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Business-funded R&D intensity: impact and complementarity of public financial support

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Abstract

There are relatively few studies that measure the macroeconomic effect of financial support policies on private investment in R&D. By distinguishing direct and indirect measures, the objective of this paper is to analyse the individual effect and the complementarity of these policies. The complementarity is studied in two ways: the complementarity between instruments and the complementarity between jurisdictions. Using a database covering 25 countries of OECD over the period 1990-2007, our dynamic panel data results show that only indirect support (tax incentives) affect directly and significantly the business-funded R&D intensity. Even though direct support (subsidies, loans) do not have any significant individual effect on business R&D, it seems that their strengthening would be detrimental to the effectiveness of indirect support. Indeed, our results show that direct and indirect support are substitutes for stimulating private investment in R&D. Finally, the fact that foreign policies for R&D do not influence the level of private investment in R&D in a country supports the idea of a jurisdiction's complementarity at the national level.

JEL classification: H25, 031, 038

Keywords: Business-funded R&D, subsidies, fiscal incentives, efficiency, panel data

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1 Introduction

The European Commission has fixed an R&D investment objective for the "2020 European Strategy"[1] at 3% of the GDP, two thirds of which are to be financed by the private sector. This objective seems somewhat ambitious however, given the reality of the situation where the EU's R&D investment for 2009 totalled at 2% of the GDP and that of the firms at 1.09% (source: Eurostat). Hence, whereas the public sector has almost attained its investment objective (0.91% vs 1%), that of the private sector remains well-below (1.09% vs 2%).

Fixing objectives for R&D expenditure is not specific to Europe as numerous countries have fixed such objectives, as is shown in the table in Appendix 1. This highlights the fact that the public authorities share the opinion that the numerous market failures are responsible for the gap between private and social returns to R&D, which in turn leads to firms under investing in R&D. This view justifies the setting up of public policies in support of private R&D and, today, most countries have implemented financial support policies. However, as we can see on figures 1-6 at the end of the paper, there exists a variety of country's profile in terms of R&D policy instruments used, their intensity and their dynamic. Even if available data principally concerns OECD countries, we still think that econometric studies evaluating the impact of support policies for R&D are also useful for other countries that use or want to use those instruments.

Indeed, even if firms under-invest in R&D, in order to be able to justify financial support one must suppose that they provide convincing incentives for the firms' investment decisions. The data available, concerning R&D in the private sector, does lead us however, to question whether or not such measures are able to provide sufficient incentives. Indeed, privately financed R&D in the EU has only increased from 1.03% of the GDP in 1999 to 1.09% in 2009 whereas the cost of national financial support for R&D has increased significantly. R&D community programmes have also seen their financial endowment greatly augmented (notably the Framework Programme for R&D). Furthermore, it may be noted that those EU countries where private investment in R&D is close to or higher than the objective fixed at 2% of the GDP (Denmark, Germany, Finland, Sweden) are countries where support for R&D, whether direct (subsidies and contracts) or indirect (fiscal measures) is less than the EU and OECD average.

Not only these statistical observations, but also the theoretical literature highlights a number of elements which might limit the positive impact of financial support for private R&D. At the microeconomic level, for instance, firms may be encouraged to partially substitute public subsidies or fiscal gain for their own R&D endeavours. At the sectoral level, it is possible that certain measures generate significant distortions which affect the allocation of capital and lead to substitution effects between firms and sectors. At the macroeconomic level, it is possible that public stimuli increase the cost of R&D input (due to tight supply) and do not permit an increase of private incentives to invest in R&D.

[1] The objectives set by "2020 European Strategy" are the same as those of the Lisbon agenda (2000) for R&D. For further information see: $http://ec.europa.eu/europe2020/index_en.htm$

Moreover, based upon the main theoretical results obtained from other analyses using Economic Geography Growth models (Martin (1999), Montmartin (2012a and b)), one can also suppose that these type of policies are subject to distortions due to their implications on the location dynamics of firms between countries, especially when countries display important gap in terms of economic development. Dealing with the wellknowed "territorial equity-growth" tradeoff, this literature goes far beyond the subject of this paper. However, it demonstrates the necessity to take into account the spatial interactions which can effect the efficiency of such policies, i.e. the efficiency of each policy implemented on one given territory (whatever it is nation, region ...) cannot be considered independently from the policies implemented in other territories.

The extensive empirical literature[2] evaluating the impact of financial support on private investment in R&D has two main specificities, as is pointed out by Guellec & Van Pottelsberghe de la Potterie (2003). On the one hand, the vast majority of studies evaluate a specific measure's capacity to create an additionality effect (leverage) on private R&D investment. On the other hand, these studies are, for the most part, carried out on a microeconomic level. Finally, to our knowledge, there exist only 3 studies which analyse the impact of the various financial support afforded to R&D at the macroeconomic level (Guellec & Van Pottelsberghe de la Potterie 2003, Shin 2006, Falk 2006).They do however, give us an idea of the general effect of the various instruments and enable us to test for complementarity or substitution effects between them. Even though available macroeconomic data is only able to distinguish between direct support (contracts and subsidies) and indirect support (fiscal measures), they can provide interesting results for defining policy-mix as both types of support for R&D rely upon very different incentive mechanisms.

Although the aim of financial support for R&D is not only to increase firms' R&D investments, we still think it important to develop this question which has hitherto been somewhat neglected at the macroeconomic level. In this paper, we will address three core questions: Do direct and indirect support enable an increase in privately financed R&D? Do these measures act as complements or substitutes where this objective is concerned? Does external financial support (from other countries) affect the intensity of private R&D investment?

If numerous studies have dealt with the first question, fewer have shown any interest in the other two. They do however, seem to be fundamental in a context where R&D activity is becoming increasingly internationalised (Hall, 2011) and budgets are being restricted, if only to provide elements concerning the internal and external complementarity between support policies for private R&D (see Wilson, 2009).

Our results, which were obtained from a sample of 25 OECD countries over the period 1990-2007, reveal a distinct difference between the capacity of direct and indirect support to increase the intensity of private R&D investment. Indeed, whereas indirect support causes

[2] See reviews by David et al. (2000), Hall and Van Reenen (2000), Mairesse and Lentille (2009)and Bérubé and Mohnen (2009).

a significant increase in firms' R&D investments, our results show that direct support remains relatively neutral. This difference in impact appears even more significant in that both measures appear to be substitutes for increasing the intensity of private R&D investment. Guellec & Van Pottelsberghe de la Potterie (2003) had previously highlighted the effects of substitution between instruments, and these should be taken into account in order to optimise the impact of mixing direct and indirect measures for private investment. Where external complementarity is concerned, our results do not, on the whole, show any particularly strong influence of external financial support (whether direct or indirect). This result, when combined with previous results, supports the empirical studies which show the marginal impact of public support upon the location of R&D activities. Hence, fiscal competition for R&D within the OECD would not be particularly harmful in that our results show that national measures are better able to galvanise internal investments than attract external investment. The lack of any significant influence of external support upon private national investment in R&D means that they do not reduce the effectiveness of internal support. This result should be correlated with those of Wilson (2009), who accounts for the important eviction effects between local indirect support, with the aim of providing an indication as to the correct geographical scale for the setting up of such measures. Indeed, if local support are ineffective for a country and external support has no significant effect, then it would seem to be desirable that direct and indirect support be implemented at a national level. Beyond these results concerning financial support for R&D, our study highlights the importance of general conditions for the financing of private R&D investment. It also suggests that the positive externalities of public R&D are more global than national. These elements lead us to believe that a greater place should be given to preferential financial measures and that developed cooperation in public R&D programmes would be conducive to encouraging firms to invest in R&D.

This article is organised as follows: Section 2 provides a review of the literature evaluating the capacity of financial support for R&D to generate leverage on the firms' R&D investments. The following section presents the empirical models which were tested. Section 4 describes data and the estimation strategy used. Section 5 presents our results and we conclude this paper in Section 6.

2 Financial support for private R&D: An overview

2.1 Direct vs. Indirect support : a necessary distinction

As highlighted by David et al. (2000, p.52):

"[...] two main policy instruments may be identified: tax incentives that reduce the cost of R&D, and direct subsidies that raise the private marginal rate of return on investment in such activities. Although not strictly necessary, the primary difference in execution between these two policy instruments is that the former typically allows the private firms to choose

projects, whereas the latter usually is accompanied by a government directed project choice, either because the government spends the funds directly or because the funds are distributed via grants to firms for specific projects or research areas"

Based upon this observation, we deemed it important to show more generally, the value of distinguishing between the two types of financial support afforded to R&D: direct (contracts[3] and subsidies) and indirect (financial measures such as tax allowances and credits). Although in this paper we have limited ourselves to discussing the effects of these financial support upon private investments in R&D, the value of distinguishing between them is even more obvious as it takes into account both their cost and their potential impact upon welfare.

As David et al. (2000) point out, economists and experts often emphasise the "friendly market" side of financial measures which leave decision-making and the management of R&D investment to the firms and which may potentially be of benefit to all firms involved in R&D (as opposed to direct support). Furthermore, direct measure is often criticised for not being allocated judiciously and for being costly in terms of management. Many economists however, also highlight the limitations of indirect support, particularly in terms of the potential impact upon welfare. Ideally, these incentive measures should promote projects where the gap between social productivity and private returns is the greatest. Nevertheless, it is clear from the microeconomic point of view that firms will finance projects where there are greater private returns and not those where the gap between social and private productivity is more significant. Inversely, direct support, which is often allocated according to a ranking of R&D projects and is predefined by public authorities, should enable the targeting of projects with considerable social returns. Finally, although indirect support do not require a dedicated budget line (and the financing thereof), it is difficult to predict their cost in terms of loss of income.

Obviously, many other elements differentiate direct financial support from indirect financial support. The table below, inspired by Carvalho (2011), offers an overall view of the main advantages and disadvantages in terms of cost, efficiency and social impact of both direct and indirect support of R&D.

[3] These, according to David et al. (2000), represent the greater proportion of direct support which includes all R&D contracts granted to private companies in the aeronautical and military sectors.

	Advantages	Disadvantages
Direct support	• Adapted to target upon activities and projects where there is a significant gap between private and social returns to R&D. • Theoretically, competition between firms ensures that public funds are used for the best R&D projects. • May be used to reduce the effects of economic cycles on firms' R&D investments. • May encourage cooperation and the transferral of technology thereby reinforcing knowledge externalities • Allows the verification of costs entailed by measures. • May enhance the reputation of firms who have received financing thereby reducing their capital cost (SMEs).	• High administrative costs for both firms and public authorities. • Impossible to put into practise for a large number of projects. • Causes distortions on the markets for the allocation of resources between different R&D fields and firms. • Project selection tends to reward lobbies. The pressure related to the result objectives of the established policies entails the risk of projects being selected due to their high success potential, ie., projects with high private returns to R&D carried out without any public funding. • Numerous potential eviction sources, due to the fact that direct measures are targeted and affect returns to R&D.
Indirect support	• Measures are more neutral as they encourage investment in R&D for all firms, particularly SMEs (although specific sectors may also be targeted). • The firms themselves decide which projects they wish to invest in. • Reduces the risk of public markets being rigged. • Does not require a specific budget line as the cost is only expressed in terms of a loss of financial income. • Implementation and management costs are relatively low (although they are tempered by the OECD (2001)). • Financial measures reduce the cost of R&D directly which theoretically reduces the potential eviction sources.	• It is difficult to control the cost of financial measures. • The effects are limited for firms who do make sufficient profit or which invest heavily in R&D (large companies) because they do not reap the maximum benefit from the financial measures. • Non-neglectable risk of eviction as these measures can reduce the cost of projects which would have been carried through anyway (particularly in the case of a large tax credit). • Financial incentives favour R&D projects with the highest short-term return. Hence, projects with high social returns to R&D will not be favoured by this type of measure. • Few knowledge externalities are generated as the firms choose the projects and cooperation is rarely a factor for eligibility.

For financial support of R&D to have a positive effect at the macroeconomic level upon private R&D investment, it must provide sufficient incentive without incurring any serious negative external effects. The literature[4] makes the distinction between three effects which can reduce the positive impact of these measures. At the microeconomic level they can only serve to finance R&D projects which would have been financed anyway or not be used to increase R&D expenditure. In which case, public funds are a (partial) substitute for private R&D funding. At the sectoral level, financial support of R&D may perturb the allocation of capital in favour of certain firms and/or sectors and thus have a low or even negative general effect. Indeed, even though these measures encourage the firms who benefit from them to increase their R&D investments, they may create distortions vis à vis the firms and sectors who do not (or only very little) and thereby cause a reduction in the latter's R&D investments[5]. Finally, at the macroeconomic level, financial support for R&D may cause a tightening of the price of R&D inputs, and in particular on that of the most important input, that is to say, labour. Indeed, implementing an important support programme for private R&D may result in a significant increase in the demand for input. As the resources in personnel, qualified for R&D activities, are relatively inflexible in the short term, the increase in demand will increase pressure for a rise in wages. Consequently, this will increase R&D margin costs and, all things being equal, will lead to a decrease in private R&D investment.

[4]See Capron et al. (1997), David at al. (2000), Hall and Van Reenen (2000).

[5]For example, subsidised firms may have a higher probability of quickly and successfully commercialising innovations which may reduce the productivity expected from the R&D projects of non-subsidised firms.

From there, the question which arises naturally is to discover whether the effects are of the same amplitude for direct and indirect support. According to David et al. (2000, p.502):

"*Because a tax credit directly reduces the marginal cost of R&D, one would not expect to see "crowding out" effects on industrial R&D spending except via the channel of an increase in the real cost of R&D (if the inputs are inelastic supply)*"

The conditions that such an observation supposes deserve to be defined. Indeed, if one State sets up an extensive tax credit for research, this will benefit all of the firms carrying out R&D activities, although some of these will not increase their investments in that area. On the other hand, if that State sets up an incremental tax credit, then the firms will be obliged to increase their investment efforts in order to benefit. By the same token, for there to be no distortion between firms and sectors, caused by the implementation of financial measures, these need to be uniformly applied to all sectors, they should concern all R&D expenditure and there should be no thresholds. Hence, the response of David et al. (2000) is valid only under certain very restrictive and unrealistic conditions. It therefore appears difficult to determine whether the effects which limit the effectiveness of indirect support are more or less strong than those which limit the effectiveness of direct support.

These different elements show the importance and the value of distinguishing between direct and indirect financial support, whether for our purpose or more generally, in order to carry out an evaluation of financial support in the field of R&D. Of course, a finer distinction between these measures would be even more relevant. For example, one could distinguish between targeted financial measures and non-targeted measures; and, where direct support is concerned, it would be interesting to distinguish between R&D contracts and subsidies which are often allocated according to more competitive standards. The available macroeconomic data does not however enable such a fine level of analysis. We will continue in this section by proposing a synthetic presentation of the results from the empirical literature, concerning the impact of financial support upon the firms' R&D investments. The necessary distinction between direct and indirect support requires that we divide this review into three parts. The first presents the empirical results pertaining only to direct support (at both the micro and macro levels). The second presents the results of empirical studies pertaining only to indirect support (also at both the micro and macro levels). Finally, the last part presents the results of macroeconomic studies which analyse the influence of both tools simultaneously.

2.2 The impact of direct financial support for private R&D: Contrasting results

As the literature on this subject is substantial there have been several articles synthesising the empirical results obtained[6]. The article written by Capron et al. (1997) analyses the results of 19 studies and reaches the conclusion that, from a general point of view, direct

[6] See reviews by Capron et al. (1997) and David et al. (2000).

support measures generate an additionality leverage effect upon private R&D. This implies that the public funds received are used entirely to finance R&D activities and that they also generate an additional effect upon the firms' incentives to invest in R&D (thus, a 1$ subsidy would result in an increase of private R&D investment superior to 1$). These most positive observation should however be kept in perspective. Indeed, as Capron et al. (1997) point out if one concentrates upon the microeconomic studies then the results become much more contrasted. Moreover, if the macroeconomic studies carried out by Levy and Terleckyj (1983) and Lichtenberg (1987)[7] demonstrate a significant leverage effect of direct support, Levy's study (1990) carried out in 9 OECD countries show that there exists considerable heterogeneity among the countries. Indeed his results show that if direct support measures exert leverage in the United States, Japan, France, Germany and Sweden, they seem to have a substitution effect in the Netherlands and the United Kingdom[8].

Furthermore, Capron et al. (1997) emphasise the fact that the majority of these studies do not take into account certain determining factors for R&D investment and the allocation of direct public subsidies for R&D. The most important of these (at the macroeconomic level) is the lack of any specification which integrates an adjustment process for firms' investments in R&D. R&D spending however, is essentially made up of long-term investment, which means that the level of previous R&D investment is a primary determining factor for current R&D investment. Our authors also note that two studies[9], which introduce a dynamic process, give an account of the substitution effect that direct support exerts upon private R&D investment. The second important, and unaccounted for, characteristic (especially for micro studies) is the exogeneity hypothesis for direct support.

In order to offer a more satisfying macroeconomic estimation of the effect that direct support exerts upon private R&D investment, Capron et al. (1997) test a specification which integrates a dynamic adjustment process for 7 OECD countries. Their results are quite different from those obtained by Levy (1990) as direct public support only seems to generate leverage upon private R&D investment in the United Kingdom. Inversely, substitution can be observed in Canada, France and Italy[10]. As the firms' R&D data is obtained by aggregating sectoral data, the authors' aim is to evaluate the extent of the sectoral distortions caused by these measures. To this end, they estimate the weighted marginal effect of direct subsidies[11]. The results are clearly different from the unweighted estimations, thereby showing that direct subsidies generate significant inter-industry external effects[12]. As, for nearly all countries,

[7]See reviews by Capron et al. (1997) and David et al. (2000).

[8]Furthermore, no significant marginal effect was found in either Switzerland or Italy.

[9]Nadiri (1980) uses data from American industry producing durable goods. And Fölster and Trofimov (1996) use individual data from Swedish firms.

[10]Direct support measures do not seem to have any significant effect in other countries (USA,Germany, Japan).

[11]This signifies that after having estimated the marginal effect for each industry, they weight these effects by using the direct national subsidies which are allocated to each industry. Thus, for each country, we obtain the weighted average of the marginal effects of each industry.

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the weighted marginal effect of direct support is greater than its effect when unweighted, the externalities connected to the setting up of direct subsidies generate negative distortions for R&D investment in general.

A few years later, David and Hall (2000) propose a more complete literary review which takes into account the 30 econometric studies carried out between 1966 and 1999. On the whole, their conclusions are similar to those of Capron et al. (1997) ie., that most studies support the idea that direct financial support creates leverage. On the other hand, if only microeconomic approaches are considered, the results are contrasted as half of the studies show leverage whereas the other half shows substitution. It is interesting to note at this stage of our analysis that econometric methods which take into account the endogeneity of direct subsidies all reach the conclusion that there is a substitution effect[13]. The results of the macroeconomic studies however, point almost unanimously to the leverage effect. Nevertheless, David and Hall (2000) do highlight the fact that the problems linked to specification and estimation in these studies[14] would lead us to believe that they over-estimate the positive effects of direct public support of R&D.

The reviews proposed by Capron et al. (1997) and David and Hall (2000) show that there is a certain contrast between the results of studies carried out at the microeconomic level and those carried out at the macroeconomic level. David and Hall (2000) uphold the belief that this difference could be at least partly connected to the fact that (at the macroeconomic level) the impact of direct support upon the cost of R&D input is not taken into account. Goolsbee (1998), using American data, shows that an increase in direct subsidies has a significant effect upon the salary raises of both engineers and researchers. According to the author, not taking this price-effect into account implies that the macroeconomic estimations proposed in the literature overestimates the effect of these measures by 30 to 50%. Wolff and Reinthaler's study (2008) carried out on a panel of 15 OECD countries between 1981 and 2002 seems to corroborate this theory. Indeed, they demonstrate that although direct support has a positive effect upon firms' R&D expenditure, they do not have any significant influence upon the number of researchers employed by the firms. As R&D's main input is labor, this result suggests that the positive effect of direct support when observed at the macroeconomic level basically reflects salary raises for the researchers.

Hence, the results provided by the literature concerning the impact of direct support of R&D remain fairly ambiguous. At the microeconomic level, the idea of a leverage effect upon direct subsidies does not seem to be the most likely hypothesis and at the macroeconomic level also, the fact that the inter-industry effects as well as the price-effect upon inputs are not taken into account would lead us to think that these studies clearly overestimate the positive impact of direct support upon firms' investment in R&D. The lack of any clear conclusion concerning direct support is reinforced by Garcia-Quevedo's meta-analysis

[13]See econometric studies by Lichtenberg (1988), Toivanen and Niininen (1998) and Wallsten (2000).

[14]Not taking into account the problem of endogeneity of direct support and the absence of adjustment processes.

(2004) of 39 econometric studies. He retains numerous elements[15] which could explain the differences between the results of theses econometric studies. None of the retained variables is of any real significance. In other words, it would be difficult to explain the differences found in the results provided by the empirical studies.

2.3 The impact of indirect financial support for private R&D : a significant impact

Hall and Van Reenen's literary review (2000) highlights that the studies carried out at the microeconomic level are just as extensive as those concerning direct support. In the case of studies using American data where a research tax was set up before 1981, there is a clear break between the results obtained with data previous to 1983 and those carried out using later data. Indeed the results of the earlier studies show that the price-elasticity of private R&D expenditure is negligible, even insignificant. The resulting cost-benefit analyses conclude that the research tax credit cannot exert a leverage effect upon firms' R&D investments. Inversely, studies using more recent data estimate that the price-elasticity of R&D expenditure is near to 1. The cost-benefit analyses which result from these estimations show significant leverage caused by indirect support, as for each dollar of lost tax revenue, the firms have invested between 1.3 and 2$ more in R&D. From these studies it also becomes apparent that tax measures have an increasing influence over time and this would appear to be connected to the partial adjustment process of investment decisions. This may explain why studies, carried out for the two first years of tax rebate in the United States (1982 and 1983), do not find any significant effect of this measure upon private R&D investment. For studies concerning countries other than the United States, Hall and Van Reenen (2000) confirm, on the whole, the results of the American studies, ie., indirect support of private R&D exerts a leverage effect in the long-term upon firms' R&D investment. The idea that tax measure for R&D have a progressive effect is also upheld by the results found by Lentille and Mairesse (2009). Based upon 33 microeconomic studies, the authors highlight a positive correlation between the estimated effect of tax allowances for research and the period analysed, ie., the more recent the data used by the study, the greater the tax measure's positive effect.

Mohnen and Lokshin's article (2009) proposes (among other things) a synthesis of the empirical results obtained following Hall and Van Reenen's review (2000). They show that, whilst the studies carried out at the macroeconomic level are in the minority, they are developed according to a structural approach which allows a better appreciation of how efficient policies are, given their effect upon welfare. These new approaches contribute a finer analysis of the effect of tax measures upon private R&D investment. Indeed, as Mohnen and Lokshin's (2009) point out, the results of these studies show that if an incremental research tax credit generates leverage on private R&D investment this is not the case for a

[15] Among these elements the author retains in particular the year of publication, the scope of each study (firm, industry, country...), the use of an adjustment process, the presence of fixed effects,...

level-based tax credit. Thus, these more recent studies confirm that tax measures are able to generate leverage upon private investment at the same time as highlighting a clear difference according to the basis upon which they are applied. Of the studies considered by Mohnen and Lokshin (2009), the one by Bloom et al. (2002) evaluates the effect of tax incentives upon private R&D investment[16] in 9 OCED countries between 1979 and 1996. The estimations obtained evaluate the price-elasticity of R&D expenditure at between -0.1224 and -0.144 in the short term and greater than -1 in the long-term (as the adjustment process of private R&D expenditure takes quite a long time). These results seem to be robust as, when the authors carry out the individual estimations for each country, they bring out the positive impact of tax measures for seven out of the nine countries included in the study.

Hence, from a general point of view, the empirical studies show that indirect financial support is able to produce a leverage effect upon private R&D investment. This conclusion however, should be treated with care for several reasons. As Mohnen and Lokshin (2009) suggest,the capacity of tax credit measures to exert a leverage effect upon private investment depends greatly upon the basis upon which they were applied. Furthermore, empirical studies, using a specification dynamic show that tax incentives have an increasing effect upon private R&D investment over time as the adjustment process for private investment is relatively slow. The effect of such measures may therefore only be correctly appreciated in the long-term.

2.4 Macroeconomic studies simultaneously measure the effects of direct and indirect support of R&D

Very few studies simultaneously measure the effects of direct and indirect support of R&D at the macroeconomic level. And yet these studies are of great interest as, amongst other things, they will allow us to analyse the complementarity of these measures in order to increase private R&D investment.

To our knowledge, Guellec and Van Pottelsberghe de la Potterie's study (2003) is the first to simultaneously analyse the effect of these two types of tool for private R&D. Their results, obtained from a panel of 17 OCED countries over the period 1981-1996 show that both direct and indirect support have a significantly positive effect upon firms' investment in R&D. The marginal 1$ impact of direct support is thus estimated at 0.7$ and, in the long-term, the price-elasticity of private R&D expenditure is estimated at -0.3. Compared to the results found in the relevant literature, the effect of direct support appears to be stronger whereas that of indirect support appears to be weaker. In our opinion, these differences are closely connected to the estimation method used by the author who measures the impact of financial support upon the growth of private R&D investment and not upon its absolute value. Guellec and Van Pottelsberghe de la Potterie (2003) also investigate the complementarity of direct and indirect support in order to boost private R&D investment.

[16] The authors only use the R&D expenditure of the industrial sectors of each country.

Their results show a significant substitution effect between direct and indirect support, ie., the increase of direct support reduces the positive effect of indirect support of private R&D investment, and vice-versa. Hence, this result demonstrates the importance of public authorities having a global approach when they define their policy-mix for direct and indirect measures.

Shin's study (2006), concerning Korean private R&D investment between 1982 and 2002 also shows that direct and indirect support both have a significant and positive effect upon firms' R&D investment. The estimated effects are however, closer to those found in the literature as the estimated marginal effect of direct support lies between 0.1 and 0.15 and R&D price-elasticity is closer to -1 in the long-term (which defines the threshold from which private over-investment in R&D compensates for the loss of tax revenue, see Falk, 2006, p.535). The only macroeconomic study which uses the intensity of private R&D expenditure is that proposed by Falk (2006). In this study, the author evaluates (amongst other things) the impact of financial support for R&D by using a panel of 21 OCED countries between 1975 and 2002. The results show that direct support does not have a significant influence upon the intensity of private R&D whereas indirect support seems to have a significant effect as R&D price-elasticity is close to -1 in the long-term. Like Wolff and Reinthaler (2008), who use a relative measurement of direct subsidies instead of their absolute amount in order to ensure that the price-effect of these measures upon R&D inputs are taken into account, we believe that the absence of their influence in Falk's study (2006) is due to the fact that direct subsidies are expressed as a percentage of the GDP. Consequently, he uses the ratio of two nominal variables which allows de facto a better recognition of the price-effect of direct subsidies upon inputs, by comparison with previous macroeconomic studies.

Finally, these three studies which give a simultaneous analysis of the impact of both direct and indirect subsidies for R&D provide conclusions which are quite close to those of studies which analyse the two types of tool separately. Tax incentives do indeed seem to have a significant positive effect upon private R&D investment whereas the positive effect of direct subsidies seems to be a lot less obvious. Furthermore, an interesting result comes to light in the study carried out by Guellec and Van Pottelsberghe de la Potterie (2003); this shows that direct and indirect subsidies are substitutes for increasing firms' R&D investments. More generally, the literature review has enabled us to highlight the significant difference between studies carried out at the microeconomic level, which have reservations concerning the impact of financial support upon private R&D (whether direct or indirect) and those carried out at the macroeconomic level, which are much more positive. It would also seem that indirect subsidies are more likely than direct subsidies to generate a leverage effect upon private R&D investment. Finally, this review demonstrates the necessity of using an empirical model, taking into account the irreversibility of R&D investments due to the great adjustment costs.

3 Empirical models

In order to measure the effects of both direct and indirect support for R&D upon the intensity of private investment in R&D, we have based our model upon the empirical models for R&D investment developed by David et al. (2000), Guellec and Van Pottelsberghe de la Potterie (2003), Shin (2006) and Falk (2006) :

$$\begin{aligned} DIRDFIPIB_{it} = & f(INTERETLT_{it}, CREDITPIB_{it}, DIRDPUBPIB_{it}, \\ & SUBPIB_{it}, BINDEX_{it-1}) \end{aligned} \tag{1}$$

where index i refers to country i and index t refers to year t. $DIRDFIPIB$ represents R&D expenditure financed by the private sector as a percentage of the GDP[17]. $INTERETLT$ represents long-term interest rates expressed as a percentage. $CREDITPIB$ represents the amount of credit given to the private sector, expressed as a percentage of the GDP. These two financial variables have been included in our empirical model in order to see whether the theoretical importance of financial conditions of firms' R&D investments can be empirically verified. $DIRDPUBPIB$ represents R&D expenditure by the public sector (with the exception of Higher Education) expressed as a percentage of the GDP. This variable is used not only because it enables us to account for the organisation of both public and private national R&D systems but also because it enables us to detect the presence of externalities between public applied R&D and private R&D. SUBPIB represents the amount of direct support received by firms and is expressed as a percentage of the GDP. By using relative measures where direct support, public R&D and private investment in R&D, are concerned, we believe that we are more able to control price-effects and thereby offer more precise macroeconomic evaluations.

Finally $BINDEX$ represents the extent of the tax system's generosity for R&D, given the various tax incentives (tax credits, tax allowances, depreciation rates,...). This indicator, which was developed by McFetridge and Warda (1983), measures the present value of the pre-tax income required to cover the initial cost of R&D investment and corporate income tax. Mathematically, the B-index is equal to the cost, after tax incentives, of a dollar's investment in R&D divided by 1 minus the tax rate on profits. The lower a country's B-Index the more generous its tax system towards R&D will be. A more complete description of the B-index, the related hypotheses and its limitations are given in Appendix 2. In the same way as Guellec and Van Pottelsberghe de la Potterie (2003) and Shin (2006) we have shifted this variable by one period in order to take into account the time that it takes firms to adapt their behaviour to changes in R&D taxation. Following Shin (2006) and Falk (2006), we define the equation for the intensity targeted for private investment in R&D as:

$$\begin{aligned} \ln DIRDFIPIB^*_{it} = & \alpha^* + b^*_1 \ln INTERETLT_{i,t} + b^*_2 \ln CREDITPIB_{i,t} \\ & + b^*_3 \ln DIRDPUBPIB_{i,t} + b^*_4 \ln SUBPIB_{i,t} \\ & + b^*_5 \ln BINDEX_{i,t-1} + e_{i,t} \end{aligned} \tag{2}$$

[17] All of the financial data is expressed in constant PPP dollars from 2000.

The existence of numerous market failures implies a strong probability that the intensity observed for private R&D expenditure will be different from its target. R&D investments are different from other investments in terms of irreversibility and duration which generate significant adjustment costs. This implies that firms will be only partially able to adjust their R&D investment behaviour to the changes in public policy and the economic environment. This leads us to create a model including a partial adjustment process for private investment in R&D such that:

$$\begin{aligned} &\ln DIRDFIPIB_{i,t} - \ln DIRDFIPIB_{i,t-1} = \\ &\theta(\ln DIRDFIPIB^{*}_{i,t} - \ln DIRDFIPIB_{i,t-1}) \end{aligned} \tag{3}$$

where $0 \leq \theta \leq 1$ represents the adjustment coefficient for the current intensity of private R&D expenditure in relation to its target level. It should be noted that the adjustment process means that the evolution of private R&D investment intensity over a given period corresponds to a fraction of the gap between the targeted intensity and the intensity observed during the previous period. When $\theta = 1$ then the adjustment is total for a given period whereas if $\theta = 0$ then there is no adjustment. By inserting equation (2) into (3) we obtain:

$$\begin{aligned} \ln DIRDFIPIB_{it} =& \alpha + \rho \ln DIRDFIPIB_{i,t-1} + \ b_1 \ln INTERETLT_{i,t} \\ &+ \ b_2 \ln CREDITPIB_{i,t} + \ b_3 \ln DIRDPUBPIB_{i,t} \\ &+ \ b_4 \ln SUBPIB_{i,t} + \ b_5 \ln BINDEX_{i,t-1} + \ e_{i,t} \end{aligned} \tag{4}$$

where $\rho = (1 - \theta)$, $b_i = \theta b^{*}_{i}$ et $\alpha = \theta \alpha^{*}$. So that the influence of the omitted variables, the national specificities as well as the effects of the economic cycle can be taken into account, we add individual and temporal fixed effects to the equation (4):

$$\begin{aligned} \ln DIRDFIPIB_{i,t} =& \beta_i + \rho \ln DIRDFIPIB_{i,t-1} + \ b_1 \ln INTERETLT_{i,t} \\ &+ \ b_2 \ln CREDITPIB_{i,t} + \ b_3 \ln DIRDPUBPIB_{i,t} \\ &+ \ b_4 \ln SUBPIB_{i,t} + \ b_5 \ln BINDEX_{i,t-1} + \tau_t + \ e_{i,t} \end{aligned} \tag{5}$$

Parameters b_i represent short-term elasticity and $b_i/(1 - \rho)$ represent long-term elasticity. In order to simplify we rewrite model (5) as follows:

$$\ln Y_{it} = \ \rho \ln Y_{i,t-1} + \ \beta^{'} \ln X_{i,t} + \ \alpha_i + \ \tau_t + \ e_{i,t} \tag{6}$$

where Y represents the dependant variable and X the matrix of explanatory variables which are assumed to be exogenous.

One important question which is raised for public authorities, who rely upon a combination of direct and indirect support, is that of their complementarity for increasing private investment in R&D. One might suppose that, relying upon very different incentive mechanisms, these means of support are conflicting. Indeed, the results found by Guellec and Van Pottelsberghe de la Potterie (2003) show that direct and indirect measures substitute for each other as it appears that an increase in either direct or indirect measures diminishes the positive effect of the other upon private investment in R&D. In order to investigate this question, we extend model (6) as follows:

$$\ln Y_{it} = \rho \ln Y_{i,t-1} + \beta^{'} \ln X_{i,t} + \delta Z_{i,t} + \alpha_i + \tau_t + e_{i,t} \quad (7)$$

where $Z_{i,t}$ is a crossed variable of direct ($SUBPIB$) and indirect ($BINDEX$) support variables.

The growing internationalisation of R&D activity (Hall, 2011) shows that location is a strategic variable for the large companies. We may therefore suppose that a country's private R&D investment will not only depend upon the characteristics and support given by that country, but also upon those of other countries. Even though the literature concerning the location of R&D investments does not point out financial support as being a determining factor, several authors emphasise the potential importance of its role (Hines 1993 & 1994, Thursby 2006, Hall 2011). Furthermore, Wilson's article (2009) clearly demonstrates the existence of the significant geographical externalities of financial support for R&D. By estimating the internal and external price-elasticity[18] of R&D expenditure for 50 American states, his results show that they are of the same amplitude but of opposing signs. This means that at the macroeconomic level, indirect support which is set up by the different American states has no impact upon private R&D. Indeed, Wilson's results (2009) show that although an increase in a state's indirect support may effectively cause an increase in private R&D investment within that state, it reduces by the same proportion any private R&D investment in neighbouring states. Hence, if indirect local support appears to effectively increase private R&D investment within one state, it is inefficient on a more general level. Given such a result, it would appear to be essential to study the impact of external financial support (both direct and indirect) upon private R&D investment in order to give a more precise estimation as to how efficient such measure are in macroeconomical terms. This would enable us, in particular, to verify the possible existence of geographical externalities for financial support for R&D on a national scale. For this purpose, we extend model (6):

$$Y_{i,t} = \rho Y_{i,t-1} + \beta^{'} X_{i,t} + \gamma^{'} W X_{i,t} + \alpha_i + \tau_t + e_{i,t} \quad (8)$$

where W is a normalised spatial weight matrix, measuring the intensity of relations between country i and and other countries $j \neq i$. The choice of a measurement for proximity is always crucial and delicate. In our case, we need to find a measurement which accounts for the proximity between countries and which is relevant such that it captures the sensitivity of private R&D investments within country i, having the characteristics of country $j \neq i$. As it is impossible to have such a measurement which depends upon so different parameters, we will use three different measures for proximity between countries. This, on the one hand will allow us to increase our chances of obtaining a measurement which is relevant to the intensity of relations between countries, and on the other hand, it will allow us to compare the influence of that measurement upon the results.

[18] External R&D price-elasticity is a reflection of how sensitive is the private investment of state i to the weighted average cost of use of R&D in other states. Different weightings are used by the author: the fifth and tenth closest neighbours in the areas of technological and employment proximity.

The first spatial weight matrix uses data from bilateral trade and defines the relations between countries i and j as such :

$$W_{ij} = \frac{1}{2 \mid T \mid} \sum_{t \in T} \left(\frac{X_{ij}^t}{\sum_j X_{ij}^t} + \frac{M_{ij}^t}{\sum_j M_{ij}^t} \right)$$

where X_{ij}^t represents the total amount of country i's exports towards country j at time t and M_{ij}^t represents the amount of country i's imports from country j during that same time. Hence, the proximity between two countries is measured by the relative average of their bilateral commercial relations on the whole of the T periods. As we do not have complete data for each year of our period of study, the average is calculated based upon the bilateral exchanges observed within the sub-set of the following periods $T = \{1995, 2000, 2005, 2008\}$. The data for bilateral trade (and which concerns all industrial sectors) is taken from the OECD's STAN database.

The second spatial weight matrix attempts to give an account of the intensity of technological relations between countries by using the collaboration data from the international patent applications PCT. The intensity of technological collaboration between countries i and j is defined as follows :

$$W_{ij} = \frac{\frac{1}{\mid T \mid} \sum_{t \in T} b_{ij}^t}{\sum_j \frac{1}{\mid T \mid} \sum_{t \in T} b_{ij}^t}$$

where b_{ij}^t represents the number of collaborations which took place between countries i and j during period t for PCT patent applications. Thus, the proximity between two countries is measured by the relative average intensity of their collaboration for international patent applications during the period being studied. The data used was taken from the OECD's REGPAT database and we have access to annual data for the whole of the period we are studying, ie., $T = 18$.

Finally, we use a spatial weight matrix based upon the geographical distance between countries. By using data for the distance "as the crow flies" between the geographical centres of each country, we define the proximity between countries i and j as :

$$W_{ij} = \frac{\frac{1}{d_{ij}}}{\sum_j \frac{1}{d_{ij}}}$$

where d_{ij} represents the distance "as the crow flies" between the geographical centres of countries i and j. Thus, the intensity of relations between two countries is measured according to the inverse of the relative distance between their respective geographical centres. The data for distance was obtained from the EuroBoundryMap database provided by Eurogeographics.

4 Data and estimation strategy

4.1 Data description

The data which is used comes from the OECD and the IMF, apart from that dealing with the B-index which was gathered from Thomson's paper (2009) which proposes a B-index value for 25 OECD countries[19] over the period over the period 1980-2006. We prefer Thomson's calculations for the B-index (2009) to those proposed by the OECD as they measure the effective average tax subsidy per dollar invested in R&D rather than the maximum subsidy as is proposed by the OECD. We refer readers to Thomson's paper (2009) for the details of his calculations of the B-index and to Appendix 2 which discusses the hypotheses for the B-index at the macroeconomic level. A good example of the different measurements incurred by the OECD's approach and that of Thomson (2009) regards, in particular, the tax measures which are submitted to very specific eligibility conditions. For instance, in 2002 Denmark set up a 150% tax allowance for collaborative fundamental research carried out by Higher Education Institutions. According to the B-index calculation provided by the OECD in 2006, this measure supposedly represents a tax subsidy of 0.16$ for each dollar invested in R&D. Thomson (2009) on the other hand, believes this measure to be too specific to be integrated into the calculations for the B-index and hence it is not counted.

dire que ces données sont pas dispo sur les pays voisins

The database covers 25 OECD countries over an 18 year period (1990-2007). However, except for where the B-index is concerned, there is data missing. The percentage of missing data for the least entered variable[20] was at 18% whereas for the most frequently entered variable (not counting the B-index)[21] was inferior to 2% with an average at 10%. the missing data is mainly related to each nation's specificities for the gathering of information for Research and Development. Indeed, Australia, Greece (until 2003), New Zealand, Norway (until 2001), and Sweden (until 2003) carry out surveys (or did) and collect statistics for R&D every two years. Other countries, such as Austria (1993), Korea (1995), Mexico (1993) or the Czech Republic (1995) only began gathering statistics for R&D during the 1990s.

In order to reduce the amount of missing information, we have evaluated the data of those countries which compile a biannual database by using the average amount of

[19] Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Korea, Finland, France, Germany, Greece, Hungrary, Ireland, Italy, Japan, Mexico, Netherlands, Norway, New Zealand, Poland, Portugal, Spain, UK, USA and Sweden.

[20] That is to say the percentage of R&D financed by the private sector.

[21] That is to say the data concerning credit afforded to the private sector.

information at $t-1$ and $t+1$ to determine the value of period t. The missing information for those countries which were late in setting up their data collecting systems have however, not been evaluated. Hence, our database consists of an unbalanced panel where $\overline{T} = 17.1$, in other words on average we have data per country for 17.1 years out of a total period of 18 years which means that the imbalance is minor. The country for which we have the least data is Korea, with only 13 years (1995-2007). Table 1 at the end of the paper shows the number of countries present per year.

Tables 2 and 3 which are presented at the end of the paper provide our series' descriptive statistics as well as the table showing the correlation between variables. The descriptive statistics show a great heterogeneity amongst countries. Indeed, the standard variation of each variable (except for the B-index) represents over 50% of their average value. In more concrete terms, this translates as a large gap between the extreme values. Hence, the average intensity of privately financed R&D expenditure is very close to 1% of the GDP, with a minimum at 0.03% and a maximum at around 3%. The State's average R&D expenditure is close to 0.25% of the GDP with a minimum at 0.07% and a maximum at 0.56%. The financial variables which have been used also show significant disparity. Although the credits afforded to the private sector average at around 91% of the GDP, they reach a maximum of 231% and a minimum of 15%. The average long-term interest rate is at 7.8% with extreme values ranging from 1% to 46%. There are also significant gaps between the variables referring to direct financial support. Although, on average, direct financial support is at around 0.08% of the GDP, it can reach a maximum of 0.45% and a minimum of approximately 0%. The value of the B-index can be found between 0.57 and 1.08 with an average of around 0.95.

Table 3, which presents the correlations between the variables, shows that there should be no problem with multicollinearity. Indeed, the highest partial correlation concerns the relation between the two financial variables (credit and interest rate) and is only at -0.54. It is interesting to note that the correlation between the variables for direct and indirect financial support are very weak (0.17), which, it would seem, precludes there being any positive, strong relation between these two variables.

4.2 Estimation strategy

Nickell (1981) showed that an OLS (Ordinary Least Squares) or a LSDV (Least Squares Dummy Variable) estimation of a dynamic model using data from a panel is biased when $N \to \infty$ and T is fixed because the lagged endogenous variable is correlated with the error term. As Bond (2002) points out, the estimation of the coefficient for the lagged variable (ρ) has an upward bias for the OLS estimator and a downward bias for the LSDV estimator. Consequently, the preliminary estimation for these models is important as it allows us to obtain bounds values for ρ.

Since the publication of Nickell's article (1981), econometric literature has developed a number of consistent estimators which use methods with instrumental variables (Anderson and Hsiao, 1982) and generalized method of moments (Arellano and Bond, 1991, Allerano and Bover 1995, Blundell and Bond 1995). The instrumental variables estimator suggested by Anderson and Hsiao (1982) estimates model (6) in first differences by using the dependent variable lagged by two periods as an instrument. This estimator is efficient when $N \to \infty$ and T is fixed. However, as Lai and al. point out (2008), the asymptotic properties of this estimator are no longer valid for a number of sample configurations which implies that there may be considerable differences between the estimator's asymptotic performance and its performance using a finished sample. This is indeed the case when the instruments used are weak or too numerous. An instrument is said to be "weak" when the constraint upon the moments that it uses gives little information in relation to the sample size (Lai and al., 2008). The problem raised by weak instruments is considerable, as Bond and al. (1995) show, as even with a sample made up of numerous individuals, the results of Anderson and Hsiao's estimator (1982) are hardly reliable when the instruments are weak.

Other estimators are based upon the generalized method of moments. In a similar way to Anderson and Hsiao's estimator (1982), the properties of these are good when $N \to \infty$ and T is fixed and with the proviso that the instruments used are not weak. We may distinguish between two types of GMM estimator (Generalised Method of Moments) for dynamic models using panel data, that is to say the first differences GMM estimator and the system GMM estimator. The first estimates model (6) by first differences using lagged variables in level as instruments, whereas the second estimates a system of equations both in first differences and in level, by using for level equations, the first differences of the lagged variables as instruments. As Arellano and Bover (1995) and Blundell and Bond (1998) demonstrate, when the data are highly persistent and the periods are few, the differences GMM estimator gives incorrect estimations as, in these conditions, the lagged variables in level (ρ) are weak instruments. Blundell and Bond (1998) demonstrate the system GMM estimator's superiority in this case. Due to the specificities of our sample and the continued high intensity of private R&D expenditure over time, it therefore appears to be more relevant to estimate our model using a system GMM estimator rather than a first-differences GMM estimator.

Another way to give an accurate estimation of dynamic models using panel data would be to correct the bias of the LSDV estimator (Nickell 1981, Kiviet 1995, Kiviet 1999, Bun and Kiviet 2003). The advantage of this method is twofold as, on the one hand the LSDV estimator often has a smaller variance than others and, on the other hand correcting the LSDV estimator's bias allows us to give a consistent estimation for all panel sizes. Furthermore, the Monte-Carlo simulations, carried out by Kiviet (1995), Kiviet (1999), Bun and Kiviet (2003) and Bruno (2005a), show the superiority of the Corrected LSDV estimator (LSDVC) in comparison to the IV and GMM estimators whether it be in terms of bias or RMSE (Root Mean Squared Error). Bruno (2005b) has developed an extension for Bun and Kiviet's LSDVC estimator (2003) for unbalanced panel data. Unlike the previous estimators however, which permitted an accurate estimation when endogenous regressors are present, the LSDVC estimators require a slight exogeneity at the least. Bruno's LSDVC estimator (2005b) supposes that the model's regressors are strictly exogenous. In our case, we suspect that at the minimum, certain of our variables may be slightly endogenous, such as the measures for direct and indirect support for R&D.

Consequently, it would seem that the potential estimators all have advantages and disadvantages given the size of our panel and the purpose of our study. In order to rule out inefficient estimators we have carried out estimations of model (6) using OLS and LSDV estimators and thus determined the bounds for ρ. Then we estimated our model using Anderson and Hsiao's difference and level estimator (1982) (AH-D and AH-N), Arellano-Bond's GMM estimator (GMM-AB), Blundell and Bond's GMM estimator (1998) as well as Bruno's LSDVC estimator (2005b). We also carried out error autocorrelation tests, over-identification tests and endogeneity tests for each explanatory variable. The results of these estimations, as well as those of the Arellano-Bond tests (autocorrelation) and the Hansen tests (over-identification) are presented in table 4 at the end of this paper. The endogeneity tests are presented in table 5.

The OLS and LSDV estimations show that the value of ρ should be between 0.862 and 0.985. The AH-D estimator gives a value for ρ inferior to that given by the LSDV estimator and we have therefore ruled out this estimator. The AH-N estimator, on the other hand, gives a value for ρ very slightly higher than to the one given by the LSDV estimator. The Hensen tests carried out on these two estimators do not permit us to confirm the validity of the instruments used for two reasons. Indeed, this test is only relevant if not too many instruments are used and this estimator uses a large number. This explains a p-value of 1 for the Hansen test. It should be noted however, that reducing the number of instruments does not improve the quality of the estimators (the value of ρ is even smaller). Hence, basing ourselves upon the ρ values given by the AH-D and the AH-N estimators, we have also ruled out these estimators.

The estimation of model (6) using the GMM-AB estimator can be found in column 5 of Table 4. The estimated value of ρ is inferior to that given by the LSDV estimator. Furthermore, the values taken by the Hansen test show that it is irrelevant due to the use of too many instruments. Reducing the number of instruments does not however, improve the quality of this estimator as it then gives imprecise estimations and an even smaller value for ρ. Consequently, we have ruled out the Arellano-Bond estimator. In column 6 the GMM-BB estimator estimates the value ρ as 0.886 which is between the values as estimated by the OLS estimator and the LSDV estimator. Yet again the Hansen test cannot be interpreted due to the great number of instruments. Reducing the number of instruments slightly increases the estimated value of ρ but gives less precise estimations (there is a high variance between the estimated parameters). When we reduce the number of instruments considerably, to a level below that of the number of countries included in our data[22], the estimated value of ρ exceeds 1. Nevertheless, although the over-identification test does not allow us to be certain that the instruments used are valid, we have kept the GMM-BB estimator as it is

[22]According to Roodman (2006),there is very little information in the literature which would enable us to know the maximum number of instruments that should be used. The minimal rule is to have a smaller number of instruments than of individuals.

the only one of all the estimators that we have considered to give us a valid estimation of ρ.

Finally, the estimation of model (6) using the LSDVC estimator is given in column 7 of Table 4. The estimated value of (ρ) is higher than that of the GMM-BB estimator and lies within the possible range. As we have already pointed out however, the LSDVC estimator is efficient if the explanatory variables are exogenous. In order to verify the relevance of this estimator we conducted a series of endogeneity tests on the model and these are presented in Table 5. These tests clearly reveal that none of the explanatory variables are endogenous with the exception of the lagged variable. These test were carried out using an instrumental variable estimator and the results are robust as the instruments used are valid and not weak (see Hansen and Stock-Yogo's tests in Table 5)[23]. Moreover, the model with the lowest RMSE (root Mean Square Error) is the model in column 5 where only the lagged variable is treated as endogenous. Hence, we prefer the LSDVC estimator which is effective for our model, however we have kept the GMM-BB estimator in order to verify the robustness of our results even though it appears to be inferior to the LSDVC estimator.

5 Results

5.1 Impact and internal complementarity of financial support for R&D

Columns 1 and 2 of the following table present the estimation for model (6).

[23]These tests were conducted by instrumenting each variable by its value during the previous period as well as the lagged variables for the growth rate and the short-term interest rate.

VARIABLES	(1) dirdefipib	(2) dirdefipib	(3) dirdefipib	(4) dirdefipib
L.dirdefipib	0.886***	0.913***	0.885***	0.904***
	(0.018)	(0.026)	(0.018)	(0.025)
credit	0.074**	0.017	0.072***	0.010
	(0.030)	(0.016)	(0.027)	(0.016)
interetlt	-0.075**	-0.068***	-0.075**	-0.056**
	(0.033)	(0.022)	(0.033)	(0.023)
dirdpubpib	-0.007	0.004	-0.006	-0.005
	(0.053)	(0.029)	(0.052)	(0.028)
subpib	-0.021	-0.007	-0.026	-0.034**
	(0.015)	(0.012)	(0.018)	(0.015)
L.bindex	-0.156**	-0.114*	-0.162**	-0.145**
	(0.066)	(0.062)	(0.064)	(0.063)
interact			0.177	0.585***
			(0.441)	(0.206)
Observations	402	402	402	402
Estimator	GMM-BB	LSDVC	GMM-BB	LSDVC
Time dummies	yes	yes	yes	yes
AR(1) (p-value)	0.013		0.013	
AR(2) (p-value)	0.957		0.935	
Hansen (p-value)	1.000		1.000	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6 : Estimations for the model (6) and (7)

As the theory suggests, our results reveal a high persistence of private R&D expenditure's intensity over time. The speed with which it adjusts to its new target is estimated at between 9 and 11% which indicates a potentially very limited reactivity of R&D investment decisions with regard to short-term economic changes. This implies that the short-term impact of financial support will be much weaker than its long-term impact.

Where "financial" variables are concerned, our results reveal a strong influence of the interest rate and, to a lesser degree, of the amount of credit afforded to the private sector. Hence, the elasticity of the short(long)-term interest rate ranges between -0.068 (-0.78) and -0.075 (0.66). If the credit afforded to the private sector have a positive effect upon the intensity of private R&D, such an impact only appears to be of any statistical significance with the GMM-BB estimator. Furthermore, although, according to GMM-BB estimator, the sensitivity of private R&D intensity to the amount of credit is similar to that of the interest rate, it is much weaker with the LSDVC estimator. These results do nevertheless indicate that there is significant influence by financial conditions upon firms' R&D investment.

Our results do not reveal any significant influence of public R&D (apart from the Universities) upon the intensity of private R&D expenditure. This result is clearly different from that of Guellec and Van Pottelsberghe de la Potterie (2003) or Shin (2006) who found a negative and a positive impact respectively. We believe that the differences between our results reside in the fact that Guellec and Van Pottelsberghe de la Potterie (2003) analyse the influence of public R&D upon the growth rate of private R&D expenditure whereas we are studying its impact upon the intensity of private R&D expenditure. As far as the positive effect highlighted by Shin (2006) is concerned, it may be connected to the fact that his measurement of public R&D includes R&D spending by the Higher Education sector, and this has also shown a distinctly positive effect for Guellec and Van Pottelsberghe de la Potterie (2003).

As far as the influence of financial support for R&D is concerned, our results show that tax incentives have a positive and significant effect whereas the effect of direct support is negative and insignificant. In the short (long)-term, the sensitivity of private R&D intensity with the B-index ranges between -0.11 (-1.31) and -0.16 (-1.37). These results are consistent with Falk (2006) and Shin's (2006) estimations which evaluate elasticity close to -1 in the long-term. This also confirms the fact that indirect support can be responsible for increasing private R&D investment. Even though the B-index is not a direct measure of the ratio between the additional R&D and the loss of tax income, a B-index elasticity higher than 1 gives a positive indication as to how tax incentives may lead to additional investment in R&D exceeding the losses in tax income (see Falk 2006).

Unlike the results of Guellec and Van Pottelsberghe de la Potterie (2003) or Shin (2006), which demonstrate a significantly positive effect, our results do not show any significant influence of direct support upon private R&D. As we have already pointed out, the use of a relative measure for direct support allows us to have a better control of the price-effect upon the R&D inputs which, as we have seen in the aforementioned articles, causes an upwards bias in the estimation of the coefficient for direct support. What is more, our result is identical to that of Falk (2006). The fact that direct support is relatively neutral where the intensity of privately financed R&D is concerned is not negative per se. It simply means that whilst direct support is used to finance R&D projects it does not produce any additional incentive to invest in R&D. In other words, the positive effects of direct support do not suffice for the private sector to develop endogenous investment in R&D (nor does such direct support generate sufficient negative effects which might lead to their substituting private financing).

In order to study the complementarity of direct and indirect support we have estimated the model (7) which introduces a crossed variable of both direct and indirect support by the name of INTERACT[24]. The results of the estimations for this extension of model (6) are shown in columns 3 and 4 of Table 6. They confirm the results of Guellec and Van Pottelsberghe de la Potterie (2003) and show that direct and indirect support are substitutes for boosting the intensity of private R&D. In our case however, the estimated coefficient

[24]The INTERACT variable is the product of the SUBPIB and the BINDEX variables.

for measuring direct support (SUSPIB) is negative (and becomes significant when the INTERACT variable is introduced). Hence, an increase in indirect support must mean that the windfall effect of direct support will also increase and that an increase in direct support will diminish the positive effect of indirect support. The instruments of direct and indirect support seem therefore to be in conflict where increasing the intensity of privately financed R&D is concerned.

Following on from Falk (2006), our results confirm the fact that indirect support can incite firms to increase their R&D investments whereas this does not seem to be the case for direct support (and without necessarily having a significant substitution effect). The different types of instrument seem to be substitutes for increasing private R&D and this brings forward the need for a global approach for defining a mixed policy along with its objectives. Our estimations show that interest rates have a significant, negative effect which leads us to believe that measures to improve borrowing conditions would significantly impact private investment in R&D. Our results show a lack of influence from public R&D, suggesting a lack of significant public R&D externalities. These results appear to be solid, as is shown by the different tests for robustness presented in Table 7.

5.2 The importance of external effects between OECD countries

In order to analyse the influence of external financial support for R&D, and more generally to consider external conditions which influence a country's firms' decisions to invest in R&D, we have carried out estimations of our model (8) using the LSDVC and GMM-BB estimators. As we have already pointed out, we have used different spatial weight matrices in order to test different types of proximity. The table below presents the estimations which were carried out and the acronyms WCOM, WDIST and WBREV refer respectively to the spatial weight matrices based upon bilateral trade, geographical distance and technological collaboration. It should be noted that the estimations for model (8) do not change the results previously obtained for model (6) and this proves its robustness. Indeed, the coefficients for the exogenous variables (which are not spatially lagged) are of the same sign and amplitude as those shown in Table 6.

VARIABLES	(1) WCOM	(2) WCOM	(3) WDIST	(4) WDIST	(5) WBREV	(6) WBREV
L.dirdefipib	0.903***	0.914***	0.885***	0.917***	0.877***	0.915***
	(0.028)	(0.026)	(0.020)	(0.026)	(0.027)	(0.028)
credit	0.069**	0.008	0.076**	0.014	0.092**	0.009
	(0.034)	(0.016)	(0.032)	(0.017)	(0.038)	(0.019)
interetlt	-0.057*	-0.041*	-0.059*	-0.047**	-0.079***	-0.062***
	(0.033)	(0.022)	(0.031)	(0.023)	(0.029)	(0.023)
dirdpubpib	0.006	0.049	0.045	0.031	-0.001	0.007
	(0.042)	(0.033)	(0.039)	(0.035)	(0.048)	(0.034)
subpib	-0.025	-0.018	-0.014	-0.011	-0.020	-0.007
	(0.018)	(0.012)	(0.016)	(0.012)	(0.019)	(0.013)
L.bindex	-0.139***	-0.166***	-0.132***	-0.144**	-0.110*	-0.103*
	(0.046)	(0.062)	(0.046)	(0.065)	(0.068)	(0.065)
wcredit	-0.077	-0.305***	0.126	-0.147	0.144	-0.305
	(0.139)	(0.114)	(0.238)	(0.115)	(0.256)	(0.195)
winteretlt	-0.016	0.018	0.256*	-0.004	0.062	-0.118
	(0.072)	(0.063)	(0.136)	(0.092)	(0.274)	(0.151)
wdirpubpib	0.472**	0.524***	0.492*	0.375*	0.411	0.105
	(0.206)	(0.189)	(0.257)	(0.221)	(0.300)	(0.273)
wsubpib	-0.034	0.119	0.148	0.289***	-0.143	-0.019
	(0.152)	(0.078)	(0.209)	(0.082)	(0.177)	(0.115)
L.wbindex	-0.465	-0.305	-0.303	-0.172	1.192	0.101
	(0.526)	(0.307)	(0.468)	(0.434)	(1.428)	(0.684)
Observations	402	402	402	402	402	402
Estimator	GMM-BB	LSDVC	GMM-BB	LSDVC	GMM-BB	LSDVC
Time dummies	yes	yes	yes	yes	yes	yes
AR(1) (p-value)	0.011		0.013		0.013	
AR(2) (p-value)	0.810		0.866		0.900	
Hansen (p-value)	1.000		1.000		1.000	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Estimations for the model (8)

The estimations which use the spatial matrix based upon bilateral trade are shown in columns 1 and 2 of Table 8. They reveal that the level of public R&D practised by a country's trade partners has a most positive influence upon the intensity of private R&D expenditure. This positive effect is important as the elasticity in the short (long)-term ranges from 0.472 (4.9) to 0.524 (6). This result is all the more interesting that in parallel the estimations do not show any significant internal influence of public R&D. This would suggest that is more global public R&D investment (internal and external) which produces positive external effects upon private R&D rather than internal public investment. The LSDVC estimator also shows a negative influence caused by the amount of credit afforded to the private sector of trade partners. This signifies that the larger the amount of credit afforded to the private sector of country i's trade partners the weaker the intensity of that country's private R&D will be. This relation shows yet again the importance of facilitating access to financing.

Where the financial support for the R&D of trade partners is concerned, this does not seem to have any influence upon internal private R&D investment. Hence, the externalities for financial support for R&D do not seem to be significant on this geographical scale and do not call into question the impact of internal financial support, and more particularly that of tax incentives.

The estimations which were carried out using the spatial matrix based upon geographical distance are shown in columns 3 and 4 of Table 8. It appears that, as for the previous estimations, there is a positive effect of neighbouring countries' public R&D investment upon the intensity of private R&D expenditure. The LSDVC estimator also shows a strong influence of external direct support. To be more precise, it would seem that an increase of the level of direct support in neighbouring countries increases internal private R&D investment. Hence, although internal measures of direct support do not affect internal private R&D investment, they do seem to favour the development of private R&D in neighbouring countries. This result is rather surprising and we will therefore refrain from making any interpretation as it may be the result of a number of different effects.

The estimations made using the spatial matrix which is based upon collaboration for PCT patent applications is shown in columns 5 and 6 of Table 8. The influence of external conditions upon the internal intensity of private R&D does not show up. In our opinion, this unexpected result may be explained in several different ways. Firstly, technological proximity influences the intensity of private R&D expenditure through other variable than those which we have chosen. The second explanation is that collaboration for PCT patent applications (which is only a small proportion of all patent applications) is not an accurate reflection of the technological interaction between countries. Finally, technological proximity may not be an adequate measurement for grasping the influence of external conditions upon the intensity of a country's private R&D expenditure.

To summarise, it would appear that the estimations carried out upon the model (8) provide several interesting lessons concerning the influence of external conditions and financial support upon internal private R&D investment. The first is that external financial support does not seem to have a very significant influence upon the intensity of internal private R&D. Indeed, even using three different proximity measurements, the influence of indirect external support is never significant and that of direct external support is only significant (and positive) when geographical proximity is used. This would tend to confirm the results found in the literature concerning the location of R&D which show that financial support is of very secondary importance when location choices are made for R&D (Hall, 2011). Furthermore, the fact that the B-index is significant whereas its spatial lagging is not (no matter which proximity matrix is used), leads us to believe that these measures are much more effective when applied to SMEs than to large firms. Obviously, it is easier for large firms to change the location of their R&D activities and take advantage of tax differentials. Our results therefore corroborate the hypothesis that tax measures are much more effective for SMEs than for large firms (see Mohnen and Loshkin, 2009). These elements also highlight the weakness of the argument which claims that these instruments (and in particular tax measures) should be used to attract external private R&D. This is even truer when the estimated coefficient for the external B-index is negative, which would (if it were significant) express an international complementarity between tax incentives implemented by different countries.

Our results also show that there is a considerable influence at the external level upon public R&D which suggests that there are more effects of public R&D externalities upon private R&D at the global level than at the national level. To a lesser degree, our estimations also show the influence of external financial conditions upon the internal intensity of private R&D. Hence, a country with more difficult financial conditions than its neighbours or trade partners will have an additional handicap when trying to boost its private R&D investments.

6 conclusion

A growing number of countries spend a considerable amount of public funding on providing financial support for private R&D activities. One of the objectives of these measures is to encourage firms to increase their investments in R&D. In this paper, we have attempted to understand the macroeconomic impact of both direct and indirect financial support upon the intensity of privately funded R&D. In order to analyse their internal as well as their external effects we have estimated different empirical models by using a panel of 25 OECD countries over the period 1990-2007.

Our results reveal a distinct difference between the impact of direct support and that of indirect support. The first does not seem to generate sufficient incentives to increase investment in privately funded R&D whereas the second has a much more notable impact. This difference in impact makes even more sense when one considers the question of complementarity between the different types of instruments. Indeed, in the same line as Guellec and Van Pottelsberghe de la Potterie (2003), our results show that direct support is a substitute for indirect support (and vice-versa) when increasing the intensity of private R&D. This means that setting up additional direct (indirect) support will increase the "windfall" effect of the indirect (direct) measures which are already in place and will diminish their effectiveness. This result highlights the need for public authorities to adopt a global approach when defining the combination of direct and indirect measures.

We have also tried to understand the extent to which external economic conditions, and more specifically external financial support, might influence the intensity of a country's private R&D. Our results have not really brought to light any highly significant influence of external financial support but do however, show the positive role of the trade partners' and neighbouring countries' public R&D. These results uphold the idea that financial support for R&D only marginally influences the location of R&D activities but is effective for supporting the internal dynamics of private R&D. Furthermore, while internal public R&D exerts no influence upon the intensity of private R&D, the positive influence of external public R&D

suggests that that externalities are produced more on a global level rather than at the national level.

Thus, with the precise objective of increasing the intensity of privately financed R&D, our results and those found in the literature tend more towards measures for indirect support. Nevertheless, as is demonstrated by Mohnen and Lokshin (2009), incremental tax credit exerts a leverage effect upon private R&D investment, this does not seem to be the case when a level-based tax credit is implemented. Similarly, tax measures appear to be much more effective for SMEs than they do for the large firms. These elements therefore highlight the importance of the options which are chosen due to the effectiveness of the tax incentives for R&D (and more generally financial support for R&D). In particular, they emphasise the superiority of targeted tax measures which will reduce the 'windfall' effects by aiming at the beneficiaries all the while retaining their "friendly market" appeal.

It would also seem that one should not over-estimate the fears of tax competition in R&D given that the dynamics of a country's private R&D investment are not really sensitive to external fiscal incentives. Whilst it is accepted that financial support for R&D at a national level is relevant (as its effect is not perturbed by the financial support of neighbouring countries), our results concerning the influence of public R&D have almost opposing implications. Indeed, the level of internal public R&D does not seem to generate any positive effects upon private R&D whereas the level of external public R&D (that of nearby countries) has an extremely positive effect. This highlights then the importance of world-wide cooperation for public R&D in order to maximise the benefits of this research for private R&D.

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Annexe 1: R&D expenditure target level in the OECD countries

Table C.1 **R&D targets and expenditures, selected OECD countries**[a]

GERD/GDP, per cent

Country/region	*R&D intensity in 2005*	*Target*	*Target date and characteristics*
Austria	2.36	3.00	2010
Belgium	1.82	3.00	2010
Canada	1.98	Top 5 OECD	2010
Cyprus	0.40	1.00	2010
Czech Republic	1.42	2.06	Target of 1% public R&D with estimated 1.06% of private expenditure in 2010
Denmark	2.44	3.00	Target of 1% public R&D in 2010
Estonia	0.94	1.90	2010
Finland	3.48	4.00	2010
France	2.13	3.00	2010
Germany	2.51	3.00	2010
Greece	0.61	1.50	2010
Hungary	0.94	1.80	Increased participation of private sector by 2010
Ireland	1.25	2.50	2013
Italy	1.10	2.50	2010
Korea	2.99	Double spending	2007
Latvia	0.57	1.50	2010
Lithuania	0.76	2.00	2010
Luxembourg	1.56	3.00	2010
Malta	0.61	0.75	2010
Netherlands	1.78	3.00	2010
New Zealand	1.14	..	Target of OECD average (0.68%) for public R&D — no year specified
Norway	1.51	3.00	Target of 1% public and 2% private R&D by 2010
Poland	0.57	1.65	2008
Portugal	0.81	1.80	Target of 1% public R&D and tripling of private R&D by 2010
Slovenia	1.22	3.00	2010
Slovakia	0.51	1.80	2010
Spain	1.12	2.00	2010
Sweden	3.86	4.00	Target of 1% public R&D and unchanged private R&D by 2010
Turkey	0.66	2.00	Target of 1% public R&D and 1% private R&D by 2010
United Kingdom	1.79	2.50	2014

[a] Values for Italy, United Kingdom and the Netherlands are for 2004, New Zealand are for 2003, and Turkey are for 2002.

Data sources: Council of the European Union 2006, Eurostat Science and Technology Database 2007, http://epp.eurostat.ec.europa.eu, (accessed February 2007)), OECD 2004c, 2006c New Zealand Ministry of Research, Science & Technology Budget Speech (May 2006).

Annexe 2: The B-index, a relevant indicator for comparing the generosity of tax systems

The B-index is a synthetic measure of the generosity of the tax system for R&D developed by McFetridge and Warda (1983). Its simplicity makes it the reference index for making international comparisons of tax systems. This index measures the present value of pre-tax income required to cover the initial cost of R&D investment and corporate income tax. Mathematically, the B-index is equal to the cost, after tax incentives, of a dollar's investment in R&D divided by 1 minus the tax rate on profits:

$$\text{B-index} = \frac{1 - \tau z}{1 - \tau}$$

where τ is the corporate tax rate and z is the present value of deductible R&D expenditure. Consequently, $(1 - \tau z)$ represents the after-tax cost per dollar of R&D expenditure. In an economy in which there are no taxes ($\tau = 0$), the value of the B-index will be 1. Another situation where the B-index can be equal to 1 is the case where all R&D expenditure are fully deductible in a current year ($z = 1$) and are taxed at the same tax rate. For example, if $\tau = 0.3$ and $z = 1$ then the B-index is equal to $B = (1 - 0.3)/(1 - 0.3) = 1$. The B-index will vary from 1 only when R&D expenditure are not fully deductible ($z < 1$) or are more than fully deductible ($z > 1$), and/or where there exist allowances or tax credits for R&D that reduce the after-tax cost of an R&D project (that is, the after-tax cost of one dollar of expenditure on R&D). Thus, the lower a country's B-Index the more generous its tax system towards R&D will be.

1. Some examples and implications of the B-index

- Deductibility of R&D expenditure

Assume that R&D expenditure are partially deductible in the current year ($z < 1$). In this case, the present value of pre-tax income required to cover the initial cost of R&D investment and corporate income tax will be higher than 1. Consequently, the value of the B-index is higher than 1 ($B > 1$) and reflects a less attractive tax treatment for R&D than the case where R&D expenditure are fully deductible (which is the benchmark of the B-index model). When R&D expenditure are more than fully deductible ($z > 1$), the B-index is a decreasing function of the corporate tax rate. In other words, the lower the corporate tax rate the higher the B-index will be. Consequently, the marginal effect of a more favorable deductibility on the B-index decreases with the corporate tax rate.

- A level-based tax credit

Assume a level-based tax credit of 10%, a fully deductible R&D expenditure and a corporate tax rate of 50%. If the tax credit is not taxable, the B-index is given by $B = (1 - 0.5 - 0.1)/(1 - 0.5) = 0.8$. In this case, the B-index is a decreasing function of the corporate tax rate. If the tax credit is taxable, then the B-index is given by $B = (1-0.5)(1-0.1)/(1-0.5) = 0.9$ whatever the level of corporate tax rate. Consequently, when the tax credit is not taxable, a decrease of the corporate tax rate reduces the marginal effect of the tax credit on the B-index whereas when it is not taxable, the variation of the corporate tax rate has no impact on the marginal effect of the tax credit on the B-index.

The generalized formula for the B-index with a level-based tax credit is the following:

$$\text{B-index} = \frac{1-\tau z - cz}{1-\tau} \qquad \text{not taxable case}$$
$$\text{B-index} = \frac{1-\tau z - cz(1-\tau)}{1-\tau} \qquad \text{taxable case}$$

where c represents the rate of the tax credit.

- The incremental tax credit

An incremental tax credit also reduces the B-index. In order to give a general measure of the impact of an incremental tax credit on the B-index, the model assume that R&D expenditure are constant in real terms over time. Under this assumption, an incremental tax credit represents a tax gain resulting from the investment of one dollar in R&D at time t minus the present value of the tax gain lost (n periods) related to the investment at time t. Consequently, the effect of an incremental tax credit is increasing with the period used as basis (t) and with the discount rate (r). The generalized formula for the B-index with an incremental tax credit is given by:

$$\text{B-index} = \frac{1-\tau z - cz(1/n)(1-(1+r)-n)}{1-\tau} \qquad \text{not taxable case}$$
$$\text{B-index} = \frac{1-\tau z - cz(1-\tau)(1/n)(1-(1+r)-n)}{1-\tau} \qquad \text{taxable case}$$

The simplicity of the B-index model allows the differenciation of R&D expenditure components. Usually, we distinguish the current expenditure from the expenditure related to the acquisition of fixed assets due to different tax treatment. The standard assumption[25] concerning the distribution of R&D expenditure is the following: 90% are current expenditure (which two thirds consist of salaries) and 10% are fixed assets (half for equipment and machines and half for buildings).

As shown by Thomson (2009) and Mohnen et Lokshin (2009), the B-index is a linear function of the user cost of capital à la Jorgenson (1963):

$$u_R = P_R(r+\delta)B$$

[25]See Mcfetridge et Warda (1983), Bloom et al. (2002) or Thomson (2009).

where P_R is a price index for R&D inputs (labor, equipment, machine, building), r is the real interest rate, δ is the depreciation rate of the stock of knowledge and B is the B-index. As we can see, the B-index is the fiscal component of the user cost of R&D. Therefore, the elasticity to the B-index can be interpreted in the same way that the elasticity to the user cost of R&D, other things being equal.

2. Limitations of the B-index and its calculation by Thomson (2009)

An important limitation of the B-index is to only consider the impact of tax incentives on the corporate taxable income. Thus, a large number of tax characteristics that affect investment decisions in R&D are excluded from the calculation of the B-index. For example, taxes on income, consumption taxes, property taxes, payroll taxes and capital taxes are excluded.

Remember that the B-index model measures the potential generosity of the tax system so that he assumes an absence of tax exhaustion. This implies that the model does not distinguish between refundable and non-refundable provisions. Similary, the model assumes that firms have sufficient taxable income to take advantage of all tax incentives so that some dynamic aspects of these measures such as retroactive or deferred provisions do not affect the value of the B-index.

Another important assumption of the B-index model is to ignore the limits of fiscal measures. Of course, in reality, the tax measures are often "capped and floored".

The B-index measure used in this paper is taken from Thomson (2009). It is built on standard assumptions of McFetridge and Warda (1983) previously explained. We refer the reader to the Thomson's article (2009) for details on the composition of R&D expenditure and the formulas used to calculate the effect of tax incentives. Obviously, the measure does not incorporate any other forms of financial support for R&D (grants, loans,...). Specific measures concerning collaboration in R&D with universities or those only applicable to SMEs are not included as well as policies of local and regional authorities. Indeed, it is not possible to model all of these measures in an index whose goal is to allow international comparisons.

3. The METR (Marginal Effective Tax Rate) and its relationship with the B-index

Given the limitations of the B-index, another approach is used to measure the generosity of a tax system based on the notion of Marginal Effective Tax Rate (METR). The objective of the METR is to provide an indicator of the tax burden related to a new investment. It takes into account both the statutory tax rate, factors that affect the tax base (depreciation, deductibility of interest, tax incentives) and withdrawals that do not affect profits as capital taxes or taxes on asset sales. In addition to the tax parameters, the calculation of a METR requires assumptions concerning the financial structure of firms, the returns on debt and assets as well as the inflation rate which will allow to calculate the financial cost of capital. The METR is also sensitive to assets used by firms to conduct their R&D and their depreciation rules. To focus on differences in tax systems, these data are often assumed to be constant for all countries studied. A central assumption in the METR model is that R&D expenditure are always used to create new assets that is expected to generate future revenues as any investment in tangible capital. Thus, all R&D expenditure are capitalized and the immediate deductibility of current expenditure represents a fiscal incentive that reduces the value of METR.

Thus the METR model differs from the B-index model in three ways:

1) The B-index does not include financial costs in the cost of an R&D investment

2) The B-index does not take into account taxes other than those related to corporate income taxes

3) The B-index model assume that the benchmark tax system allows full deductibility of R&D expenditure instead of being capitalized and depreciated as is the case with the METR model

If the METR model appears to provide a more accurate measure of the impact of tax incentives, it is also much more costly in terms of computation. In addition, as shown in the report of the Finance's Department in Canada (2009) that compares the values of the B-index and the METR for 36 countries (30 belonging to the OECD):

"The B-index, which is the most commonly used indicator for making international comparisons, shows a substantially lower level of tax assistance for R&D largely because the methodology adopts a benchmark tax system in which R&D spending is expensed rather than capitalized as in the METR frame§. Nevertheless, using the B-index methodology does not have a large impact on the international rankings of tax assistance for R&D."

This result is not surprising because, as shown by Warda (2001), the METR is a function of the B-index:

$$\text{METR} = \frac{(r-\rho+d)B - C}{(r-\rho+d)B}$$

where B is the B-index and C represents the after tax real rate of return of an investment in R&D which is determined exogenously. The greater simplicity of the B-index model for international comparisons led us to retain this indicator in this paper. The values of the B-index are taken from Thomson (2009).

Tables

Date	Freq.	Percent	Cum.
1990	15	3.51	3.51
1991	20	4.68	8.20
1992	21	4.92	13.11
1993	23	5.39	18.50
1994	23	5.39	23.89
1995	25	5.85	29.74
1996	25	5.85	35.60
1997	25	5.85	41.45
1998	25	5.85	47.31
1999	25	5.85	53.16
2000	25	5.85	59.02
2001	25	5.85	64.87
2002	25	5.85	70.73
2003	25	5.85	76.58
2004	25	5.85	82.44
2005	25	5.85	88.29
2006	25	5.85	94.15
2007	25	5.85	100.00
Total	427	100.00	

Table 1 : Unbalanceness of the data

Variable	Obs	Mean	Std. Dev.	Min	Max
dirdefipib	427	0,95%	0,65%	0,03%	2,96%
dirdpubpib	427	0,24%	0,10%	0,07%	0,56%
subpib	427	0,08%	0,07%	0,00%	0,45%
credit	427	91,89%	47,14%	15,21%	231,08%
interetlt	427	7,74%	5,609%	1,00%	45,75%
bindex	402	0,951	0,107	0,57	1,08

Table 2 : Descriptive statistics

	dirdefipib	subpib	dirdpubpib	credit	interetlt	bindex
dirdefipib	1					
subpib	0.5000	1				
dirdpubpib	0.2802	0.3400	1			
credit	0.4809	0.1622	0.0663	1		
interetlt	-0.4093	-0.1096	-0.0945	-0.5421	1	
bindex	0.1937	0.1733	0.0760	-0.1165	0.1938	1

Table 3 : Correlation between variables

VARIABLES	(1) dirdefipib	(2) dirdefipib	(3) D.dirdefipib	(4) D.dirdefipib	(5) dirdefipib	(6) dirdefipib	(7) dirdefipib
L.dirdefipib	0.985***	0.862***	0.819***	0.865***	0.837***	0.886***	0.913***
	(0.009)	(0.022)	(0.186)	(0.248)	(0.048)	(0.018)	(0.026)
credit	-0.005	0.022	-0.021	-0.005	0.075*	0.074**	0.017
	(0.010)	(0.017)	(0.036)	(0.037)	(0.042)	(0.030)	(0.016)
interetlt	-0.042***	-0.070***	-0.056	-0.109**	-0.052*	-0.075**	-0.068***
	(0.015)	(0.019)	(0.037)	(0.043)	(0.032)	(0.033)	(0.022)
dirdpubpib	-0.000	-0.000	-0.097*	-0.147**	-0.031	-0.007	0.004
	(0.010)	(0.028)	(0.053)	(0.066)	(0.041)	(0.053)	(0.029)
subpib	-0.016**	0.001	-0.041***	-0.041***	-0.022	-0.021	-0.007
	(0.006)	(0.011)	(0.014)	(0.016)	(0.022)	(0.015)	(0.012)
L.bindex	-0.062*	-0.118**	-0.231***	-0.233***	-0.155***	-0.156**	-0.114*
	(0.034)	(0.058)	(0.086)	(0.090)	(0.056)	(0.066)	(0.062)
Observations	402	402	352	377	377	402	402
R-squared	0.992	0.890					
Estimator	OLS	LSDV	IV-AH-AD	IV-AH-L	GMM-AB	GMM-BB	LSDVC
Time dummies	yes	yes	yes	yes	yes	yes	yes
AR(1) (p-value)					0.020	0.013	
AR(2) (p-value)					0.941	0.957	
Hansen (p-value)			1.000	1.000	1.000	1.000	

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4 : Preliminary estimates of model (5) and autocorrelation tests

VARIABLES	(1)	(2)	(3)	(4)	(5)
L.dirdefipib	0.811***	0.811***	0.803***	0.857***	0.851***
C-Stat [p value]	[0.001]	[0.002]	[0.001]	[0.012]	[0.007]
credit	0.020	0.028	0.024	0.019	0.144
C-Stat [p value]	[0.580]				
interetlt	-0.064**	-0.051*	-0.057**	-0.043*	-0.049*
C-Stat [p value]	[0.841]				
dirdpubpib	0.045	0.048	0.009	0.059	0.019
C-Stat [p value]	[0.155]	[0.159]		[0.140]	
subpib	0.052	0.051	0.054*	0.006	0.008
C-Stat [p value]	[0.147]	[0.132]	[0.139]		
L.bindex	-0.035	-0.134*	-0.138*	-0.145**	-0.149**
C-Stat [p value]	[0.323]				
Observations	377	377	377	377	377
Estimateur	IV-2SLS	IV-2SLS	IV-2SLS	IV-2SLS	IV-2SLS
Time dummies	yes	yes	yes	yes	yes
Hansen (p-value)	0.995	0.991	0.9632	0.8282	0.9113
Stock-Yogo	N/A	5-10%	0-5%	0-5%	0-5%
(Biais relatif IV vs MCO)					
RMSE	**0.0729**	**0.0727**	**0.0728**	**0.07056**	**0.07047**

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Endogeneity tests for explanatory variables

Notes : The endogeneity test used is based on the difference between two Sargan-Hansen tests (one where suspect regressors are treated as endogenous and one where they are treated as exogenous). Under the null hypothesis, the instruments are assumed to be exogenous. In the table, we only report the p-value of this test (C-stat). The over-identifying restrictions test of Hansen measures the validity of the instruments used, i.e, whether or not the instruments are correlated with the error term. Under the null hypothesis, the instruments are valid instruments. The **Stock-Yogo test** measures the weakness of the instruments used, that is, he checks if instruments are weakly correlated with the endogenous regressors. This test is based on a measure of the bias from IV estimation relative to the bias from OLS estimation. Consequently, for the second estimation, the bias from IV estimation does not represent more than 10% of the OLS estimation's bias. In other words, the IV estimation reduces the estimation bias by a factor of 10 compared to OLS. In general, a relative bias higher than 20-30% shows the weakness of instruments.

VARIABLES	(1) dirdefipib	(2) dirdefipib	(3) dirdefipib	(4) dirdefipib	(5) dirdefipib	(6) dirdefipib	(7) dirdefipib
L.dirdefipib	0.913***	0.905***	0.913***	0.912***	0.919***	0.904***	0.906***
	(0.026)	(0.025)	(0.025)	(0.024)	(0.023)	(0.025)	(0.022)
credit	0.017	0.021	0.016	0.016		0.010	
	(0.016)	(0.017)	(0.019)	(0.018)		(0.016)	
interetlt	-0.068***	-0.062***	-0.068***	-0.068***		-0.056**	
	(0.022)	(0.017)	(0.021)	(0.022)		(0.023)	
dirdpubpib	0.004	0.006	0.005			-0.005	
	(0.029)	(0.029)	(0.025)			(0.028)	
subpib	-0.007	-0.005	-0.008	-0.007	-0.013	-0.034**	-0.044***
	(0.012)	(0.013)	(0.010)	(0.013)	(0.013)	(0.015)	(0.015)
L.bindex	-0.114*	-0.106*	-0.112*	-0.114*	-0.156**	-0.145**	-0.185***
	(0.062)	(0.064)	(0.064)	(0.067)	(0.065)	(0.063)	(0.064)
date		-0.003*					
		(0.002)					
interact						0.585***	0.723***
						(0.206)	(0.201)
Observations	402	402	385	402	402	402	402
Estimateur	LSDVC	LSDVC	LSDVC	LSDVC	LSDVC	LSDVC	LSDVC
Time dummies	yes	no	yes	yes	yes	yes	yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7 : Robustess checks of model (5) and model (6)

Notes : Columns (1) and (6) are results presented in the paper. Columns (2)-(5) test the robustness of the estimation (1). Estimation (3) has been realized by suppressing data on the United States. Estimation (7) tests the robustness of the estimation (6). As we can see on the table, the estimations presented in the paper are robust to the elimination of explanatory and time dummy variables as well as to the elimination of one country from our panel.

Figures

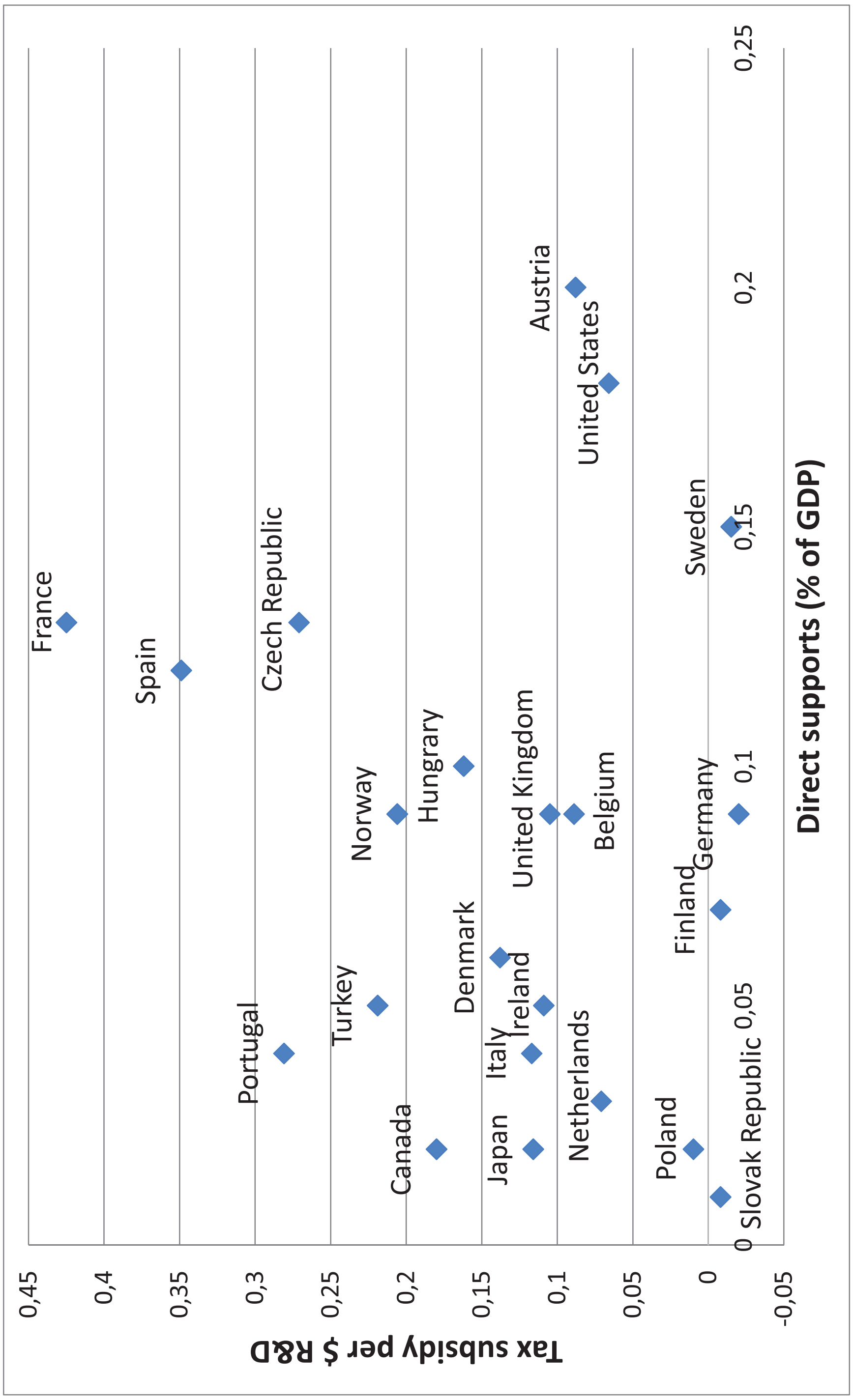

Figure 1 : Country's profile of Financial supports to R&D (2009) direct (subsidies, contracts, loans) and indirect (fiscal incentives) support

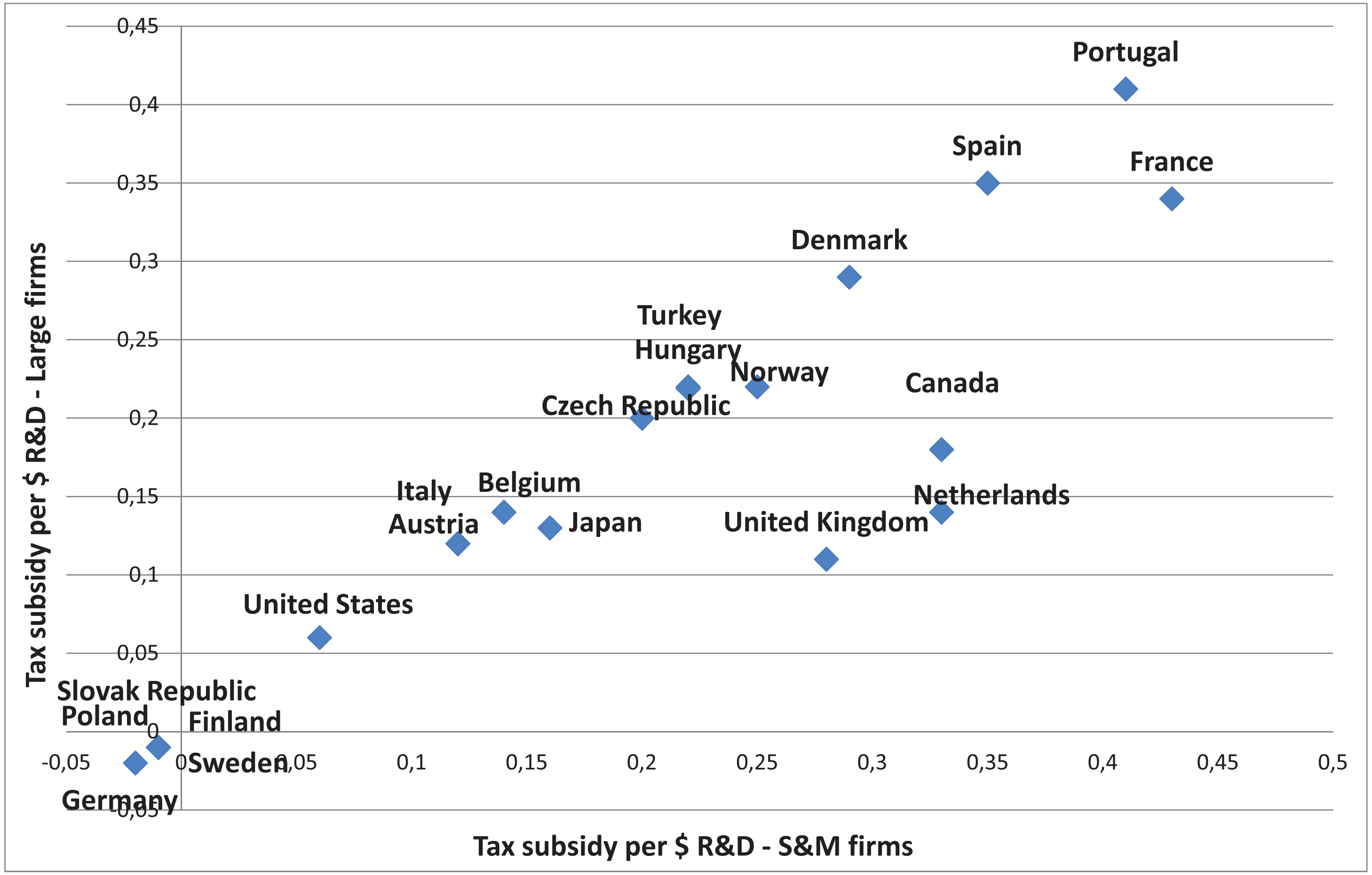

Figure 2 : Tax incentives system for S&M and large firms: An overview

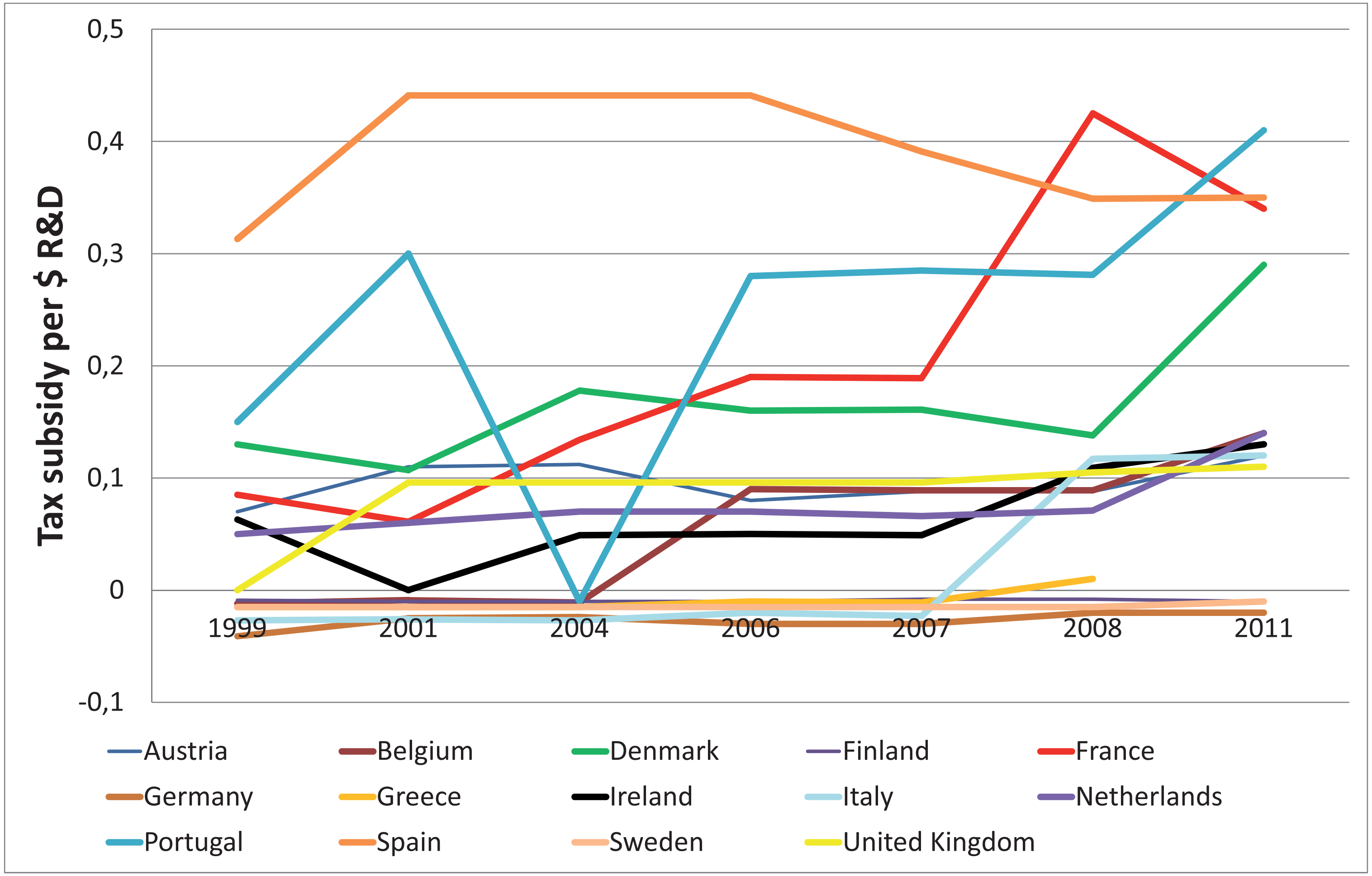

Figure 3 : Evolution of tax subsidy per $ invested in R&D – EU countries

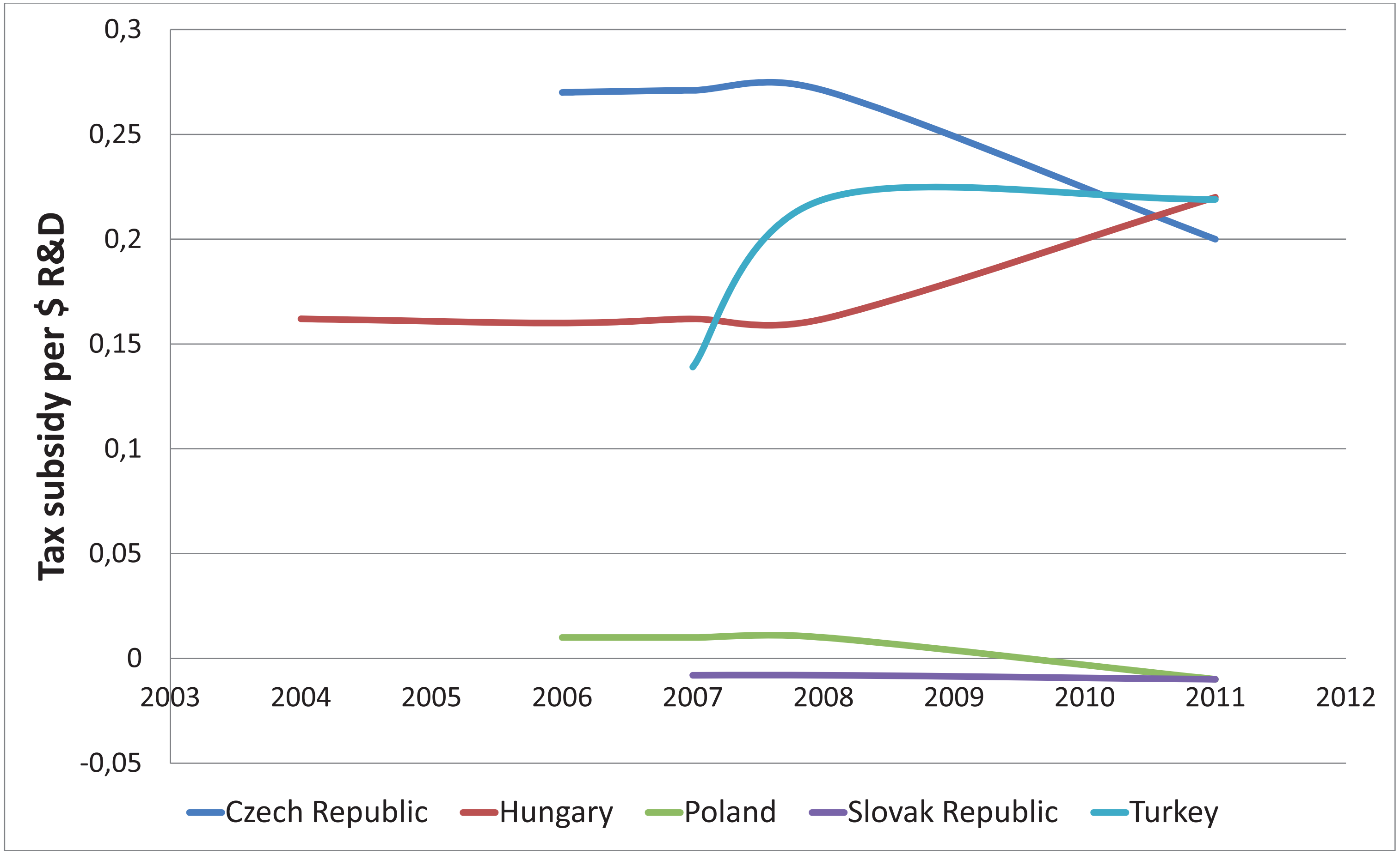

Figure 4: Evolution of Tax subsidy per $ invested R&D – New EU members & some EMEA countries

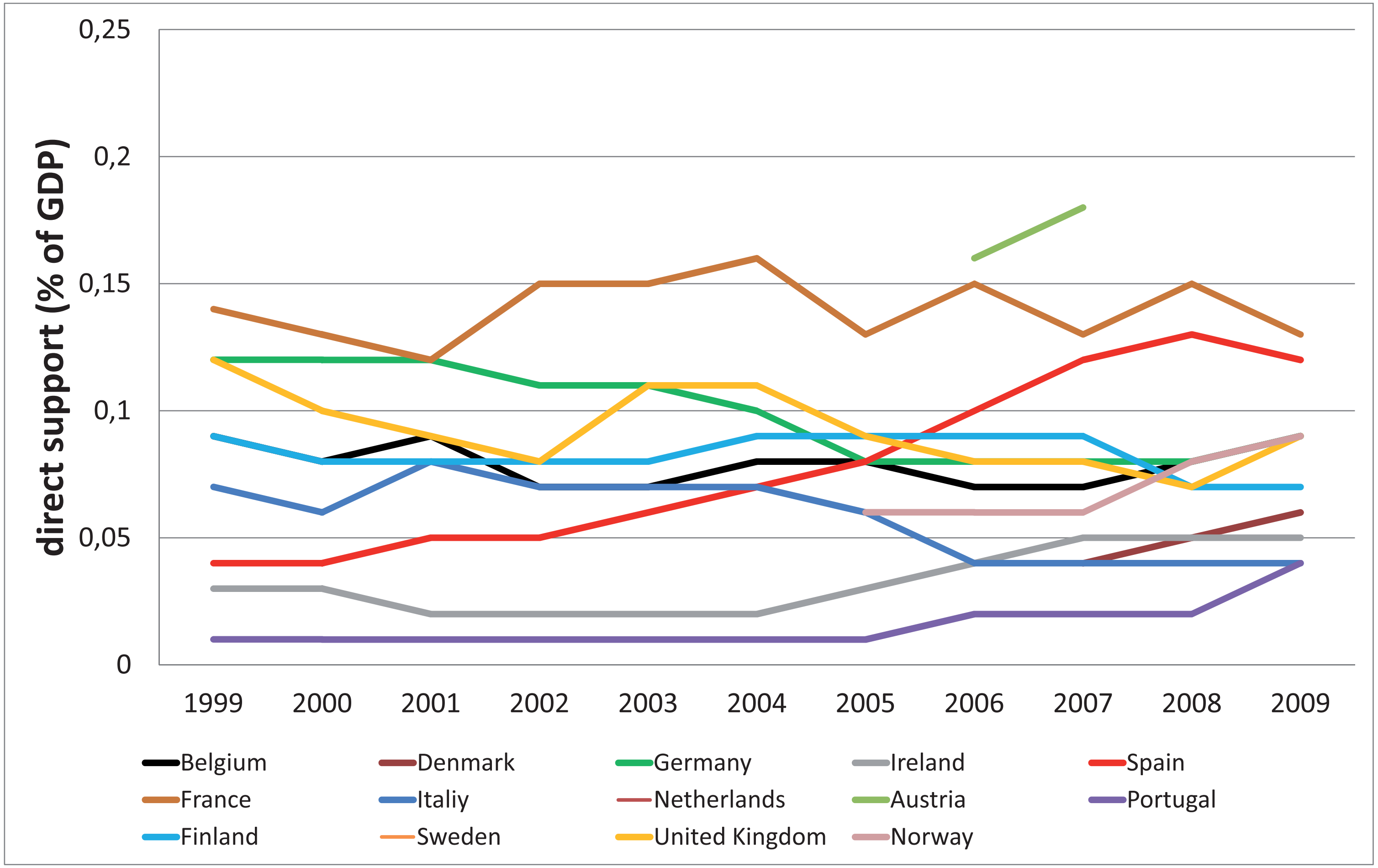

Figure 5 : Evolution of direct support in EU countries (1999-2009)

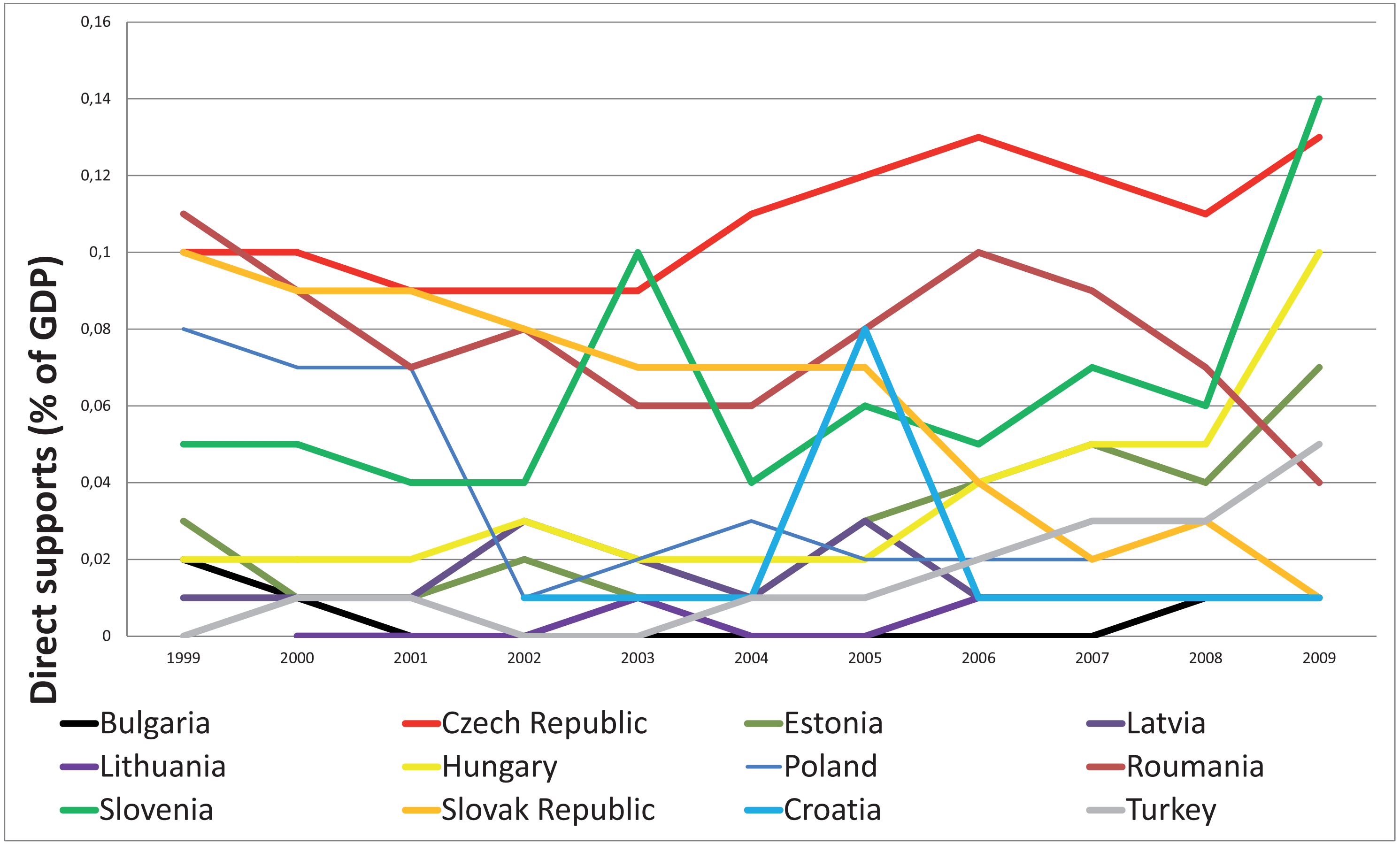

Figure 6 : Evolution of direct support in new EU members and some EMEA countries (1999-2009)

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