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DO TAX CREDITS SIGNIFICANTLY AFFECT THE LEVEL OF R&D EXPENDITURE?

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Abstract

This dissertation paper investigates empirically the effect of R&D tax incentives on the level of R&D investments. The econometric model is based on a panel of data in nine OECD countries over a 15-year period (1981-1996). It includes both state and time fixed effects in order to avoid omitted variable bias estimations and an instrumental variable to overcome endogeneity problems. The estimation results show that, on average, a 1% fall in the cost of R&D capital increases by 0.30% the level of R&D investments (ceteris paribus).

Contents

1. Introduction

Research and Development is a relevant sector both for firms and macro-policies. Firms, by investing in R&D are able to innovate and gain competitive advantage. Nations, by implementing new technologies are able to sustain economic growth [1]. Hence, advanced economies policy makers have been concerned about the level of R&D of their countries for large parts of the 20th Century. These concerns have been sharpened by facts: the growth miracle of the Asian tigers economies over the 1980s and mid-1990s was based on high-tech investments. While, the decline of the Italian rate of growth from the 1990s is related to low capital stock in the high tech sectors. It is clear that investments in R&D are a source of profits for individual firms and the engine of economic growth.

However, markets left on their owns will probably deliver a lower level of innovation than socially desirable. The first reason is that knowledge is not completely excludable: ideas can be easily copied and implemented by competitors discouraging firms to invest in R&D. The second reason why markets might fail is that private investors and banks can difficulty monitor innovative firms. Information asymmetry between researchers and investors makes difficult to obtain funding, especially for young and innovative enterprises. Thus, government intervention is important to prevent market failure.

Many countries in order to increase the level of innovation and avoid market failure decided to implement R&D tax incentives: from the OECD estimates, in 2012 the costs of R&D tax credits in US were around $ 9.7 billion and in EU around $ 12.5 billion[2]. Tax credits can apply to the total R&D expenditure (volume-based schemes) or to the increment of R&D expenditure (incremental schemes). Generally, volume-base R&D tax credits are preferred over incremental ones, since the latter result in higher administrative and compliance costs [3]. Furthermore, R&D tax incentives are targeted to

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[1] Romer (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992).

[2] OECD R&D Tax Incentives Indicators, EU includes Austria, Belgium, Czech Republic, Denmark, France, Hungary, Ireland, Italy, Netherland, Norway, Portugal, Spain and UK.

[3] Benchmarking R&D tax incentives designs, from the final report "A Study on R&D Tax Incentives", European Commission

specific groups of firms, commonly SME (Small Medium Enterprises) or young companies.

The main advantage of adopting R&D tax credits rather than direct government subsidies as innovation policy tool lies in their generic nature: decisions regarding R&D investments are left to companies that are more likely to make more efficient allocations than central authorities.

Several recent studies show a positive impact of R&D tax incentives on R&D expenditure: one euro foregone of tax revenue on R&D tax credits raises expenditure on R&D by less than one euro[4]. However, these authors studied the effectiveness of R&D tax credit with different methodologies making difficult the comparison of their outcomes. Moreover, they concentrated only upon one country and such approach may lead to misleading results. Firstly, because the change in R&D expenditure is purely macro-economic and therefore without a cross-country data is difficult to disentangle the true effect of the R&D incentive from contemporaneous macro-economic events. Second, the effectiveness of R&D tax credits depends on the framework conditions such as the availability of skilled labour, universities, infrastructure, culture, the pattern of intellectual property rights and so on. Hence, the results obtained by concentrating only upon one country seek to control for these endogenous variables.

In this dissertation paper is used a panel of data in nine OECD countries[5] over a 16-year period (1981-1996), following the methodological approach of Nick Bloom, Rachel Griffith, John Van Reenen (2000). In section 2 will be described the literature of R&D tax incentives. Section 3 lays out the theoretical framework. Section 4 describes the data of both the dependent variable ‘R&D’ and the independent one ‘user-cost of R&D capital’. Section 5 outlines the econometric models and Section 6 shows the results.

[4] Cornet and Vroomen (2005), Lokshin and Mohnen (2012), Mulkay and Mairesse (2013).

[5] Australia, Canada, France, Germany, Italy, Japan, Spain, United Kingdom, United States

2. Literature

Empirical literature on the impact of R&D tax credits on R&D expenditure is wide, especially in the last fifteen years. The quantitative evaluation of R&D tax credits is divided in two methods: structural and direct approach. The structural approach estimates the response in a firm's R&D expenditure to changes in the user-cost of R&D capital. The user cost of capital is the 'actual cost' faced by the firm for investing in R&D. One of its main determinants is the firm tax credit, next to the wage rate of researchers and the cost of equipment[6]. The second approach consists in regressing R&D expenditure directly on a variable that includes the presence and strength of the tax credit. The two approaches do not only differ for the interpretation of the estimated coefficient, but also in their set of assumptions and econometric challenges.

2.1. Structural approach

The structural approach models the R&D expenditure as a function the user cost of R&D capital. This method was developed in the pioneer work King and Fullerton (1984), which describes the cost of R&D capital as dependent on tax credit, statutory tax rate, real interest rate, depreciation and rate of inflation. The main advantage of the structural approach lies on the fact that the independent variable captures both the effects of the tax credit and other R&D costs faced by the firm. Thus, it allows for a more complete understanding on how changes in tax credit affect R&D expenditure. Moreover, it permits to make estimation of short (1 year) and long run effects (from 5 to 15 years). The main challenge of adopting this method is reverse causality: the user cost of R&D capital is determined simultaneously with the R&D level. Generally policy-makers introduce fiscal R&D incentives as a consequence of underinvestment in R&D. Thus, the size of the credit depends on the amount of R&D performed leading to potential underestimation of its effectiveness. Lokshin and Mohnen overcame this endogeneity problem by using instrumental variable (IV) techniques. In their study of the Dutch payroll withholding tax credit (WBSO) they found that, on average, a 10% decrease in the user-cost of R&D capital leads to 4% more R&D expenditure in the

[6] Hall and Van Reenen (2000)

short run, and 6% more in the long run. However, it is difficult to find a suitable instrumental variable and the use of an invalid instrument will increase estimation bias.

Another issue that may further increase misleading results is selection bias. It occurs when are compared the performance of firms that invest in R&D and therefore eligible for tax credit, with firms that do not invest in innovation. Hence, the difference in performance between the two groups is not exclusively driven by the eligibility of the tax credit, but also by differences in firm characteristics.

In table 1 are shown the estimated effects found in studies that adopt the structural approach. The negative estimates imply a positive correlation between tax credit and the level of R&D expenditure. More precisely, the estimated elasticities range from -4.4 to -0.03. However, these results may be imprecise due to reverse causality or selection bias. As the final report of the European Commission "Study on R&D Tax Incentives" states, we can consider more reliable the estimations of Lokshin and Mohnen (2012) and Mulkay and Mairesse (2013). Hence, a good empirical research should report elasticity between -0.6 and -0.1.

Table 1

Study	Published[c]	Country	Period	Scheme	Obs. level	Method	Dependent variable	Mean result	
								short-run	long-run
Baghana and Mohnen (2009)	yes	Quebec	1997-2003	incremental, volume	firm	OLS	log R&D level	-0.08	-0.12
Bloom et al. (2002)	yes	OECD	1979-1999	incremental, volume	industry	IV	log R&D level	-0.25	-0.97
Caiumi (2011)	no	Italy	1998-2005	Volume	firm	matching; GMM	log R&D level	-0.30	-0.60
Corchuelo, Martinez-Ros (2009)	no	Spain	1990-1998	incremental, volume	firm	selection model; IV	log R&D level	-1.09[a]	
Corchuelo, Martinez-Ros (2009)	no	Spain	2002	incremental, volume	firm	selection model; IV	log R&D level	-0.47[a]	
Dagenais et al. (1997)	no	Canada	1975-1992	Volume	firm	IV	log R&D level	-0.07[a]	
Harris et al. (2009)	yes	North. Ireland	1998-2003	Volume	firm	GMM	log R&D level	-0.53	-1.37
HMRC (2010)	no	United Kingdom	2003-2007	enhanced allowance, volume	firm	GMM	log R&D level	*Total:* -0.91[b] *SME scheme:* -2.32 *Large:* -2.41	*Total:* -2.60[b] *SME scheme:* -2.16 *Large:* -3.65
Koga (2003)	yes	Japan	1989-1999	incremental	firm	IV	log R&D level	-0.61[a]	
Lokshin and Mohnen (2012)	yes	Netherlands	1996-2004	volume	firm	IV	log R&D level	-0.38	-0.63
Mulkay and Mairesse (2003)	no	France	1982-1996	incremental	firm	fixed effects	log R&D level	-0.14	-0.05
Mulkay and Mairesse (2008)	no	France	1983-2002	incremental	firm	fixed effects	R&D intensity	-0.14	-0.28
Mulkay and Mairesse (2013)	yes	France	2000-2007	incremental, volume	firm	fixed effects; GMM	log R&D level		-0.16
Parisi and Sembenelli (2001)	no	Italy	1992-1997	volume	firm	Tobit, rand. eff.	log R&D level	-4.36[a]	
Poot et al. (2003)	no	Netherlands	1997-1998	volume	firm	OLS	log R&D level	-0.11	-1.12
Rao (2013)	no	United States	1981-1991	incremental	firm	IV	R&D intensity	-1.64	
Westmore (2013)	no	OECD	1983-2008	incremental, volume	country	OLS	log R&D level	-0.03	-0.88
Wilson (2009)	yes	United States	1981-2004	incremental	firm	OLS	log R&D level	-1.21	-2.18

[a] Short-run or long-run not specified; [b] Estimates that assumed endogenous user-cost elasticity; [c] Study has been published in peer-reviewed journal

from the final report of the European Commission "Study on R&D Tax Incentives".

2.2. Direct approach

The direct approach consists in comparing the level of R&D expenditure of a ‘treatment group’ with the level of a ’control group’. Some studies make a binary regression simply comparing firms that received and did not receive the tax credit. While others use more elaborate ways, such as matching or difference-in-differences (DID). Matching techniques consists in two steps. First, create a model that predicts the adoption for the tax credit, given firm characteristics. Second, firms that receive the R&D tax incentive are matched with non-recipient ones that share similar observable characteristics. Then, the impact of the tax credit is obtained by comparing the R&D performance between the matched entities. Corchuelo and Martìnez-Ros introduced for the first time this matching technique in a study on Spanish R&D tax credit. The outcome of their work was a positive effect of the R&D tax incentive, especially for large firms. However, matching techniques do not account for self-selection of firms into the treatment group (selection bias), while difference-in-differences (DID) estimator does. It focuses on firms that shared very similar characteristics and R&D behaviour before the introduction of a policy that affected only a part of them. If the firms that were affected by the policy change invested more in R&D than the unaffected ones, it can be concluded that the introduction of the tax credit has been effective. Cornet and Vroomen (2005) applied difference-in-differences (DID) to a Dutch reform that involved the introduction of a targeted tax credit to start-up firms. It resulted to have a positive effect, since induced an increase in R&D wages between 10% and 20%. Although direct approach includes a variety of methods, such as matching or difference in differences, the literature seems to agree that R&D tax credit have a positive correlation with R&D expenditure.

3. Theoretical Framework

In this dissertation paper is used the structural approach in order to quantify the effectiveness of the R&D tax credit. It was developed in King and Fullerton (1984) and its objective is to derive the pre-tax real rate of return on the marginal investment project that is necessary in order to earn a minimum rate of return after tax.
The derivations presented below are the ones in Nick Bloom, Rachel Griffith, John Van Reenen (2000).

3.1 Economic rent

Let us consider a profit-maximizing firm that undertake an investment in R&D in period one and earns a return in period two. There are three assumptions. 1) This firm is financed by retained earnings 2) the ultimate shareholder is exempt from personal taxes 3) the firm cannot predict tax changes. In the absence of taxes, the firm's value at time *t* is given by the net present value of the income stream, V_t^* (the symbol * stands for 'in the absence of tax'):

$$(1 + i)\, V_t^* = D_t^* + V_{t+1}^* \qquad (3.1)$$

where, i is the nominal interest rate and D_t^* is the amount of dividend paid by the firm to the ultimate shareholder in the absence of taxes.

$$D_t^* = f(G_{t-1}) - R_t \qquad (3.2)$$

where, $f\ (.)$ is the net income function, G_{t-1} is the value of R&D stock at the end of period $t-1$ and R_t is the investment in R&D. The dynamic equation of the R&D stock is given by: $G_t = (1-\delta)(1+\pi)\, G_{t-1} + R_t$

Hence, the current value of R&D stock is given by the value of the previous year R&D stock adjusted for economic depreciation rate δ and the one period inflation rate π, plus the new R&D investment.

Let us now consider an investment in R&D that increases the stock by one unit in period t only by letting R&D investment rise by one unit in period t and decline by one unit, less depreciation, in period $t + 1$ so that:

$$dR_t = 1 \quad and \quad R_{t+1} = -(1-\delta)(1+\pi) \tag{3.3}$$

This perturbation of the capital stock gives a return of:

$$df(G_t) = (p+\delta)(1+\pi_t) \tag{3.4}$$

where, p is the pre-tax financial return. The economic rent Π^* resulting from a change in R&D stock in absence of tax is given by the change in (3.1). Using (3.2), (3.3) and (3.4) it can be written as:

$$\Pi^* = (1+i)\, V_t^* = D_t^* + V_{t+1}^*$$

$$= 1 + \frac{(p+\delta)(1+\pi)+(1-\delta)(1+\pi)}{(1+i)} \tag{3.5}$$

$$= \frac{1+p}{1+r} - 1 = \frac{p-r}{1+r}$$

where, r = $\left[\frac{(1+i)}{(1+\pi)} - 1\right]$ is the real interest rate.

3.2 Corporate income tax

Let us now consider how tax will influence the firm's economic rent, holding pre-tax financial return and real interest rate constant. Exist three ways through which corporate income tax can be included:

1) The firm pays tax on its revenues at rate τ.
2) The cost of investment in R&D is reduced by depreciation allowances, A^d.
    - Declining balance basis at rate ϕ, the value of depreciation allowance will be $\tau\,\phi$ in period one, and falls in next periods by $(1-\phi)$. Thus, the net present value of the stream of depreciation allowances, A^d, is:

$$A^d = \frac{\tau\,\phi(1+r)}{(\phi+r)} \tag{3.6}$$

- Straight-line depreciation:

$$A^d = \tau\,\phi \tag{3.7}$$

3) The cost of investment in R&D is reduced by tax credits, A^c. The net present value of the tax credit depends on whether it applies to the total R&D expenditure (volume-based schemes) or to the increment of R&D expenditure (incremental schemes).

- Volume based tax credit, the value of the credit A^c will equal the rate $\tau^{\,c}$ that is:

$$A^c = \tau^{\,c} \tag{3.8}$$

- Incremental credit with a base that is defined as the k-period moving average, the value of the credit A^c is:

$$A^c = \tau^c (B_t - \frac{1}{k}\sum_{i=1}^{k}(1+r)^{-i}B_{t+i}) \tag{3.9}$$

  where, τ^c is the statutory tax rate, B_{t+i} is a parameter that takes value one if R&D expenditure is above its incremental base in period t and zero otherwise.

The A^c and A^d are the net reduction in investment costs. Therefore, the decline in the investment by $(1-\delta)(1+\pi)$ in period $t+1$, induce a reduction of $(A^d + A^c)$ $(1-$ $-\delta)(1+\pi)$ in in these allowances.

3.3 User-cost of R&D capital

Let us now include any attributed credit available on dividends paid to the shareholders; it is assumed that dividends are paid net of any such credit so that the value of the firm in presence of tax becomes: $(1+i)\,V_t^* = \gamma D_t^* + V_{t+1}^*$

where, γ measures the degree of 'tax discrimination' between retained earnings and distributions.

Now the net present value of the firm of economic rent in the presence of tax can be defined:

$$\Pi^* = (1 + i)\, V_t^* = \gamma D_t^* + V_{t+1}^*$$

$$= \gamma \left(\frac{(p + \delta)(1-\tau) + (1-\delta)\left(1-\left(A^d + A^c\right)\right)}{(1+r)} - \left(1 - \left(A^d + A^c\right)\right) \right)$$

It is important the impact of tax on the marginal project, where economic rent is equal to zero. Setting $\Pi = 0$ and solving for p we obtain the cost of capital:

$$p^{cost\ of\ capital} = \frac{\left(1-\left(A^d + A^c\right)\right)}{(1-\tau)} (r + \delta) - \delta$$

Adding back depreciation to cost of capital, it is possible to formulate the user cost of capital for a domestic investment in R&D for three assets (indexed by j), for each country (i) and year (t):

$$p_{ijt}^d = \frac{\left(1-\left(A_{ijt}^d + A_{ijt}^c\right)\right)}{(1-\tau_{it})} \left[r_{it} + \delta_j\right] \tag{3.10}$$

The depreciation allowances and tax credits vary according to the type of asset, countries and time. The real interest rate and the statutory tax rate vary over country and time. The depreciation rates vary over assets.

4. Data

In this dissertation paper is used a panel of data in nine OECD countries (Australia, Canada, France, Germany, Italy, Japan, Spain, UK and US) over a 15-year period (1981-1996), following the structural approach. In this section will be explained the data collection of both the dependent variable 'R&D expenditure' and the independent one the 'user-cost of R&D capital'.

4.1 The user cost of R&D capital data

There are not available databases including series of the tax-adjusted user cost of capital across countries and over time. Probably it is because tax data are very difficult to obtain due to their confidentiality. In this work, the estimations of user-cost of R&D capital are considered as calculated in Nick Bloom, Rachel Griffith, John Van Reenen (2000), whose authors collected details of the tax system in each of the nine countries for every year from 1979 to 1997. As it is described in the framework section, the user cost of R&D capital is determined by several factors:

$$p_{ijt}^{d} = \frac{\left(1-\left(A_{ijt}^{d}+A_{ijt}^{c}\right)\right)}{(1-\tau_{it})}\left[r_{it} + \delta_j\right]$$

Here, three types of assets (indexed by *j*) are used for R&D activities — current expenditure, buildings and plant and machinery. Current expenditure on R&D is assumed not to realize its full value immediately, as the other two types of asset. The depreciation rates used are 30% for current expenditure in R&D, 3.61% for buildings and 12.64% for plant and machinery. Thus, the user cost of R&D capital for each country is given by: $p_{it}^{d} = \sum_{j=1}^{3} w_j \; \rho_{ijt}^{d}$

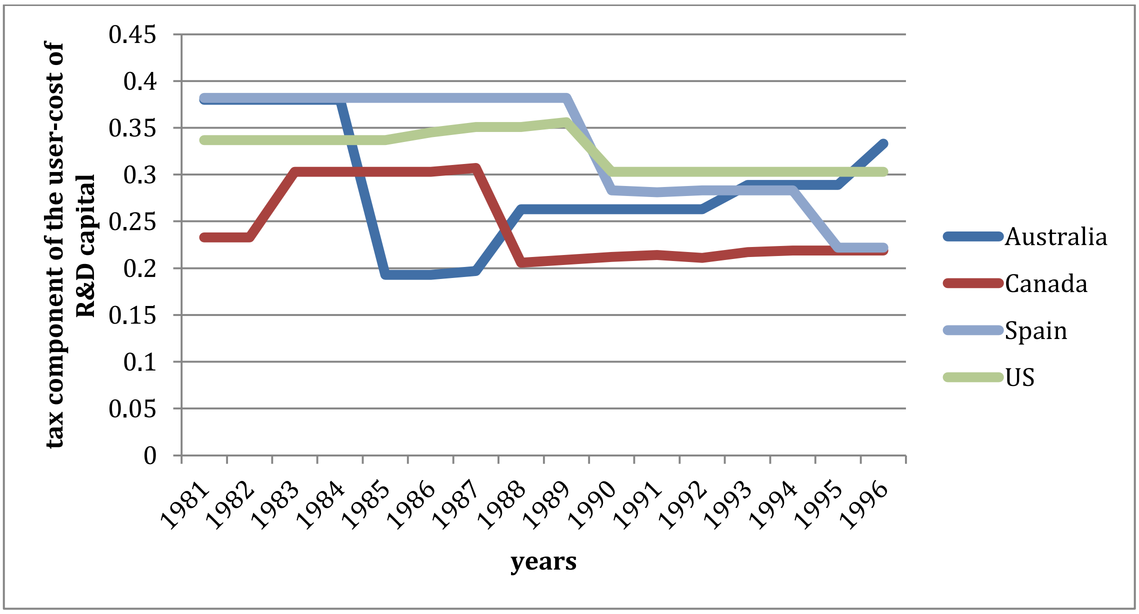
where, w_j are the weights equal to 0.90 for current expenditure, 0.036 for buildings and 0.064 for plant and machinery[7]. Inflation rate and real interest rate vary across country and over time[8].

[7] See Cameron (1994)

Table A.1 shows the user-cost of R&D for each country over 16 years calculated in Nick Bloom, Rachel Griffith, John Van Reenen (2000). Furthermore, to better capture the impact of the tax credits, the authors calculated the 'tax component' of the user cost, denoted $\left(\rho_{it}^{d\tau}\right)$. It is calculated as equation (3.10) but it considers constant real interest rate of 10% and inflation rate of 3.5% across countries and over time. Table A.2 shows the 'tax component' of the user cost.

The user cost of R&D capital changes considerably both across countries and over time. In figure 1 is charted the tax component of the user cost of the four most generous countries: Australia, Canada, Spain and USA.

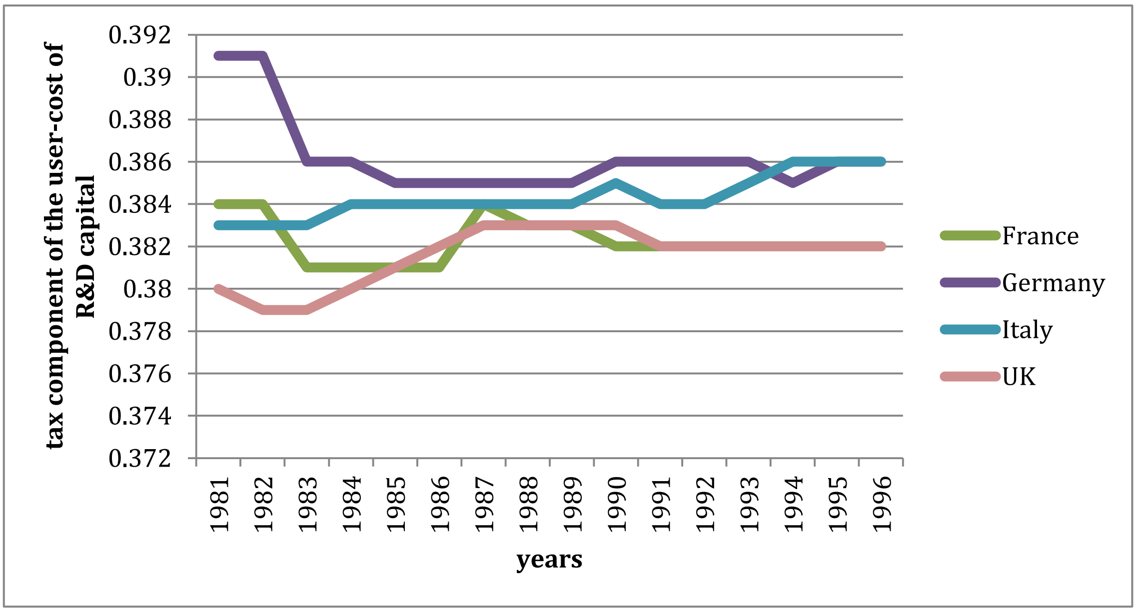
Fig. 1



Hence, at some point these countries show lower values of 'tax component', implying more generous regimes. For example, Australia from 1985 to 1987 and Spain in 1995. On the contrary, Fig. 2 shows the four less generous countries: France, Germany, Italy and UK.

[8] Nick Bloom, Rachel Griffith, John Van Reenen (2000) considers values from OECD Economic Outlook. Interest rate used is the long-term interest rate on government bonds and the inflation rate is GDP deflator.

Fig. 2



4.2 R&D expenditure data

I used for the dependent variable the OECD database (ANBERD) that contains data on business enterprise R&D (BERD) across the main OECD countries since 1973. Several recent studies show an increase in the internationalization of R&D[9]. Hence, the main advantage of using ANBERD database lies on the fact that data are reported at the country level on the basis of the location at which R&D activities has been performed. While company accounts data, which does not typically specify the geographical location of R&D activities, might be unreliable.

In a research on R&D tax incentives I had to focus on R&D activities industry-funded and not government-funded. The reason is that government-funded R&D activities are not eligible for tax credits and therefore including them may lead to estimation bias. Hence, I used a different data source called the Main Science Technology Indicators (MSTI) that permits to separate BERD by source of finance. It shows the percentage of industry-funded business enterprise R&D of the main OECD countries for each year.

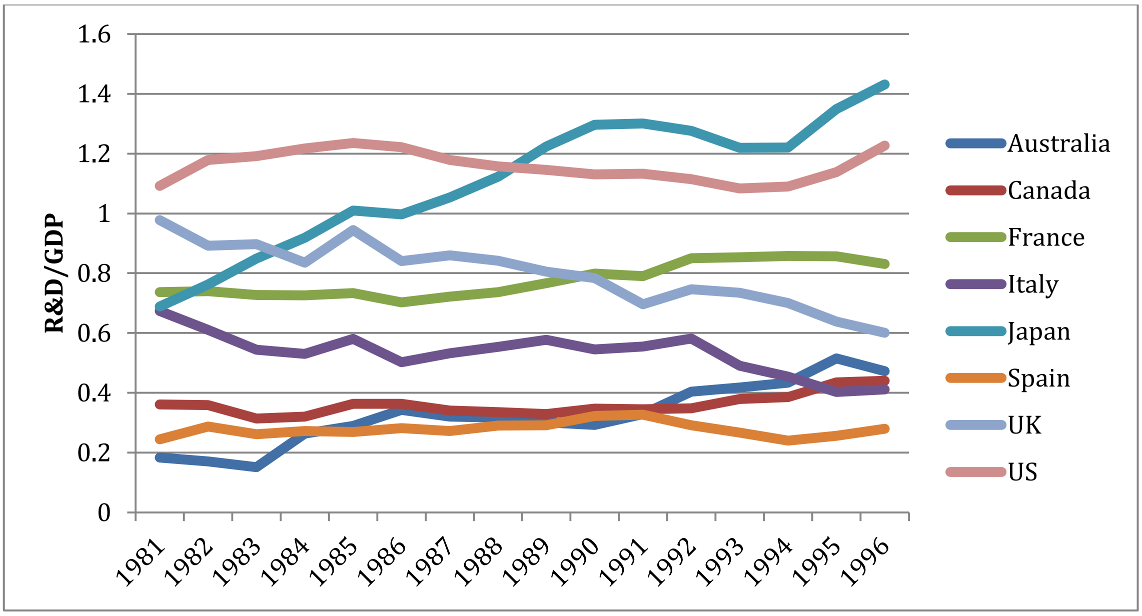
[9] Grandstrand (1999), Serapio and Dalton (1999) and Patel and Vega (1999).

Furthermore, I only took into account the R&D expenditure in the manufacturing sector due to the difficulty of measuring R&D in the service sector[10]. In the dataset created here, the manufacturing sector accounts for an average of 82% of business-conducted R&D. Thus, considering only R&D in the manufacturing sector should not lead to estimation bias.

The base sample in this dissertation paper contains 135 country-year observations[11]. In Figure 3 are shown the ratio of business enterprise R&D (industry-funded) to GDP in each country. What can be inferred is that R&D intensity has increased from 1981 to 1996 in most of the countries, except for Italy and UK. Moreover, some of these countries (e.g. Japan) have experienced a faster rate of change than others (e.g. France).

An interesting point can be made about reverse causality. Spain that is one of the most generous countries as shown in Fig. 1 has a low level of R&D intensity. It is evident that Spanish government has been introducing fiscal R&D incentives over these years due to underinvestment in R&D.

Fig. 3



[10] Young (1996)

[11] I have 15 years of data (1981-1996) for 9 countries (Australia, Canada, France, Germany, Italy, Japan, Spain, United Kingdom and United States).

5. Econometric model

The basic model used in this empirical investigation follows the structural approach:

$$r_{it} = \alpha + \beta\, y_{it} - \gamma\, \rho_{it}^{d} + \mu_{it} \tag{5.1}$$

where, i indexes countries and t years, α is the intercept, r_{it} is the natural logarithm of industry-funded R&D; y_{it} is the natural logarithm of GDP and ρ_{it}^{d} is the natural logarithm of the user-cost of R&D capital as defined by equation (3.10). As many authors in the literature that followed the structural approach did, I used a non-linear regression log-log. In this way is possible to estimate directly the elasticity of the dependent variable with respect to the independent ones. Hence, the coefficient γ describes the price elasticity of R&D with respect to its user-cost. The basic model (5.1) is run with OLS estimates, under heteroskedasticity-roboust standard errors. It means that the variance of the distribution of the error term μ_{it} given the independent variable X_{it} depends on X_{it}: $var(\mu_{it}|y_{it})\ or\ var(\mu_{it}|\rho_{it}^{d})$ are not constant.

However, the level of R&D expenditure does not only depend on the cost of capital, but also on other factors that vary across countries: the expectation about the future, the availability of skilled labour, universities, culture, the strength of intellectual property rights and so on. With the basic model (5.1) we cannot control for these variables leading to omitted variables bias estimations. Hence, we need a model that captures such effects: as long as these factors are constant or change slowly over time, they can be captured by country fixed effects (f_i). There could also be macro-economic events that affect the investments in R&D, such as the world demand condition or a shock in technology. Especially over the period of the data collected here, new computer-based technologies have affected the R&D performance in the industrialized countries. As long as these factors can be considered constant across countries, it is possible to control them by including a full set of time dummies (t_t). Thus, the state and time fixed effect regression model is:

$$r_{it} = \beta\, y_{it} - \gamma\, \rho_{it}^{d} + f_i + t_t + \mu_{it} \tag{5.2}$$

It can be written in terms of a common intercept and the $n-1$ and $T-1$ dummy variables:

$$r_{it} = \alpha + \beta\, y_{it} - \gamma\, \rho_{it}^{d} + \varphi_2 D_{2,i} + \cdots + \varphi_n D_{n,i} + \delta_2 B_{2,t} + \cdots + \\ + \delta_T B_{T,t} + \mu_{it}$$

With the combined state and time fixed effect regression model we are able to eliminate omitted variable bias arising from both unobserved variables that are constant across states and unobserved variables that are constant over time.

As shown in the previous section, one of the main issues discussed in the literature is reverse causality: the user cost of R&D capital is determined reciprocally with the level of R&D expenditure. We therefore need to find a valid instrument that captures the movements of the user cost of R&D capital that are uncorrelated with the error term μ_{it}. First, the instrumental variable should be correlated with the user-cost of R&D capital (relevance condition): $corr\left(Z_{it}, \rho_{it}^{d}\right) \neq 0$. Second, the instrument should not be correlated with the error term (exogeneity condition): $corr\left(Z_{it}, \mu_{it}\right) = 0$. The real interest rate can be considered a right candidate since it satisfies the relevance condition: the level of real interest rate influences investments in R&D. However, it is correlated with the dependent variable R&D due to the fact that the real interest rate is generally procyclical. Thus, the instrument is not valid. Let us now check if the tax component of the user-cost of R&D capital $\left(\rho_{it}^{d\tau}\right)$, can be a valid instrumental variable. First, I regressed the 'user-cost of R&D capital' against the 'tax component' to verify the relevance condition:

```
Coefficients:
              Estimate Std. Error z value Pr(>|z|)
(Intercept)   0.023268   0.007148   3.255  0.00113
tax.component 0.798263   0.020340  39.245  < 2e-16
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Heteroskadasticity robust standard errors used

Residual standard error: 0.01477 on 142 degrees of freedom
Multiple R-squared:  0.9083,    Adjusted R-squared:  0.9077
F-statistic:  1540 on 1 and Inf DF,  p-value: < 2.2e-16
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The coefficient on the instrument is highly significant at 5% since the z value in absolute terms exceeds 1.96. It means that the more are the tax liabilities, the higher will be the cost of investing in R&D. Thus, the relevance condition is satisfied. Second, the instrumental variable to be exogenous must be uncorrelated with the error term μ_{it}. The level of taxes is mainly driven by political considerations and not by investments in R&D. Thus, the 'tax component' affects the level of R&D expenditure only indirectly through the cost of R&D capital. There is a way to statistically test whether the instrument is correlated with the error term or not, but it requires more instruments than endogenous regressors (J-test). We can conclude that the user-cost of R&D capital $\left(\rho_{it}^{d\tau}\right)$ is a valid instrument since it satisfies both the relevance and exogeneity conditions.

The R&D expenditure is a highly persistent series, meaning that its current value depends on the level of the previous year. Running a combined state and time fixed effect regression model under heteroskedasticity-robust standard error as equation (5.2), might lead to inconsistent estimators. Hence, if the residuals are autocorrelated over time, the heteroskedasticity-robust standard errors might lead, incorrectly, to lower standard errors. We therefore need to use heteroskedasticity and autocorrelation-consistent (HAC) standard errors that are valid when the error term μ_{it} is potentially heteroskedastic and potentially autocorrelated. More specifically, by running a combined state and time fixed effect regression model under HAC standard errors, we allow for serial correlation in the residuals over time within a country (cluster), but treat the errors as uncorrelated across countries.

6. Results

I imported the dataset on R-Studio and ran the different econometric models in order to obtain a precise estimation of the user-cost of R&D capital coefficient γ.

Table 2

Main results[12]

Dependent variable: the natural logarithm of industry-funded R&D, $\ln(R\&D)$.				
Regressors	(1) OLS	(2) OLS	(3) IV	(4) IV
$\ln(user\ cost)$	0.758 ** (0.13)	-0.155 (0.146)	-0.332* (0.152)	-0.332* (0.16)
$\ln(output)$	1.44** (0.02)	0.344* (0.147)	0.313* (0.13)	0.313 (0.327)
Country dummies	no	yes	yes	yes
Year dummies	no	yes	yes	yes
Cluster Standard Errors	no	no	no	yes
R^2	0.97	0.992		
Residual Standard Error	0.259	0.15	0.022	

I first run the basic model (5.1) with OLS estimates, under heteroskedasticity-robust standard errors[13]. Here, both the coefficients are significant at 1% level, but in contrast with the literature, the user-cost of R&D capital is positively correlated with the level of R&D expenditure. Hence, this model does not control for unobserved variables that are

[12] The individual coefficient is statistically significant at the *5% or **1% significance level.

[13] I installed the packages 'devtools' and 'gragusa/ase'

constant across states and unobserved variables that are constant over time, leading to omitted variable bias estimations.

In column (2) is shown the combined state and time fixed effects regression model as defined by (5.2). In accordance with the literature the coefficient γ is negative, meaning that the user-cost of R&D capital (ρ_{it}^{d}) is negatively correlated investments in R&D (r_{it}). Unfortunately, it is not significant even at the 10% level since the z value in absolute terms is lower than the critical value 1.645 ($|-0.992| < 1.645$). Probably, it is due to the fact that governments give tax credits when the R&D intensity is low (see Spain). Thus, the user cost of R&D capital is determined simultaneously with the R&D level leading to estimation bias (reverse causality).

To address this endogeneity problem, it is shown in column (3) the IV regression model that includes as an instrument the tax component of the user cost of R&D capital, $\left(\rho_{it}^{d\tau}\right)$. The coefficient γ is negative and significant at 5% level since the t value in absolute terms exceeds 1.96 ($|-2.130| \geq 1.96$). It implies that, on average, 1% decrease in the cost of R&D capital increases by 0.30% the level of R&D investments (ceteris paribus). However, these results might be inconsistent because the error term μ_{it} is potentially autocorrelated over time. In column (4) is shown the IV regression model under HAC standard errors[14]. It considers as clusters 'states' and therefore allows for serial correlation in the residuals over time within a country (not across). The coefficient γ is negative and significant at 5% level as in column (3), but the coefficient β is not anymore significant. Hence, for both the coefficients the standard errors have increased, especially for β, due to HAC standard errors. These estimations results are more precise and, in accordance to the literature, report a price elasticity of R&D with respect to its user-cost between -0.6 and -0.1.

[14] I installed the package 'ivpack' that includes the function cluster.robust.se (ivmodel, clusterid).

7. Conclusion

Research and Development is an important source of profits for individual firms and it is one of the main determinants of economic growth. Hence, policy makers of industrialized countries have implemented R&D tax credits in order to prevent market failures (not excludability of knowledge and information asymmetry) and incentivize investments in R&D. On the basis of previous works, I developed an empirical analysis to quantify the effectiveness of the R&D tax incentives. I followed a ‘structural approach’, in the sense that I considered as the independent variable the cost of investing in R&D. It is determined negatively from R&D tax credit and positively from statutory tax rate, interest rate and depreciation rate. Thus, negative results imply a positive correlation between the tax credit and R&D investments.

I built a panel of data in nine OECD countries (Australia, Canada, France, Germany, Italy, Japan, Spain, UK and US) over a 15-year period (1981-1996) in order to run a state and time fixed effect regression model. In this way I was able to control for omitted variables that are constant or change slowly over time (availability of skilled labour, culture, strength of intellectual property rights, etc.) and omitted ones that are constant across states (technological shocks). In addition, I included as an instrumental variable the ‘tax component of the cost of R&D capital’ in order to overcome reverse causality: the user cost of R&D capital is determined simultaneously with the level of R&D investments. Finally, I ran the TSLS regression model under HAC standard errors considering as clusters ‘states’. Hence, it permits to obtain more precise estimations by allowing the error term to be autocorrelated over time within a state.

In accordance with the literature, I found that the user-cost of R&D capital has a negative and significant coefficient: on average a 1% fall in the cost of R&D capital increases by 0.30% the level of R&D investments (ceteris paribus). On the basis of these results, I can state that R&D tax credits significantly affect the level of R&D expenditure.

Appendix

A.1

User-cost of R&D capital, ρ_{it}^{d}

	Australia	Canada	France	Germany	Italy	Japan	Spain	UK	USA
1981	0.324	0.189	0.311	0.322	0.293	0.309	0.291	0.313	0.289
1982	0.325	0.193	0.323	0.32	0.308	0.326	0.293	0.319	0.295
1983	0.324	0.264	0.323	0.33	0.312	0.329	0.319	0.341	0.291
1984	0.347	0.291	0.333	0.336	0.314	0.32	0.323	0.34	0.305
1985	0.176	0.28	0.339	0.332	0.326	0.316	0.34	0.335	0.293
1986	0.164	0.267	0.342	0.35	0.331	0.321	0.298	0.34	0.293
1987	0.169	0.269	0.35	0.339	0.333	0.323	0.348	0.332	0.284
1988	0.226	0.195	0.346	0.333	0.331	0.324	0.345	0.326	0.291
1989	0.237	0.191	0.337	0.321	0.342	0.307	0.35	0.322	0.298
1990	0.24	0.198	0.354	0.344	0.352	0.316	0.265	0.342	0.241
1991	0.24	0.194	0.342	0.329	0.341	0.312	0.251	0.305	0.233
1992	0.242	0.211	0.345	0.314	0.362	0.305	0.245	0.323	0.225
1993	0.25	0.21	0.327	0.306	0.345	0.305	0.24	0.319	0.228
1994	0.269	0.221	0.336	0.322	0.339	0.316	0.242	0.337	0.239
1995	0.269	0.221	0.336	0.322	0.339	0.316	0.199	0.337	0.239
1996	0.31	0.221	0.336	0.322	0.339	0.316	0.199	0.337	0.239

A.2

Tax component of the user-cost of R&D capital, $\rho_{it}^{d\tau}$

	Australia	Canada	France	Germany	Italy	Japan	Spain	UK	USA
1981	0.38	0.233	0.384	0.391	0.383	0.366	0.382	0.38	0.337
1982	0.38	0.233	0.384	0.391	0.383	0.366	0.382	0.379	0.337
1983	0.38	0.303	0.381	0.386	0.383	0.366	0.382	0.379	0.337
1984	0.38	0.303	0.381	0.386	0.384	0.366	0.382	0.38	0.337
1985	0.193	0.303	0.381	0.385	0.384	0.366	0.382	0.381	0.337
1986	0.193	0.303	0.381	0.385	0.384	0.366	0.382	0.382	0.345
1987	0.197	0.307	0.384	0.385	0.384	0.366	0.382	0.383	0.351
1988	0.263	0.206	0.383	0.385	0.384	0.366	0.382	0.383	0.351
1989	0.263	0.209	0.383	0.385	0.384	0.366	0.382	0.383	0.356
1990	0.263	0.212	0.382	0.386	0.385	0.366	0.283	0.383	0.303
1991	0.263	0.214	0.382	0.386	0.384	0.366	0.281	0.382	0.303
1992	0.263	0.211	0.382	0.386	0.384	0.366	0.283	0.382	0.303

1993	0.289	0.217	0.382	0.386	0.385	0.366	0.283	0.382	0.303
1994	0.289	0.219	0.382	0.385	0.386	0.366	0.283	0.382	0.303
1995	0.289	0.219	0.382	0.386	0.386	0.366	0.222	0.382	0.303
1996	0.333	0.219	0.382	0.386	0.386	0.366	0.222	0.382	0.303

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OECD, ANBERD (Analytical Business Enterprise Research and Development) database, ISIC Rev.2 – archived version.

OECD, MSTI (Main Science and Technology Indicators) database.