 1 provides a complete description of the B-index). 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. It is a kind of average effective rate of taxation of R&D. The underlying methodology is highly flexible and enables various types of tax treatment to be modelled in a comparable manner. [3]

We rely on a simple R&D investment model that considers business-funded R&D as a function of output, four policy instruments (government funding of R&D performed by business, tax incentives, government intramural expenditure on R&D, research performed by universities), time dummies, and country-specific fixed effects.[4] Since research activities are subject to high adjustment costs, a dynamic specification that distinguishes short-run from long-run elasticities is required. The model allows for a dynamic mechanism by introducing the lagged dependent variable. It is worth noticing that a dynamic specification for an R&D investment equation is not a common procedure in the existing literature on the effectiveness of government support to R&D.[5] On *a priori* grounds, however, the inclusion of lagged private R&D may be seen as an important determinant of present R&D investment. Mansfield (1964, p. 320) notes 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.” Therefore, the behaviour of private investors can be best described in terms of a dynamic mechanism that allows for a long-term adjustment path. The model is written as follows:

$$\Delta RP_{i,t} = \lambda \Delta RP_{i,t-1} + \beta_{VA} \Delta VA_{i,t} + \beta_{RG} \Delta RG_{i,t-1} + \beta_{B} \Delta B_{i,t-1} + \beta_{GOV} \Delta GOV_{i,t-1} + \beta_{HE} \Delta HE_{i,t-1} + \tau_t + e_{i,t} \quad (1)$$

This equation is a first-difference auto-regressive model. *RP*, *VA*, *RG*, *B*, *GOV*, and *HE* are respectively business-funded and -performed R&D, business sector value added, government funding of R&D implemented in business, the B-index (which reflects the fiscal generosity for R&D, see Annex 1), government intramural R&D expenditure (*i.e.* public labs), and higher education R&D outlays (*i.e.* university research). The 17 OECD 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 τ characterises time dummies.[6] In this model, the short- and long-term effects of the exogenous variables are $[\beta]$ and $[\beta/(1-\lambda)]$, respectively. The signs of the parameters associated with the four policy tools can be either positive or negative, depending on whether the stimulating and spillover effects outweigh the crowding-out, substitution and displacement effects.

3. RESULTS

Before estimating the dynamic model (1) and its various extensions, we investigate in a simpler, non-dynamic framework the influence of the policy instruments on business R&D, with the purpose of capturing basic relationships and their time pattern. Results reported in Table 1 show that the major effect of value added on private R&D investment is contemporaneous, with an elasticity of about 1.20. All policy instruments have a significant impact on business-funded R&D, although with different signs and time patterns.

Government-funded R&D has a positive and significant effect only after a one- or two-year lags. Fiscal incentives have a contemporaneous, and a larger one-year lagged, positive impact (remember that a lower B-index reflects higher tax breaks, hence the negative sign in the estimate). Apparently, the effect of tax breaks is quicker and shorter than the effect of government funding. Such a difference was already found in Guellec and van Pottelsberghe (1999), and it is mentioned in David *et al.* (1999). Our interpretation is the following: tax concessions are not conditional on the type of R&D performed by the recipient, and therefore do not affect the composition of R&D, most of which is anyway of a short-term nature (in almost all OECD countries, basic research is less than 5% of business R&D – see OECD 1999c). Hence their short-term impact, just like the impact of funding coming from any other source with no conditions attached. The same does not hold for government subsidies and contracts. These are spent in projects either chosen by the government or at least fulfilling certain conditions decided by the government. In most cases, the research will be of an upstream, if not basic, nature, creating new opportunities that induce firms, in the future, to start further research projects with their own money. The leverage effect of government funding takes time – this is consistent with its goal of generating knowledge spillovers.

Government and university research both have a negative and significant impact on business-funded R&D. Moreover, this negative impact is spread over several years (although there is no contemporaneous impact), especially in the case of government research. The crowding-out effect (due either to an induced increase in the cost of R&D or to direct displacement, see Figure 1) dominates the stimulating effect. As a matter of fact, the main objective of public labs is to work for the government, not for business; spillovers may occur but they are not instantaneous and are not the primary goal. The negative impact of university research shows the difficulty of transferring basic knowledge to firms.[7]

Table 1. **The lag structure of the determinants of private R&D expenditures[1]**

	Value added (ΔVA)	**Government funding (ΔRG)**	**Fiscal incentives (ΔB)**	**Government research (ΔGOV)**	**Higher education (ΔHE)**
Expected sign	(+)	(+)	(-)	(?)	(?)
Time lag					
T	1.201***	-0.009	-0.163***	0.014	-0.002
	(23.32)	*(-1.25)*	*(-3.01)*	*(0.80)*	*(-0.15)*
T-1	-0.032	0.085***	-0.343***	-0.072***	-0.070***
	(-0.52)	*(11.66)*	*(-10.92)*	*(-3.99)*	*(-5.14)*
T-2	0.210***	0.090***	-0.007	-0.002	-0.031**
	(3.36)	*(13.02)*	*(-0.21)*	*(-0.09)*	*(-2.30)*
T-3	-0.057	-0.018**	0.007	-0.084***	0.033*
	(-0.88)	*(-2.33)*	*(0.23)*	*(-4.44)*	*(1.89)*
T-4	0.170***	0.013	0.039	-0.043**	0.013
	(3.14)	*(1.59)*	*(1.19)*	*(-2.03)*	*(0.71)*
Sum	1.581	0.157	-0.506	-0.199	-0.134

Note: The estimates cover 17 countries for the 1983-96 period (165 observations due to time lags). The variables are expressed in first differences of logarithms (growth rates). *RP*, the dependant variable denotes business-funded R&D investment, *VA* value added, *B* the B-index, *GOVRD* government intramural expenditure on R&D and *HERD* higher education expenditure on R&D. SURE estimates including one intercept. *** indicates the parameters that are significantly different from zero at a 1% probability threshold; ** at 5%; and * at 10%.

Table 2 reports the panel data estimates of equation (1), correcting for the potential contemporaneous correlation of the error term across countries within a three-stage least squares (3SLS) method.[8] The Breush-Pagan test indicates that the error term of the OLS estimates is subject to significant contemporaneous correlation across countries.[9] The estimates presented in column 1 show that the short-term (long-term) private R&D elasticities are 1.36 (1.54) for value added, 0.07 (0.08) for government funding, -0.29 (-0.33) for tax incentives, -0.07 (-0.08) for government research and -0.04 (-0.05) for university research.[10]

Table 2. **The impact of policy instruments on business-funded R&D**

	Dependent variable is ΔRP_t						
		Funding rate		***Instability***	***Interact.***		***Defence***
Regression #	***1***	***2***	***3***	***4***	***5***	***6***	***7***
Fit (ΔRP_{t-1})	0.115***	0.154***	0.127***	0.108**	0.102**	0.118**	0.147***
	(2.54)	*(3.23)*	*(2.94)*	*(2.25)*	*(2.46)*	*(2.49)*	*(3.05)*
ΔVA_t	1.357***	1.355***	1.306***	1.388***	1.349***	1.355***	1.362***
	(19.67)	*(18.83)*	*(20.21)*	*(19.63)*	*(21.82)*	*(19.24)*	*(18.27)*
ΔRG_{t-1}	0.074***			0.106***	0.076***	0.063***	0.079***
	(11.05)			*(10.27)*	*(11.54)*	*(8.07)*	*(8.82)*
ΔB_{t-1}	-0.294***	-0.292***	-0.292***	-0.843***	-0.206***	-0.295***	-0.293***
	(-7.74)	*(-7.88)*	*(-7.27)*	*(-4.08)*	*(-6.19)*	*(-7.93)*	*(-7.54)*
$\Delta GOVRD_{t-1}$	-0.066***	-0.070***	-0.079***	-0.071***	-0.075***	-0.073***	-0.011
	(-3.77)	*(-3.92)*	*(-4.62)*	*(-4.11)*	*(-4.20)*	*(-4.10)*	*(-0.36)*
$\Delta HERD_{t-1}$	-0.043***	-0.044***	-0.062***	-0.041***	-0.045***	-0.055***	-0.046***
	(-2.89)	*(-2.90)*	*(-4.17)*	*(-2.75)*	*(-3.22)*	*(-3.46)*	*(-2.89)*
ΔRG_{t-1}* *DGT-high*		-0.030					
		(-1.30)					
ΔRG_{t-1}* *DGT-medium high*		0.042*					
		(1.80)					
ΔRG_{t-1}* *DGT-medium low*		0.085***					
		(10.02)					
ΔRG_{t-1}* *DGT-low*		-0.012					
		(-0.42)					
ΔRG_{t-1}* (GT_{t-1})			1.757***				
			(10.55)				
ΔRG_{t-1}* $(GT_{t-1})^2$			-6.936***				
			(-6.95)				
ΔRG_{t-1}* *GT-instability*				-18.412***			
				(-4.65)			
ΔB_{t-1}* *B-instability*				3.400***			
				(2.82)			
ΔRG_{t-1}* ΔB_{t-1}					1.154***		
					(7.17)		
ΔRG_{t-1}* $\Delta GOVRD_{t-1}$						-0.039	
						(-0.49)	
ΔRG_{t-1}* $\Delta HERD_{t-1}$						0.176**	
						(1.94)	
ΔRG_{t-1}* $DEFshare_{t-1}$							-.002***
							(-3.05)
$\Delta GOVRD_{t-1}$* $DEFshare_{t-1}$							-0.004***
							(-2.59)
Adj-R2	0.374	0.370	0.386	0.374	0.386	0.368	0.368

Note: See Table 1. The estimates cover 17 countries for the 1984-96 period (199 observations). *DGT-high* = a dummy variable equal to one for the countries whose average subsidisation rate is over 19% and 0 otherwise, *DGT-medium high* [11% - 19%], *DGT-medium low* [4% - 11%], *DGT-low* [0% - 4%]. *GT* is the share of government funded R&D in total business-performed R&D, *GT-instability* and *B-instability* the standard deviation over the studied period of *GT* and *B*, respectively, and *DEFshare* the defence budget R&D as a percentage of total government budget appropriations or outlays for R&D. All regressions are estimated with the 3SLS 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% probability threshold; ** at 5%; and * at 10%.

How do these elasticities translate into dollar terms? What is the impact of one dollar spent in any of these policies on the amount of R&D spent by firms? Estimates of the marginal *rate of return* of these policies, consistent with the estimated elasticities, are reported in Table 3. The marginal return is calculated as the product of the elasticity and the ratio of the impacted variable (business R&D) on the impacting one. If two policy instruments have the same elasticity, the one whose relative amount is largest will have the lowest return. It turns out that one dollar of government spending generates at the margin a 0.70 dollar increase in business-funded R&D (then 1.70 in total R&D) when it is direct funding, a 0.44 dollar reduction when it is spent in government research, a 0.18 dollar reduction when it is spent in university research. These reductions are less than the initial, one dollar, government expenditure. In other words, total R&D (public + business) will rise after government has increased its spending: the crowding-out effect of these last two instruments is only partial. In a similar vein, a one dollar increase in value added induces an additional 0.03 dollar of private R&D (assuming an OECD average R&D intensity of about 2%).

Government spending may have an impact not only on the amount spent in R&D by business, but also on the price of R&D: increased demand for the scarce resources used for R&D, especially researchers, should push their price up. Goolsbee (1998) estimates the elasticity of the R&D worker wage with respect to government spending to 0.09 in the long term. Subtracting this price effect from the coefficients estimated in Table 2 leads to an elasticity of -0.01 for direct funding in the long term (0.08-0.09), therefore making government funding neutral with respect to business R&D. However, Goolsbee's estimate is based on the United States, for the years 1968-94. As the share of government was especially high in the first part of this period (between 50 and 60% until 1980, compared with 33% in 1996), which is not in the range of the present work, the elasticity estimated by Goolsbee must significantly overestimate what happens in countries other than the United States and for the period studied here. It remains true, however, that part of the effect identified above is due to a price increase, not to an increase in the real resources allocated to research.

Table 3. **Average marginal effect of a 1 dollar increase in public support to R&D**[1]

***X* =>**	**Business performed R&D**		**R&D performed by public institutions**
	Government funded (*RG*)	**Government intramural (*GOV*)**	**Higher education (*HE*)**
Long-term elasticities (β)	0.08	-0.08	-0.05
(*RP/X*)	8.71	5.54	3.59
Marginal effect on *RP* (ρ)	0.70	-0.44	-0.18
Marginal effect on total R&D	1.70	0.56	0.82

1. Since the elasticities β are equivalent to ($\partial RP/\partial X$) / (X/RP), *X* standing for *RG*, *GOV*, or *HE*; the marginal effects (ρ) of a 1 dollar increase in government support on private R&D investments are computed as follows : $\rho_X = \beta_X * RP/X$. The marginal effect on total R&D is equal to 1 + ρ_X. The elasticities come from Table 2, column 1, the ratio (RP/X) is for 1997, averaged over OECD countries.

In column 2 of Table 2, the private R&D elasticity of government R&D is allowed to vary across four groups of countries. The countries are grouped according to their average subsidisation rates: over 19% for the highly funded, from 11 to 19% for the medium-high funded, 4 to 11% for the medium-low funded, and under 4% for the low funded. The largest elasticities, are obtained for the countries belonging to the two "medium" groups. The countries with the highest or the lowest funding rates exhibit non-significant elasticities. These figures suggest that the effectiveness of government funding increases up to a particular threshold and then decreases. Other estimates, with a finer breakdown of countries, also showed much weaker elasticities for the countries with the highest and the lowest levels of funding.

In order to test directly for this inverted U-curve that seems to characterise the relationship between government and privately financed R&D, the estimated private R&D elasticity of government funding is combined with the rate of direct support, in a quadratic specification :

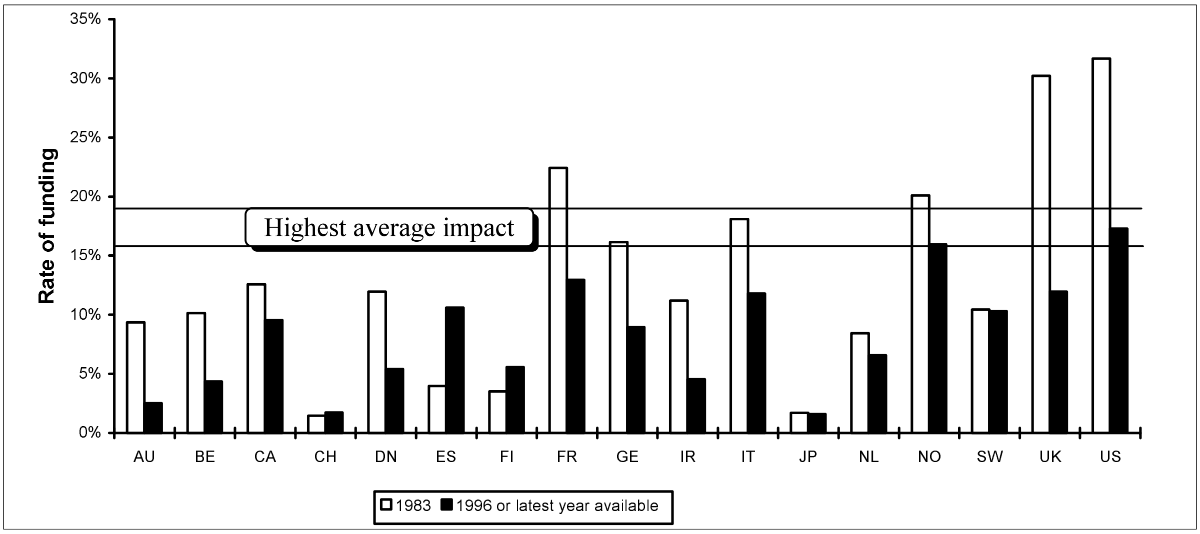
$$\beta_{RGi,t} = \alpha_1 x_{i,t} + \alpha_2 x_{i,t}^2 , \qquad (2)$$

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

The results of this specification, in which α_1 and α_2 are the parameters of interest, are reported in the third column of Table 2. They suggest that the private R&D elasticity with respect to government support increases with the subsidisation rate up to a threshold of 12.7%, then decreases with the subsidisation rate, and becomes negative over a threshold of 25.4%. The relative position of each country is reflected in Figure 2.

Figure 2. **Share of government funding in business performed R&D in 1983 and 1996**

Percentages



Note: AU denotes Australia, BE Belgium, CA Canada, CH Switzerland, DN Denmark, ES Spain, FI Finland, FR France, GE Germany, IR Ireland, IT Italy, JP Japan, NL The Netherlands, NO Norway, SW Sweden, UK United Kingdom, US United States.
Source: Table 1.

It could be argued that the variation across countries of the private R&D elasticity with respect to government R&D simply reflects a constant marginal effect of (or rate of return to) R&D funding across countries. Indeed, a constant elasticity implies that the additional dollar of private R&D for each additional public dollar spent, *i.e.* the marginal effect of government funding, decreases with the rate of funding. Hence, an elasticity varying across countries could translate into constant marginal effects.[11] As reported above, the product of the estimated elasticities (columns 1 and 2 in Table 2) and the ratio of private R&D to government R&D shows that one dollar of government money induces an average increase of 70 cents in business-funded R&D. It varies across countries, from no significant marginal effects among the countries with high and low government funding rates, to 47 cents and 101 cents for countries with "medium-high" and "medium-low" rates, respectively.[12]

The effect of the time stability of the policy tools on their effectiveness is investigated by combining the direct subsidies and the B-index with proxies for their respective stability.[13] 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 funding rate (*GT*) and of the B-index over the period 1983-96. For both policy tools, the estimates presented in column 4 of Table 2 show that the more volatile a policy is, the less effective. R&D investment involves a long-term commitment and translates into sunk costs. Such investment is therefore likely to be sensitive to uncertainty, including uncertainty arising from fiscal or government funding. Past instability is taken by firms as a signal of likely future change. These results confirm Hall's (1992) insight that the impact of R&D tax incentives on US firms grew over time, after it appeared that the scheme was to be maintained in the future. Similar evidence concerning R&D subsidies is reported in Capron and van Pottelsberghe (1997) at the industry level. They find for the G7 countries that R&D is more likely to be stimulated in those industries where government funding is more stable.

The interaction between the various policy tools is also important. The question is whether they are complements or substitutes in stimulating business-funded R&D, *i.e.* are they mutually reinforcing or do they partly cancel each other out? Estimates reported in columns 5 and 6 of Table 2 show that government funding of business R&D is a substitute for fiscal incentives, is complementary to university research, and does not interact with government research. In other words, increasing the direct funding (tax incentives) of business research reduces the stimulating effect of tax incentives (direct government funding). When government funding of business research is high, the negative effect of university research is reduced. This result can be interpreted as government funding helping firms to digest knowledge (otherwise poorly used) coming from university. In a way, this result shows the potential usefulness of university research to the economy, as and when complementary instruments are implemented to help its results to be transferred to firms. The strong interaction between the various policy tools underlines the necessity of an integrated approach to R&D policy; a loss of effectiveness is to be expected when the instruments are used separately.

We now investigate whether defence-oriented R&D funding has a special effect on business-funded R&D. The usual argument of technology spillovers does not fit very well to defence R&D. Military technology is fairly specific, with less emphasis on cost but a requirement for robustness in the extreme conditions of a battle field. There are also severe secrecy constraints attached to defence R&D that make its outcome difficult to apply to widely diffused civilian products. In addition, the results of R&D procurement may not necessarily be used by the R&D performer, which implies that firms do not provide their own financial contributions to such R&D, leading to no leveraging effect. But, because defence contracting is attractive (high-reward, low-risk), firms might allocate their own resources (researchers, equipment), that otherwise would have been used for civilian purposes. Hence, even if defence R&D had a positive impact on business-funded R&D, the effect may be expected to be lower than the effect of a same amount of funding that would flow into projects with a civilian purpose.

The share of defence in government R&D budgets in OECD countries is around 30% on average (OECD, 1999c). However, there are huge differences across countries, with three of them having a high share (the United States around 60%, France and the United Kingdom around 30%) and the rest under 10%. In order to estimate the specific impact of defence funding, we allow the elasticities of private R&D (*RP*) with respect to both direct government funding of business R&D (*RG*) and government intramural R&D (*GOV*) to have a fixed component and a component that varies with the share of defence in the total government R&D budget appropriation [as in equation (2)].[14] The results reported in column 7 of Table 2 show that the two elasticities are inversely related to the share of defence-oriented public R&D: the higher the share of defence, the lower the effect of government funding on business R&D. The effect of government research, which was negative in the estimates above, jumps to zero when it is cleaned of its "defence" component. In other words, it seems that non-defence government intramural research, which is overwhelming in most OECD countries, has no negative effect on business R&D.[15]

4. POLICY IMPLICATIONS

Among the major instruments of government policy, both fiscal incentives and direct funding stimulate business-funded R&D, whereas government and university performed research seem to have a crowding-out effect. In short, when the purpose is to increase business-funded R&D, it is apparently better to give money than knowledge to business. However, it must be reminded that publicly produced knowledge may result in technology that is used by business while not inducing it to increase its research expenditure. Moreover, it is not the major purpose of government laboratories to produce knowledge for the business sector. When the defence component is isolated from the civilian one, only the former has a negative impact on business, the latter being neutral. For university research, barriers to the transfer of knowledge to business can be mitigated by government (targeted) funding of business R&D. And, whereas the crowding-out effect is immediate (contemporaneous with the research spending), spillovers may take time to reach industry, beyond the horizon of our estimates. Various features affect the effectiveness of these policies. First, countries that provide a level of direct funding to business that is either too low or too high stimulate private R&D less than countries with an intermediate level of public funding. The effectiveness of government funding of business R&D seems to have an inverted-U shape, increasing up to a subsidisation rate of about 13%, and decreasing beyond that level. Over a level of 25%, additional public money is likely to substitute for private funding. These figures are only illustrative, as the actual thresholds may depend on the policy pattern and economic conditions in place, which differ across countries and change over time. Second, stable policies are more effective than changing (volatile) policies. Third, the effectiveness of each of the various policy tools depends on the use of the others: in particular, government funding of business R&D and tax incentives are substitutes: increasing the use of one reduces the effectiveness of the other.

An analysis carried out at an international and aggregate level does not lead to specific conclusions with regards to policy design. However, broad policy recommendations can be drawn from these results. 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 firms. Second, the various policy instruments should be consistent with each other, which implies co-ordination between the various administrative departments involved in their design and management. Third, if government is willing to stimulate business R&D, providing too low or too high a level of funding is not effective. Fourth, although defence-related R&D funding does not aim to stimulate private R&D expenditure, its crowding-out effect on business, civilian R&D has to be taken into account. Fifth, the research performed in universities presents a potential usefulness for business that can be improved through targeted government funding to enhance the transfer of technology.

ANNEX 1. THE B-INDEX

The B-index is a synthetic measure of fiscal generosity towards R&D. It has been elaborated by Warda (1996). Algebraically, the B-index is equal to the after-tax cost of a 1 dollar 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: 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: declining balance - DB: $A_d = \frac{\delta}{\delta + r}$, 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 year's 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. Assumptions *i), ii)* and *iii)* are treated similarly, whereas 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-year-average case *v)*, the term between brackets is equal to .171; in the two-year average case *iv)* it is .132; and in the one-year case it is .091. For example, the United States has an incremental tax credit of 20% 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 four 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%. The base amount therefore varies 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% 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 where there is one. Therefore, the flexibility of the policies according to refunding, carry-back and carry-forward of unused tax credit, and flow-through mechanisms are not taken into account by the B-index. In practical terms, the B-index of a country that applies 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. **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. & equip.	Buildings	Level	Increm.	Special Aalowances	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%			yes	42 - 32	0.84 - 0.83	11 - 10
Denmark	100	100	100			25% (C, M, B)		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.
Source: OECD (1998).

Table A2. **Estimated marginal impact (or elasticity – ε) of publicly financed R&D on private R&D**[1,2]

Author(s)	Comments on specification, RHS variables and results	β
Firm-level		
Rosenberg (1976) USA - 1963 - C.S. of 100 firms	Includes output growth, concentration and barrier to entry dummies, the market share, fraction of high-tech inputs, fraction of highly subsidised inputs, and employment; OLS.	2.35*
Shrieves (1978) ε USA - 1965 - C.S. of 411 firms	Includes output, technology profiles and product-market factors, and a concentration ratio; OLS. The estimated parameter is negative for different kinds of industries, except materials.	-.53*
Carmichael (1981) USA - 1977 - C.S. of 46 transport firms	Includes output. OLS. The estimated parameter is nil for large firms.	-.08*
Link (1982) USA - 1977 - C.S. of 275 firms	Includes firm's relative profits, product diversification, the ownership form, and a concentration ratio; OLS. The parameter is negative for basic research, nil for applied research, and positive for development.	.09*
Lichtenberg (1984) USA - 1977 - C.S. of 991 firms	No other variables, the estimated parameter stays negative in growth rates (1972-77); OLS.	-.22*
Scott (1984) ε USA - 1974 - C.S. of 3 387 lines of business	Includes output and firm dummy; OLS.	.08*
Switzer (1984) USA - 1977 - C.S. of 125 firms	***Dynamic*** specification, including change in output, capital investment, dividend payments, long-term debt, internal financing, a concentration ratio; 3SLS.	.08
Lichtenberg (1987) USA - 1979-84 - T.S.C.S. of 187 firms	Includes output and time dummies. When the output is separated into sales to government and other sales, the parameter becomes insignificant; OLS.	.13*
Holemans and Sleuwagen (1988) ε Belgium - 1980-84- T.S.C.S. of 59 firms	Includes dummies for output, employment, industry and foreign firms, a concentration ratio, a diversification index, and payment for royalties and fees; OLS.	.36*
Antonelli (1989) ε Italy - 1983 - C.S. of 86 firms	Includes output, a diversification dummy, the share of exports in total sales, US sectoral R&D intensity, price-cost margin, and profitability; OLS.	.37*
Leyden and Link (1992) USA - 1987 - C.S. of 137 laboratories	Includes shared efforts (*e.g.* in conferences), inter-laboratory agreements, and a two-digit R&D/Sales ratio; 3SLS.	1.99*
Industry-level		
Nadiri (1980) ε USA - 1969-75 - T.S.C.S. of 10 industries	***Dynamic*** specification, including value added, labour, fixed capital, utilisation rate, and the ratio of wage to user cost of capital; OLS. Negative impact for five durables industries.	.01*
Levin and Reiss (1984) [3] USA - 1967, 72, 77 - C.S. of 20 industries	Includes age of capital, a concentration ratio and sectoral dummies; Instrumental variables technique.	.12*
Lichtenberg (1984) USA - 1963-79 - T.S.C.S. of 12 industries	Includes time and industry dummies, variables in growth rates; OLS. When the time dummies are withdrawn from the model, the parameter becomes positive (.22*).	.01
Mamuneas and Nadiri (1996) USA - 1956-88 - T.S.C.S. of 15 industries	Translog cost function, including output, labour, physical capital, the relative price of materials, a time trend, and industry dummies; MML.	.54*

Table A2 (*cont'd*). **Estimated marginal impact (or elasticity – ε) of publicly financed R&D on private R&D**[1,2]

Author(s)	Comments on specification, RHS variables and results	β
Country-level		
Lichtenberg (1987) USA - 1956-83 - T.S.	Includes output and a time trend. Estimates adjusted for first-order serial correlation of residuals. When output is separated into sales to government and other sales, the parameter becomes insignificant.	.33*
Levy and Terleckyj (1983) USA - 1949-81 - T.S. (private business)	Includes output, corporate taxes, unemployment, and age of R&D stock. Generalised least squares.	.21*
Levy (1990) 9 countries -1963-84 -T.S.C.S.	Includes output and country dummies. Box-Cox procedure applied to the panel data. The estimates are positive for four countries (including the United States and Japan), insignificant for two, and negative for the United Kingdom and the Netherlands.	-.73* to .41*

1. The last column reports the average impact (or elasticity: ε) of government R&D on private R&D in the main existing empirical studies.
2. T.S. = time series; C.S. = cross section; T.S.C.S. = panel data; OLS = ordinary least squares; 3SLS = three-stage least squares, MML = maximum likelihood.
3. The estimates by Levin and Reiss have to be interpreted as a negative relationship between government and private R&D because the dependent variable is total R&D instead of privately financed R&D.

* Significantly different from zero at a 10% probability threshold.

Source: Adapted and extended from Capron and van Pottelsberghe (1997).

NOTES

1. An attempt to measure the simultaneous effect of direct government funding to business R&D and tax incentives on privately funded and performed R&D is presented in Guellec and van Pottelsberghe (1999). The present document improves on these results by taking into account other types of public R&D and by performing new econometric specifications.

2. Smaller countries in the European Union, like Belgium and Sweden (4%), tend to have a lower share of public research performed in public labs than do larger countries, especially France and Italy (more than 20%).

3. The B-index is similar to the marginal effective tax rate (METR) computed for eight OECD countries by Bloom *et al.* (1997). However, the latter is composed of a tax component and an "economic component" which is the sum of the firm's discount rate (actually, the interest rate) and R&D depreciation rate, less the rate of inflation. The empirical results of Bloom *et al.* show that the tax component significantly affects business-funded R&D expenditure, while the economic component has no significant impact.

4. 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.

5. Only two of the 18 studies surveyed in Annex Table A2 adopt a partial adjustment mechanism for the R&D investment equation.

6. Country dummies, which would control for the fixed effects generated by "*level*" variables, are not included due to the first difference specification. In addition, in a dynamic context, adding country dummies would yield inconsistent estimates because the lagged endogenous variable is among the right-hand side variables. Indeed, Nickell (1981) and Keane and Runkle (1992) show that the within transformation introduces a correlation between the lagged endogenous variable and the error term. However, had they been introduced into the regression equation, unreported results have shown that they would have been similar. Time dummies are included to take into account technology shocks common to all countries that are not controlled for by the exogenous variables, such as the increasing use of information technology.

7. It should be kept in mind, however, that a four-year lag might be too short to capture the longer-term effects of basic research. The effects of basic research can take several decades before reaching the application stage (Adams, 1990). Moreover, it is not clear whether positive externalities should translate into increased private R&D expenditures.

8. The econometric method is three-stage least squares. The first two stages, which are deemed to take into account the presence of the endogenous variable among the right-hand side variables, correspond to an instrumental variable procedure. The last stage is used to correct for the contemporaneous correlation of the residuals. Stage 1: fit ΔRPt with $\Delta RPt\text{-}2$ and all the other exogenous variables. Stage 2: regress equation (1), with the fit of $\Delta RPt\text{-}1$. Stage 3: correct for the contemporaneous correlation of the residuals.

9. This test has to be interpreted with caution. If it globally rejects the hypothesis of cross-sectional correlation for each pair of countries, there may still be a strong correlation between some pairs of countries. In this case, the correction for contemporaneous correlation has to be made, even if the null hypothesis is not rejected. With the present estimates, 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 characterised by a cultural and geographical proximity, or size similarity.

10. These estimated long-term effects are similar to those obtained by summing up the significant parameters in the non-dynamic model that includes several lags (see Annex Table A1) : 1.58 for value added, 0.16 for government funding, –0.51 for fiscal incentives, -0.20 for government intramural expenditure, and -0.07 for university research.

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

12. Additional econometric results reported in Guellec and van Pottelsberghe (1999), were used to estimate directly marginal effects, 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. Results are similar to those reported here.

13. There is less of a case for an effect of the stability of government or university research affecting their impact on business-funded R&D.

14. In other words, we assume that βRG and βGOV in equation (1) have the following form: $\beta = c + \gamma \,.\, DEFshare$, where c is the fixed component of the elasticity and γ reflect the component that varies with respect to the share of defence-related R&D in total government budget appropriation on R&D.

15. Guellec and van Pottelsberghe (1999) relied on a different approach to obtain an insight into the effect of defence-related government support. Data on the share of government procurement for defence purposes were collected from five countries. It turned out that the defence component of direct government funding of business R&D has a negative and significant impact for the three countries with very high funding rates. In the present study, we use data available for 17 OECD countries, which is the share of defence in total government budget outlays on R&D (including procurement and intramural research).

REFERENCES

Adams, J. (1990), “Fundamental Stock of Knowledge and Productivity Growth”, *Journal of Political Economy,* 98(4), pp. 673-702.

Arrow, K. (1962), “The Economic Implications of Learning by Doing”, *Review of Economic Studies*, 29(2), pp. 155-173.

Bloom, N., R. Griffiths and J. Van Reenen (1997), “Do R&D Tax Credits Work? Evidence from an International Panel of Countries 1979-94”, paper presented at the TSER Conference on Innovation, Competition and Employment, 21-22 August, Chania.

Capron, H. and B. van Pottelsberghe de la Potterie (1997), “Public Support to Business R&D: A Survey and Some New Quantitative Evidence”, in OECD, *Policy Evaluation in Innovation and Technology: Towards Best Practices*, pp. 171-188, OECD, Paris.

David, P.A. and B.H. Hall (1999), “Heart of Darkness: Public-private Interactions inside the R&D Black Box”, *Economic Discussion Paper,* No. 1999-W16, Nuffield College Oxford, June.

David, P.A., B.H. Hall and A.A. Toole (1999), “Is Public R&D a Complement or a Substitute for Private R&D? A Review of the Econometric Evidence”, *NBER Working Paper,* No. 7373, Cambridge, MA.

Goolsbee, A. (1998), “Does Government R&D Policy Mainly Benefit Scientists and Engineers?”, *American Economic Review*, 88(2), pp. 298-302.

Guellec, D. and B. van Pottelsberghe (1999), “Does Government Support Stimulate Private R&D?”, *OECD Economic Studies*, 29, 1997/II, pp. 95-122.

Hall, B. (1992), “R&D Tax Policy during the Eighties: Success or Failure?”, *NBER Working Paper,* No. 4240, Cambridge, MA.

Kealey, T. (1996), *The Economic Laws of Scientific Research*, McMillan Press, London.

Keane, M.P. and D.E. Runkle (1992), “On the Estimation of Panel-data Models with Serial Correlation when Instruments are not Strictly Exogenous”, *Journal of Business & Economic Statistics*, 10(1), pp. 1-9.

Lichtenberg, F. (1984), “The Relationship between Federal Contract R&D and Company R&D”, *American Economic Review Papers and Proceedings*, 74, pp. 73-78.

Mamuneas, T.P. and I.M. Nadiri (1996), “Public R&D Policies and Cost Behaviour of the US Manufacturing Industries”, *Journal of Public Economics*, 63, pp. 57-81.

Mansfield, E. (1964), “Industrial Research and Development Expenditure”, *Journal of Political Economy*, 72, August, pp. 319-340.

Mohnen, P. (1997), “R&D Tax Incentives: Issues and Evidences”, Université du Québec à Montréal and Cirano, mimeo.

Nickell, S. (1981), “Biases in Dynamic Models with Fixed Effects”, *Econometrica,* Vol. 49, pp. 1417-1426.

OECD (1994), *The Measurement of Scientific and Technical Activities 1993: Standard Practice for Surveys of Research and Experimental Development – Frascati Manual*, OECD, Paris.

OECD (1998), *Technology, Productivity and Job Creation: Best Policy Practices*, OECD, Paris.

OECD (1999a), *The OECD STAN Database for Industrial Analysis*, OECD, Paris.

OECD (1999b), *Main Science and Technology Indicators*, 1999/1, OECD, Paris.

OECD (1999c), *Benchmarking Knowledge-based Economies: A Scoreboard of Indicators*, OECD, Paris.

Warda, J. (1996), “Measuring the Value of R&D Tax Provisions, in OECD, “Fiscal Measures to Promote R&D and Innovation” [OCDE/GD(96)165], pp. 9-22, OECD, Paris.

Young, A. (1998), “Measuring Government Support for Industrial Technology”, OECD, Paris, mimeo.