Financing R&D Through Tax Credit in France

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Preliminary Draft
May 2008

Summary

The aim of this article is to evaluate the effect of the cost of R&D capital, and more particularly of the tax credit on R&D expenditure, introduced in France since 1983, as a fiscal incentive to private R&D. A user cost of R&D capital is derived with imperfect capital markets, corporate and shareholders taxation. A special treatment is devoted to the introduction of the incremental tax credit on R&D expenditure. We distinguish the user cost with or without the tax credit in order to assess its specific effect.

Data on French companies over the period 1979 – 2003 are used in the empirical test in order to evaluate the determinants of the R&D. The effect of the user cost on R&D is identified by the change in the tax policies during the estimation period. More particularly the changes in the statutory rate of tax credit, the floor and the ceiling to its the use allow measuring the effect of this major incentive to the private R&D.

The main determinant of the R&D expenditure remains always the future demand prospects, but the user cost of R&D capital has also a negative effect, especially because the tax credit strongly reduces its user cost. It is shown that if the rate of this tax credit is raised by 10 %, the optimal stock of R&D capital will increase by around 2.4 %, which is far from being negligible. In this case, the long run increase in the R&D expenditure is around 2 times larger than the budgetary cost for the government.

JEL Classification : O32, H25,H32

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Keywords: R&D, R&D Capital, Coporate Taxes, R&D Tax Credit, Cost of Capital

1. INTRODUCTION

These last years several papers were interested in the effects of liquidity constraints on the investment and the R&D expenditure by using international comparisons based on panels of companies. For the R&D, it appears that the financial constraints are stronger in the countries where the financial source is more market-oriented like in the United States or in the U.K., while they were less pronounced for the countries of continental Europe like Germany or France.

However these papers generally neglect the effect of the cost of the capital on the investment mainly because this cost of the capital is difficult to measure at the individual level of companies. Recently, Chirinko, Fazzari and Meyer (1999 and 2002) proposed to use prices of investment at a very detailed sectoral level, combined with different depreciations rates in order to obtain a sufficient individual variability for the user cost of capital. They found a cost elasticity of the investment of about -0.3 to -0.5.

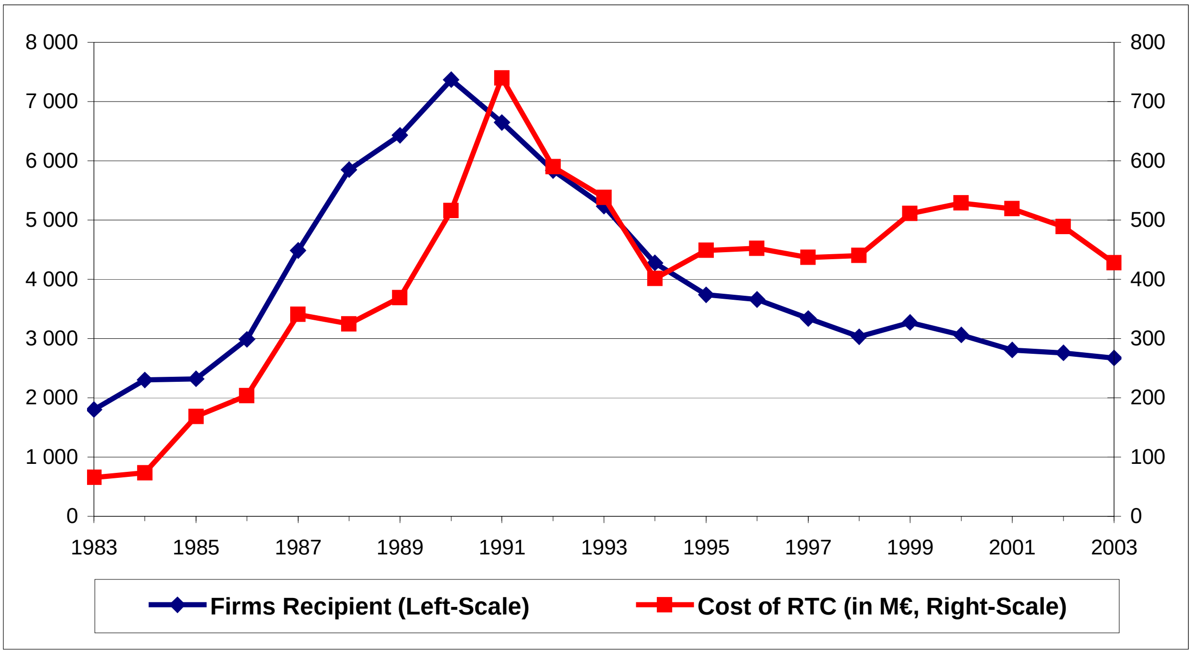
This recent approach is opposite to the more traditional one which uses the characteristics of the tax system in order to compute a firm's own cost. It was initiated empirically in a neo-classic model of the investment by Hall and Jorgenson (1967). Thereafter, the theory was improved to analyze the effect of the tax systems on the investment by Stiglitz (1973), Auerbach (1983), King and Fullerton (1984) or Mayer (1986). Devereux, Keen and Schiantarelli (1994) developed an empirical analysis of asymmetries of the tax system, whereas Summers (1981) estimated the effect of taxation in a model of the type Q of Tobin. Cummins, Hassett and Hubbard (1994) suggest the use of the changes in tax system to obtain a natural experiment allowing to estimate the effect of the cost of capital and the tax policy on firm's investment. Harhoff and Ramb (2000) use this method to empirically evaluate the effect of the German tax system and Crépon and Gianella (2001) applied this approach for France with a complete model of factors demand.

Since the beginning of the Nineties, this approach was applied to the R&D expenditure of companies. First, Hall (1992) was studying the financial constraints and the source of financing for the R&D expenditure. After some first attempts in the eighties[1], the effect of tax policy on firm's R&D was evaluated by Hall (1993) in the United States. This study was adapted for many countries: let us quote for example Harhoff (1994) for Germany, Dagenais, Mohnen and Therrien (1997) for Canada, Griffith, Sandler and Van Reenen (1995) for Great Britain, whereas Bond, Harhoff and Van Reenen (1999) compare Germany and Great Britain or Bloom, Griffith and Van Reenen (1999) which carry out an international study on a set of countries.

The aim of this article is to evaluate the cost of R&D capital, and more particularly of the tax credit on the R&D expenditure of French firms. We use the traditional derivation of the user cost of R&D capital in the presence of taxation proposed by Hall and Jorgenson (1967). This paper is mainly intended to the study of the tax credit for R&D, which was established since 1983 in France in order to sustain the firm's R&D and to correct the policy based on specific research contract between firms and government. The French tax credit is incremental because it is based on the increase of R&D expenditure with respect to a period of reference. This incentive mechanism was modified many times since 1983 with changes in basis, rate, ceiling level or reference period. All of this change will be documented in section 3.

[1] See for example the papers by Eisner, Steven et Sullivan (1983) or Mansfield et Switzer (1985) which propose such an analysis..

As shown in Figure 1, the number of companies which enter into this tax credit program reached 7 500 in 1990, but decreased after to fall down to 3 300 in 1999. The total budgetary cost for the government begins at 430 Million Francs (66 M€) in 1983, to reach a top of 5 Billion Francs (740 M€) in 1991, which was a considerable burden for public finances. It decreases thereafter to stay between 400 and 500 M€ by year. The cost for the budget is 428 M€ in 2003 before the policy reform of 2004.



Source : Ministry of the Research and the New Technologies.

Figure 1 : Number of Firms and Total Budget Cost of the R&D Tax Credit, 1983 – 2003.

These data should be compared to the R&D expenditure of all French firms which amount to 21.6 Billion Euros in 2003 or to 11.3 Billion Euros for only the firms which use the R&D tax credit. Approximately 52 % of the total R&D expenditure are affected by this tax credit. On average, the tax credit reduces the cost of the R&D expenditure for firms by 7.5%.

[Results on effect of RTC in various paper….]

The empirical model will be presented in the next section. It is based on the neoclassical model for the optimal R&D capital. An optimal long-run capital, which depends on demand and user cost of capital is derived with no explicit adjustment cost. It is placed into a dynamic specification with errors correction in order to estimate the long-run effects as well as short run dynamics. The third section will be devoted to the computation of the user cost of capital at the firm's level and to its decomposition according to the introduction of the R&D tax credit system. The impact of the tax credit will be studied according to the case where the firm can fully benefit from tax credit, or the case where the firm cannot use the all the tax credit because it is above the authorized ceiling, or because there is a decrease of the firm's R&D.

The estimation results will be presented in Section 4 for a model without theoretical a priori for the user cost of capital. It is a purely descriptive benchmark model where the tax credit rate is introduced as a determinant of the R&D. A second set of results is commented for the full model without or with tax credit. We will investigate the long run effect on R&D from a policy that raises the rate of tax credit. Finally some comments will be made on the simultaneity issues and on the robustness of our estimates.

2. THE EMPIRICAL MODEL OF R&D CAPITAL DEMAND

Following the seminal papers of Jorgenson (1963) in the Sixties, we use the neo-classic model of the investment based on the traditional equilibrium relationship between the marginal productivity of the capital and the real user cost of capital which is outlined in Appendix A. This long run relation is also valid for the R&D capital stock in order to determine its optimal level for the firm. The level of production depends on the stock of R&D capital *K*, and on a set of other factors of production *X*, like labor, energy or fixed capital that are freely adjustable. *C* is the user cost of capital, which will be defined below, and *P* the price of output.

$$\frac{\partial F_{t+1}(K_t, X_{t+1})}{\partial K_t} = \frac{C_{t+1}}{P_{t+1}} \tag{1}$$

The temporal shift in this equilibrium condition comes from the delays between capital installation and the production. The R&D capital here is defined at the end of the period *t*. But the production is assumed to be only affected by the capital inherited from the last period. The R&D expenses of year *t* are passed into the R&D capital only at the end of that year. Therefore the optimal capital stock at the end of the period will depend on the expected production, the expected output price, and the expected user cost of capital. To obtain an empirical equation, we assume a production function with a constant elasticity of substitution $\sigma = \rho/(1+\rho)$ between the R&D capital and the other production factors, where ν is the returns to scale, not necessarily constant.

$$Q_{t+1} = F_{t+1}(K_t, X_{t+1}) = \gamma\left[\delta K_t^{-\rho} + (1-\delta) X_{t+1}^{-\rho}\right]^{-\nu/\rho}$$

The optimal capital stock in logarithmic form is then :

$$k_t = \alpha + \beta q_{t+1} - \sigma(c_{t+1} - p_{t+1}) \tag{2}$$

where variables in small letters indicate the logarithm of the variable, with $\beta = \sigma + (1-\sigma)/\nu$ the output elasticity and σ the price elasticity of R&D capital respectively. The output elasticity of capital is one ($\beta = 1$) if there are constant returns to scale : $\nu = 1$, or if the production function is Cobb-Douglas (with a unit elasticity of substitution) : $\sigma = 1$.

Now we introduce a more realistic assumption about the price setting. We assume that the price is also a variable of decision for the firm because it has a market power, especially with differentiated goods. This assumptions allows to eliminate the use of the output prices in the equation because they are generally not observed at the individual level, but rather at a more aggregate level.

To avoid using the real production (*Q*) because it is computed by deflating the current production by the output price index, the demand of capital model is transformed (3) in order to use the nominal level of production ($V = P.Q$) instead, and thus the price variable (*P*) is eliminated. It is assumed that the company faced a demand with a constant price elasticity $Q = D_0.P^{-\varepsilon}$ $(\varepsilon > 1)$ with $D_0 = Q_0 / P_0^{-\varepsilon}$ is a demand independent from the firm's output price, but which depends on the general price level and on the overall business cycle. By inverting the demand, a relation between price and nominal production is obtained : $P = D_0^{1/\varepsilon}.Q^{-1/\varepsilon}$, and thus the real output can be written as $Q = D_0^{-1/(\varepsilon-1)}.V^{\mu}$, with the mark-up rate $\mu = [1-(1/\varepsilon)]^{-1}$. This last expression in logarithms is then substituted in (2) in order to remove the real production. The optimal demand for R&D capital will then be expressed as :

$$k = a' + \theta v - \sigma c \qquad (3)$$

with $a' = a + \left(\dfrac{\sigma - 1}{(\varepsilon - 1)\nu}\right) d_0$ and $\theta = \left(\sigma + (1-\sigma)\dfrac{\mu}{\nu}\right)$.

The optimal capital stock is always negatively affected by the user cost with an elasticity proportional to the elasticity of substitution between this capital stock and the other factor (composite) of production. If the production function is Cobb-Douglas ($\sigma = 1$), the nominal output elasticity of the capital will be still unit : $\theta = \beta = 1$ as in the previous case with the real production. On the other hand if there are constant returns to scale ($\nu = 1$), the output elasticity becomes:

$$\theta = \sigma + (1-\sigma)\mu \geq 1 \qquad \text{if } \sigma \leq 1$$

If the elasticity of substitution is assumed lower than unity ($\sigma < 1$), the output elasticity of capital will be less than unity if the returns to scale are more important than the mark-up coefficient:

$$\theta = \sigma + (1-\sigma)\frac{\mu}{\nu} \leq 1 \qquad \text{if } \nu \geq \mu \geq 1.$$

The optimal R&D capital (3) depends on the nominal user cost of capital (*c*) and on the nominal production of the firm. The autonomous demand will be expressed in the estimates by time-dummies, in the absence of other proxy variables. In order to take account of the various delays in R&D projects, this long-run expression is then introduced into a dynamic specification in the form of an autoregressive distributed lags model with 3 lags : ADL(3,3).

$$\begin{aligned} k_t = {} & \alpha + \gamma_1 k_{t-1} + \gamma_2 k_{t-2} + \gamma_3 k_{t-3} + \beta_0 v_{t+1} + \beta_1 v_t + \beta_2 v_{t-1} + \beta_3 v_{t-2} \\ & + \sigma_0 c_{t+1} + \sigma_1 c_t + \sigma_2 c_{t-1} + \sigma_3 c_{t-2} + \varepsilon_t \end{aligned} \qquad (4)$$

Opposite to the traditional model of investment in which this specification is differentiated in order to obtain an accelerator specification, this ADL model will be transformed into an error correction model ECM(3,3) for the estimation[2]. As in most studies on the investment or R&D, the logarithmic difference in the R&D capital stock is replaced by the R&D rate ($\Delta k_t \approx R_t / K_{t-1} + \text{constant}$ with R_t the firm's R&D expenditure). Sometimes a distributed lag in the profit rate is added up to the empirical model in order to take account of a liquidity constraint because of imperfect capital markets or of asymmetric information between the firms and investors. However here this liquidity constraints as proxy by the past profit rate are clearly rejected by the data as in previous study by Mulkay, Hall and Mairesse (2000) for R&D in France. Thus the empirical equation will be, with the individual effects α_i and time effects φ_t :

$$\begin{aligned}\frac{R_{it}}{K_{it-1}} &= \alpha_i + \eta_1 \frac{R_{it-1}}{K_{it-2}} + \eta_2 \frac{R_{it-2}}{K_{it-3}} + \xi_0 \Delta v_{it+1} + \xi_1 \Delta v_{it} + \xi_2 \Delta v_{it-1} \\ &\quad + \zeta_0 \Delta c_{it+1} + \zeta_1 \Delta c_{it} + \zeta_2 \Delta c_{it-1} + \phi(k_{it-1} - v_{it} - c_{it}) + \lambda v_{it} + \lambda' c_{it} + \varphi_t + \varepsilon_{it}\end{aligned} \quad (5)$$

In this errors correction model, the long-run effects of the R&D determinants depend only on the parameter on correction of error ϕ which largely determines the speed of adjustment, and on the parameters on the level variables λ. They are given by the expressions :

$$\theta^{LR} = 1 - \frac{\lambda}{\phi} \quad \text{and} \quad -\sigma^{LR} = 1 - \frac{\lambda'}{\phi} \quad (6)$$

On the other hand, short run elasticities are a recursive nonlinear function, which can be computed from all the dynamic parameters of the ECM specification. However it is possible to give a simple expression for the mean lag for the determinants of the R&D respectively the nominal sales and the user cost of capital) as :

$$\theta^{ML} = \frac{\xi_0 + \xi_1 + \xi_2}{\phi - \lambda} + \frac{\eta_1 + \eta_2 - 1}{\phi} \quad \text{and} \quad -\sigma^{ML} = \frac{\xi_0' + \xi_1' + \xi_2'}{\phi - \lambda'} + \frac{\eta_1 + \eta_2 - 1}{\phi} \quad (7)$$

The first term depends on the dynamic parameters on the variable considered, which corresponds to distributed lags part, whereas the second term depends on dynamics of the dependent variable. The long-run elasticities and the mean lags with their standard errors can be computed from the estimated parameters and the variance-covariance matrix.

In the empirical section, the errors correction model will be estimated on an unbalanced panel data over a fairly long period (up to 25 years of observations are available from 1979 to 2003). The generalized method of moments (GMM) seems the most tempting a priori (Arellano and Bond, 1991). In this case, the model is initially differentiated in order to remove the individual effects, and variables lagged twice or more are used as instruments. The advantage of this method

[2] Mairesse, Hall et Mulkay (1999) outlines the differences in the approach based on the accelerator model and the approach by the error correction model. The later allow to preserve the long run equilibrium relationship, whereas there is no static equilibrium by differencing, but an equilibrium growth path in the former. This modifies deeply the dynamic properties of the model. Moreover the use of an error correction model is only a reparametrization by a linear transformation of the ADL model which gives adjustment path to the optimal capital stock (see Mulkay, Hall, Mairesse, 2001). Bond, Elston, Mairesse et Mulkay (2003) present an international empirical comparison of investment models including Euler equations with explicit adjustment cost function.

rests on the fact that the instruments are used to control the bias due to the presence of the lagged dependent variable in the regressors, as well as the simultaneity bias. However instrumenting the first differences of the variables by their levels leaves a small correlation between the explanatory variables and the instruments, implying roughly imprecise estimates, even if the instruments prove to be valid. Therefore it is quite difficult to draw the relatively precise conclusions with this method of estimation.

Following Mulkay, Hall and Mairesse (2001), we rather prefer to use the traditional within-individuals method of estimations where the individual effects are removed by centering the variables relative to their individual average. In the empirical specification, a temporal fixed effect is added in order to control for unobserved variables, which are constant over individuals. Therefore only the intra-individual and intra-temporal variability is considered in the estimations. Unfortunately it is then impossible to identify the effects of the firms-invariant variables, such as the aggregate prices. However this within-firms estimation method is certainly biased due to the presence of the lagged dependent variable as a regressor (see Nickell, 1981), but this bias decreases quickly when the number of time periods increases, as it is the case with out fairly long panel data.

The measurement errors are another source of bias, which leads to small parameters estimates if they are random distributed or if they can be considered as a noise. These measurement errors are likely to occur with the user cost of capital, which depend on several assumptions about the firm's behavior. But generally we are not able to control for such an individual behaviour with the available accounting data. Therefore this can be a reason for which the parameters estimates can be biased downward. Finally the endogeneity of the explanatory variables can lead to another source of bias. We consider here that this simultaneity endogeneity bias is relatively weak, and it does not change dramatically the parameters estimate[3].

3. THE RESEACH TAX CREDIT IN FRANCE

3.1. A decomposition of the user cost of capital

The contribution of this study is to introduce the cost of R&D capital as a determinant of R&D expenditure. In this section a decomposition of the user cost of capital will be presented in order to focus on the effect of the research tax credit. More particularly the variability of each variable in the time or individual dimension will be investigated because the within-firms estimation method is based only on the within-time within-firms variances and covariances.

Following the seminal study of by Hall and Jorgenson (1967), an expression for the user cost of capital is derived in Appendix A, which depends on the price, interest rate, economic depreciation of the capital, and finally the rates of taxation and tax depreciation. Ignoring the firm and time indices, the user cost of capital is :

[3] Mairesse, Hall and Mulkay (1999) showed with a fixed investment equation and the same type of model that there are relatively small differences between the within-firms and GMM estimates, but the later exhibit very large standard errors.

$$C = P^{RD}\left[sr + (1-s)\frac{\rho}{1-\tau} + \frac{\delta}{1-\tau} - \frac{\pi}{1-\tau} - \frac{\tau\Psi}{1-\tau}(\rho+\delta-\pi) - \frac{\gamma}{1-\tau}(\rho+\delta-\pi)\right] \quad (8)$$

where P^{RD} is the price index of R&D expenditure, τ the corporate tax rate on profits, s the debt ratio, ρ the discounting rate, δ the economic depreciation rate, π is the rate of inflation on investment price, $\Psi = \delta_f / (\rho + \delta_f)$ is the fiscal depreciation allowances with δ_f the rate of depreciation allowed by the tax laws, and finally γ is the impact of the tax credit for one unit of R&D expenditure. The part in square brackets will be called the rate of user cost of capital because it can be interpreted as the part of one unit R&D that is used in one period as a rental price.

Assuming no risk premium, generally difficult to measure at the individual level of the company, the net yield required by the investors ρ is given by equalizing for the shareholder the return on bonds of the company $(1-t_o)R$ (with R the interest rate on riskless bonds), which is taxed at a rate t_o, and the return on a share of the company $\left[1-(dt_d+(1-d)t_p)\right]\rho$. The tax on shareholder income is different according to dividends[4] t_d or capital gains t_p, with d the exogenous rate of distribution of dividends out of total net profit. These tax rates have been modified many times during the period of observation 1980 - 2003 due to the changes in economic policy (see Table B3 in data appendix B). They can be considered as natural experiments for the firms which can adapt their behavior according to the policy changes[5].

As the user cost of the capital is introduced in logarithms in the R&D capital demand schedule, it can be splitted into two parts : the R&D price index and the rate of user cost of capital (ω) which contains the inflation, depreciation and interest rates as well as the tax parameters.

$$\log(C) = \log(P^{RD}) + \log(\Omega) \quad (9)$$

with :

$$\Omega = \left[sr + (1-s)\frac{\rho}{1-\tau} + \frac{\delta}{1-\tau} - \left(\frac{\pi}{1-\tau}\right) - \frac{\tau\Psi}{1-\tau}(\rho+\delta-\pi) - \frac{\gamma}{1-\tau}(\rho+\delta-\pi)\right] \quad (10)$$

We propose here a decomposition of the user cost of the capital (8) in order to assess the effects of the research tax credit. If we define (ω) as the rate of user cost of capital without the research tax credit :

$$\omega = \left[sr + (1-s)\frac{\rho}{1-\tau} + \frac{\delta}{1-\tau} - \left(\frac{\pi}{1-\tau}\right) - \frac{\tau\Psi}{1-\tau}(\rho+\delta-\pi)\right],$$

the logarithm of the rate of user cost of capital can be rewritten as :

$$\log(\Omega) = \log(\omega) + \left[\log(\Omega) - \log(\omega)\right] = \log(\omega) + \log(\psi) \quad (11)$$

[4] In France there is an inputation mechanism which attenuates the double taxation on dividends, first at the firm level and at the shareholder level. This system is called "Avoir Fiscal" with a rate t_{AF} such that the dividend tax rate is $t_d = t_{IR}(1+t_{AF}) - t_{AF}$ where t_{IR} is the marginal income tax rate. In the empirical study, we use the maximum marginal income tax rate.

[5] See Crépon and Gianella (2001) for comments on the chance in the tax rates.

In this expression the first part corresponds to the basic user cost of capital without the fiscal incentive of the research tax credit, and the second part is the differential effect of this research tax credit on the rate of user cost of capital. As $\psi = \Omega / \omega$ it shows how the rate of user cost of capital decreases when the tax credit is taken to be account because ($\Omega \leq \omega$, and $\psi \leq 1$). Therefore it is possible to estimate the effect of each part of the rate of user cost of capital with different coefficients because it is not sure that this parameter is the same for both part, due to measurement errors or individual unobserved factors.

3.2. The Research Tax Credit (RTC)

A tax credit on the R&D expenditure has been introduced in France since 1983 as an incentive to increase private R&D[6], mainly directed towards small and medium-sized businesses. This is an incremental tax credit because its basis is on the increase in the R&D expenditure relative to a past level. The tax law concerning this research tax credit (RTC henceforth) has changed many times during the period with change on its basis[7], on the concerned industries[8], on its rate, and on its ceiling (see Table B3 in appendix B).

In 1983 and 1984, the rate of the RTC was fixed at 25% of the increase in the R&D expenditure relative to the previous year with a ceiling of 3 million French Francs (0.46 M€). In 1985, the rate of the RTC passed to 50 %, with a ceiling of 5 million Francs (0.76 M€). In 1988, the ceiling was re-examined with a rise for an amount of 10 million Francs (1.5 M€). The ceiling finally reached a level of 40 million Francs in 1991 (6.1 M€) and was not revised any more thereafter[9]. However, starting from this date (1991), the increase in the R&D expenditure was computed relative to the two previous years average. Moreover, between 1988 and 1990, a second incremental tax credit was proposed on the increase in the R&D expenditure of R&D compared to a base year 1987, with a ceiling of 0.9 million Francs (0.14 M€).

Even if the budget envisaged a possibility of refunding of this RTC if the companies would cease or decrease their R&D expenditure, this last provision was not generally applied. We will also neglect the impossibility to use current tax credit because it can be carry forward on future profit during 3 years. In the same way, we will not take account of the possibility to offset “negative” tax credit (due to a decrease in R&D) on later “positive” tax credits. That implies that the tax credit research is not available when the expenditure of R&D of the company decreases. In consequence, there is also a floor to the use of the RTC.

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[6] The internet site of the Ministry of Research gives more information about the Research Tax Credit in France : http://www.recherche.gouv.fr/technologie/mesur/cir , The French R&D tax credit is also described in the « Guide du Crédit d’Impôt Recherche » where we can find the precise definition of the RTC and the application process. The report on the « Mesures de soutien à l’Innovation et au développement technologique » (March 2002) of the Ministry of Research evaluates in a chapter the RTC system up to 2001. Finally, Asmussen et Berriot (1993) have studied the RTC on the early period 1983-1989. All these documents are unfortunately in French.

[7] There is a special definition of the R&D expenditure which serves as the RTC basis, this is a materials, investment and salaries of researchers plus a share of the overhead expenses. We assume here that there is a constant ratio between the basis for R&D Tax Credit and the R&D expenditure observed in the R&D surveys, which are defined along the lines of the Frascati manual.

[8] The industry of food, drink and tobacco, and the industry of clothes and leather were excluded form the RTC system before 1992, but they were eligible since 1992.

[9] Except with the introduction of the Euros where the ceiling was rounded from 6.098 M€ to 6.100 M€.

The R&D Tax Credit has been reformed in 2004 with the introduction of a part of tax credit based on the "volume" of R&D expenditure at a rate of 5% : this leads to an immediate decrease in the price of R&D for firms by 5 %.. In the same time, the incremental tax credit rate was reduced to 45% instead of 50%. The ceiling was increased to 8 M€ in 2004. In 2006 the rate of tax credit on the "volume" has been put to 10 % while the incremental rate was then decreased to 40%, and the ceiling was set at 10 M€. These reforms pushed the budgetary costs to 928 M€ (instead of 428 M€ in 2003), an rise of 117 %!

A second reform in 2007 changes radically the system : the incremental tax credit was suppressed. Instead a very generous tax credit was decided : there is a tax credit on the total R&D expenditure with a rate of 30 % up to a ceiling of 100 M€ or R&D expenditures, and with a rate of 5% for R&D expenditure above 100 M€, without any ceiling ! We cannot measure the efficiency of such reforms because our data covers the period up to 2003.

Table 1 shows the parts of the firms in the sample which are under the floor and above the ceiling, as those which fully benefit from the RTC. Our figures are rather close to those of the Ministry of Research (2000, 2002) which notes that in 1996, it has 51 % of recipients among the 7 008 applicants to the program. This is to be compared with 54 % recipients in the sample with our computations.

	FLOOR	FULLY RECIPENTS	CEILING	TOTAL
1983	47.1%	49.9%	3.1%	459
1984	40.9%	54.6%	4.4%	496
1985	40.7%	51.4%	7.8%	589
1986	41.2%	52.1%	6.7%	624
1987	40.3%	53.0%	6.7%	894
1988	38.7%	56.5%	4.8%	982
1989	38.8%	56.1%	5.1%	1 058
1990	39.7%	56.2%	4.1%	1 167
1991	35.6%	62.8%	1.6%	1 251
1992	41.1%	57.5%	1.4%	1 273
1993	43.6%	55.0%	1.4%	1 326
1994	42.7%	55.8%	1.5%	1 473
1995	41.9%	56.8%	1.3%	1 592
1996	45.0%	54.2%	0.8%	1 590
1997	44.7%	54.1%	1.2%	1 582
1998	41.2%	57.3%	1.5%	1 576
1999	40.3%	57.4%	2.3%	1 565
2000	47.0%	51.4%	1.6%	1 381
2001	47.5%	50.2%	2.3%	1 237
2002	48.9%	49.3%	1.8%	1 133
2003	53.3%	45.5%	1.2%	1 021
TOTAL	**40.5%**	**51.6%**	**2.4%**	**25 701**

Table 1 : Floor and Ceiling of the Research Tax Credit in the Sample

The part of the firms at to the floor (with decreasing R&D expenditures) has a rising trend since 1991 by reaching 53 % of firms in 2003 and 1996, whereas this level was lower at the beginning of the period. That can be explained by the economic business cycle, but also by the fact why the RTC becomes more and more difficult to obtain because it is necessary to increase each year its R&D. The part of the firms exceeding the ceiling strongly decreased when the ceiling quadrupled as from 1991. After 1991 this ceiling is effective only for less than 3% of firms in the sample. Finally the CIR applies fully for approximately 52 % of the firms of the sample, but with a decreasing trend after 1991.

The computation of the effective tax credit rate θ^* and the parameter γ for the incremental RTC is presented in Table 2 with θ the rate of tax credit : 25 % in 1983 and 1984, and 50 % since then. Until 1990, the basis of the RTC is the increase in the expenditure of R&D relative to the previous year. But as from 1991, it is based on the difference between the current R&D expenditure and the average of the two previous years. Compared to the derivation of the appendix A, this slightly increases the γ parameter by multiplying it by a factor $(1.5+\rho)/(1+\rho)$ larger than 1. Thus the tax credit effect will be higher than the effect over the former period (before 1991) if the other tax parameters were constant.

Another interesting features of the incremental tax credit is that its effect rises when the required nominal rate of return ρ increases. As the average nominal rate of returns declines over the period due to a lesser inflation rate, the effect of the RTC has fallen drastically since the eighties. With a nominal rate of incremental tax credit of 50 %, as the average nominal rate of returns has fallen from 11.5 % in 1990 to 5% in 2003, the effective rate of R&D tax credit has decreased from 7.5% to 3.5% between 1990 and 2003 reducing the incentive effect of this policy.

Firms	Effective Rate of R&D Tax Credit	Parameter of the R&D Tax Credit	
		$1983 \leq t \leq 1990$	$t \geq 1991$
At the Floor $R_t \leq R_{t-1}$	$\theta^* = 0$	$\gamma = 0$	$\gamma = 0$
Between the Floor and the Ceiling $R_{t-1} < R_t \leq \overline{R}_{t-1}$	$\theta^* = \theta$	$\gamma = \theta \frac{\rho - \pi^{RD}}{1+\rho}$	$\gamma = \theta \frac{\rho - \pi^{RD}}{1+\rho}\left(1+\frac{1}{2}\frac{1+\pi^{RD}}{1+\rho}\right)$
Above the Ceiling $R_t > \overline{R}_{t-1}$	$\theta^* = \theta\left(\frac{\overline{R}_{t-1}}{R_t}\right)$	$\gamma = \theta^* \frac{\rho - \pi^{RD}}{1+\rho}$	$\gamma = \theta^* \frac{\rho - \pi^{RD}}{1+\rho}\left(1+\frac{1}{2}\frac{1+\pi^{RD}}{1+\rho}\right)$
Level of Ceiling $(\overline{R}_{t-1})$		$\left(\frac{RTC_t^{\max}}{\theta}\right) + P_t^{RD} R_{t-1}$	$\left(\frac{RTC_t^{\max}}{\theta}\right) + \left(\frac{P_t^{RD} R_{t-1} + P_t^{RD} R_{t-2}}{2}\right)$

Table 2 : Effective rate of R&D Tax Credit and γ Parameter.

The general ceiling for the tax credit is noted $RTC_t^{\max}$. It corresponds to a maximum level of firm's R&D ($\overline{R}_{t-1}$), also shown in the Table 2, which depends on its R&D in the previous years. To take account of the floor of the RTC, the effective tax credit rate θ^* is set to zero when the R&D expenditure does not increase relative to the previous years level. On the other hand if the RTC exceeds the authorized ceiling, the effective tax credit rate θ^* is proportionally reduced to the R&D surplus. The effect of the special tax credit of the years 1988 to 1990, relative to the base year 1987 is obtained in the same way as that derived in Appendix A, but with more complex expressions given that it relates to the difference between the current R&D and the R&D carried out for the year 1987.

Figure 2 presents the annual averages of the research tax credit parameter γ according to various assumptions. This γ parameter is a percentage that can be interpreted like the reduction price of the R&D because of the RTC. The basic effect of the price reduction for a firm fully benefiting from the RTC (with an increasing R&D expenditure, but below the ceiling) is shown in bold. The normal line corresponds to the average effective parameter, taking into account the firms which does not benefit from the RTC because they are below the floor (decrease in R&D expenditure), or firms above the ceiling with a reduced effect of the RTC.

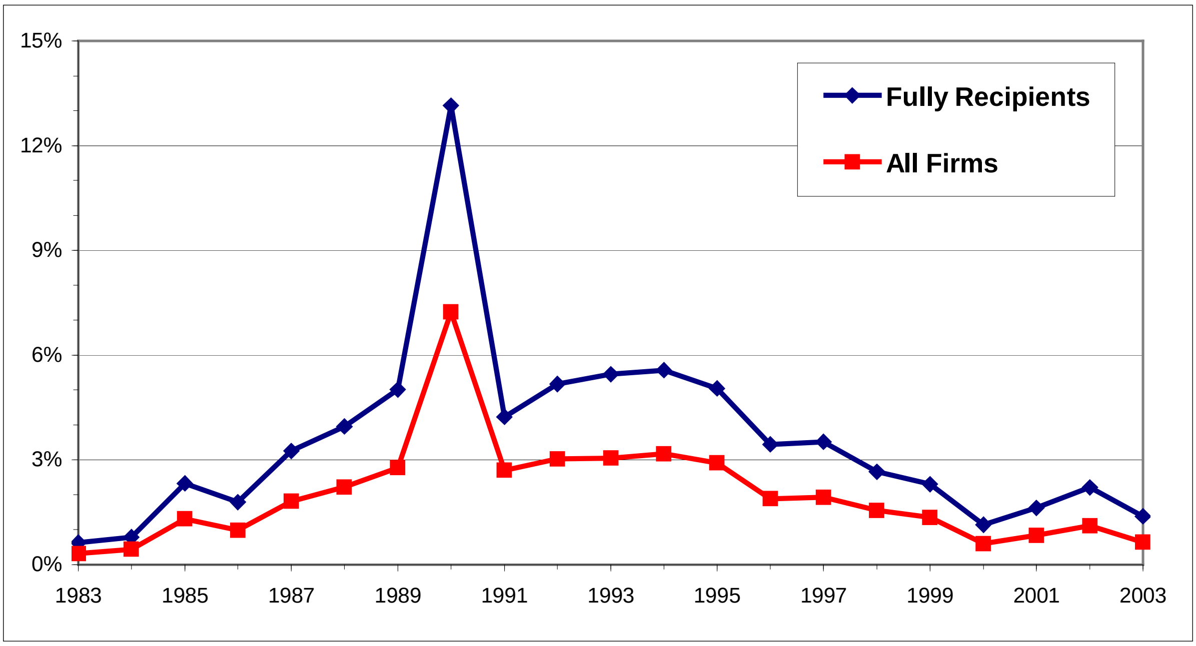

Figure 2 : Average Effects of the Research Tax Credit - γ Parameter.

On average, the tax credit reduces the price of the R&D by 3.5 %. For 100 Euros of R&D carried out by the firm, approximately 3.5 Euros are refunded to him on average by a tax cut. This effect increased until 1991, to reach 7 %, but it declines since then until the end of the observation period with less than 2 % after 2000. An investigation of this decline in incentives shows that the main causes is the fall in the nominal rate of returns. However, if the company can fully benefit from the RTC, the average effect is larger by about 1.5 point. The special tax credit from 1988 to 1990 strongly increased the incentives to carry out R&D. In 1990, the average effect was 7 %, whereas for the companies being able to use fully these two tax credits, it culminated to 13 %.

The averages of the logarithm of rate of user costs of capital are given in Figure 3 with or without the introduction of the research tax credit. The average rate of change in this rate of user cost due to this RTC is also given on the right scale of this figure. The rate of user cost of capital has a clear increasing trend during the period 1980-1994 with short-term variations. Thereafter, this rate of user cost is decreasing since 1993. An inspection of the various components entering into its expression shows that the evolution is mainly due to the difference between the nominal interest rates and the inflation rate on the R&D.

The difference between both rate of user costs is due to the effect of the research tax credit. It does not seem to be a large difference due to this tax credit. Started in 1983, the incentive effect has increased up to 5 % in 1991 (except for the exceptional year 1990). As we have shown earlier this effect has been reduced during the nineties from 5 % in 1995 to a very small average decrease in user cost by 1 % in 2003.

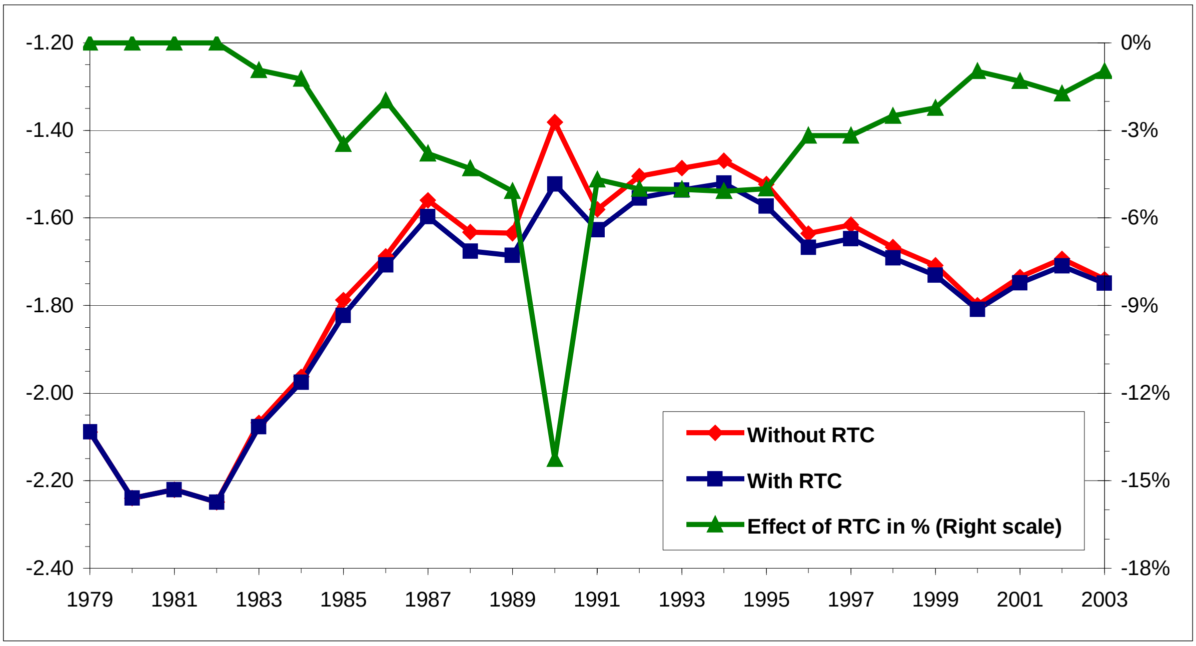

Figure 3 : Average Log Rate of user cost of R&D Capital : 1979 – 2003.

3.3. Descriptive Statistics (1979 – 2003)

Some descriptive statistics (median, quartiles, average and standard deviation) on the main variables used in the analysis are presented in Table 3. The average size of the firms in the sample is rather high with a median of 313 workers, because larger companies are more likelihood to do R&D. The median number of R&D workers is only 13, with again a strong asymmetry in the distribution : the average is 7 times higher than the median. These firms carry out on average 9.6 M€ of R&D per year, or 110 000 Euros per researcher.

The median rate of R&D (*R/K*) is 15.7%, whereas a depreciation of R&D capital of 15 % was assumed, which leaves a small 0.7 % per year median net increase of the R&D capital stock. The annual growth rate of employment is on average 0.3 % while the average growth rate of nominal value added is 3.7 %, mainly due to the average inflation of 3.5 %. The nominal user cost of the R&D capital increased annually by 3.4 % on average, including 2.5 % because of the inflation on R&D, and 0.9 % because of the change in the rate of user cost of capital that we have documented before.

The average rate of user cost of R&D capital, which represents the cost of detention of one unit (or a real franc) of R&D, is about 19.5 % without the RTC effect and 18.8 % with it. The effect of the tax credit is relatively weak because it lowers the rate of user cost by only 0.7 percentage point in average.

VARIABLE	First Quartile	Median	Third Quartile	Mean	Standard Deviation	Within Standard Deviation	Between Firms Variability	Between Years Variability	Within Variability
L	127	313	770	1 075	4 718	1 690	94.0%	0.1%	5.9%
L^{RD}	6	13	36	86	436	203	90.0%	0.0%	10.0%
R	368	922	2 991	9 663	57 262	31 298	86.1%	0.3%	13.7%
R / K	0.120	0.157	0.200	0.170	0.097	0.125	23.8%	0.7%	75.5%
$\text{Log}(V)$	8.590	9.496	10.460	9.576	1.439	0.508	93.2%	1.1%	5.7%
$\text{Log}(K)$	7.968	8.797	9.965	9.089	1.593	0.298	97.9%	0.5%	1.6%
$\Delta\text{Log}(L)$	-0.040	0.000	0.044	0.003	0.198	0.277	10.0%	0.6%	89.4%
$\Delta\text{Log}(L^{RD})$	-0.071	0.000	0.105	-0.093	0.965	1.033	47.6%	0.1%	52.4%
$\Delta\text{Log}(V)$	-0.058	0.043	0.141	0.037	0.308	0.435	6.3%	2.2%	91.5%
$\Delta\text{Log}(K)$	-0.032	0.007	0.048	0.014	0.080	0.100	25.5%	1.6%	72.9%
γ	0.000	0.011	0.035	0.020	0.026	0.028	17.0%	28.3%	54.6%
ω (without RTC)	0.170	0.193	0.221	0.195	0.044	0.032	41.9%	34.2%	23.9%
Ω (with RTC)	0.165	0.186	0.211	0.188	0.042	0.034	43.3%	26.7%	30.0%
ψ (change)	-0.062	-0.019	0.000	-0.036	0.049	0.053	17.0%	29.0%	54.0%

Sample : 25 701 observations on 2 431 manufacturing firms. Period : 1979 - 2003.
Variables : L : total employment and L^{RD} : R&D employment, R : total R&D expenditure (in thousands of Euros), K : (real) R&D capital stock, V : nominal value added (in thousands of Euros).
γ (basic) : the parameter of the RTC effect on the user cost of capital (see Table 2)
ω (without RTC) is the rate of user cost of capital without the research tax credit effect, whereas Ω (with RTC) includes this RTC effect. $\psi = \log(\omega) - \log(\Omega)$ shows the change in the user cost due to the RTC effect.

Table 3 : Descriptive Statistics on the Variables (1979 - 2003).

The standard-deviation in double within dimension (within firms and within years) are also given in Table 3, as well as the decomposition of total variability in the sum of a variability between firms, a variability between years and the double-within variability. This decomposition is important because only this double within variability will be exploited in the estimation of the next section. Usually on data of panel, variables in level like employment, or the R&D expenditure has a very low double within variability, because total variability comes mainly from the differences between the companies. The opposite is noticed with the R&D rate or the growth rates of value added which are very volatile, with a low intertemporal variability. However a large part of the variability of the user cost of capital is due to the intertemporal differences, which indicates that its average annual level varied largely during the period. The share of double within variability of the RTC effect is about 54 % which can be used in estimation after removing firm-specific effects which can be due to fiscal parameter of the firm and the fact that it can reach the floor of the ceiling of the tax credit, as well as the time-specific effects which can be the sign of policy change in the tax credit system.

The rate of user cost of capital, with or without the RTC effect, has relatively little double within variability, with a standard deviation around 4 %. Moreover, the share of double within variability is weak with less than 21 %, and even 14 % when there is no RTC effect taken into account. However the difference in the rate of user cost due to the RTC, is mainly a matter of double within variability (48 %).

4. THE EMPIRICAL EFFECT OF THE USER COST OF CAPITAL.

4.1. A descriptive empirical model.

Now let us turn to the empirical results of the econometric estimation of the determinants of R&D expenditure. In this section a simple error correction model, introducing directly the effect of the R&D tax credit is estimated in the within firms dimension with a full set of time dummies, which amounts exploiting only the double within variances and covariances.

A constrained form for the user cost of capital is not imposed here. Therefore we focus only on the direct effect of the R&D tax credit which reduces the user cost of capital. We compute the reduction parameter γ which can be interpreted as the percentage reduction in the price of R&D expenditure due to the R&D tax credit (see Table 2). It depends on the nominal tax credit rate and the floor or ceiling level for each firm. It varies also with the firm's nominal rate of return. This variable is included in the error correction model as additional variables.

$$\frac{R_{it}}{K_{it-1}} = \alpha_i + \eta_1 \frac{R_{it-1}}{K_{it-2}} + \eta_2 \frac{R_{it-2}}{K_{it-3}} + \xi_0 \Delta v_{it+1} + \xi_1 \Delta v_{it} + \xi_2 \Delta v_{it-1} + \phi(k_{it-1} - v_{it}) + \lambda v_{it} + \delta_0 \gamma_{it} + \delta_1 \gamma_{it-1} + \delta_2 \gamma_{it-2} + \delta_3 \gamma_{it-3} + \varphi_t + \varepsilon_{it} \quad (12)$$

Here we discuss particularly the long run elasticities of the optimal R&D capital with respect to its various determinants. The whole set of estimated parameters of the model will also be shown in order to assess the short run dynamic adjustment process.

An attempt to introduce a profit rate measure as an additional variable measuring a liquidity constraint does not prove successful. The long run coefficients of this profit rate are never significant, and even slightly negative in most of our regressions. Therefore we do not add up such a profit rate in all of the following estimations because the liquidity constraints do not seem to limit the R&D expenditure[10]. This can be due to the high persistence in the firm's R&D process.

[10] This fact had already been mentioned for France by Mulkay, Mairesse and Hall (2001).

The estimated parameters, the regression statistics and the long run effects are presented in Table 4, with standard error robust to general heteroscedasticity. The R^2 adjusted for the degrees of freedom, reached 36.7 %, which is quite small but satisfactory on panel data. This implies that most of the individual variability in the R&D rate cannot be explained by such the variables, and it remains a large part of idiosyncratic variability in firm's R&D behavior.

	(1)		**(2)**	
Parameters of Error Correction Model				
	Estimates	Std. Error	Estimates	Std. Error
R/G (t-1)	0.267**	*(0.058)*	0.247**	*(0.060)*
R/G (t-2)	0.054	*(0.036)*	0.066	*(0.039)*
Δlog(V) (t+1)	0.010**	*(0.003)*	0.009*	*(0.003)*
Δlog(V) (t)	-0.020**	*(0.006)*	-0.017**	*(0.006)*
Δlog(V) (t-1)	-0.014**	*(0.003)*	-0.014**	*(0.003)*
Error (t)	-0.112**	*(0.007)*	-0.092**	*(0.008)*
log(V) (t)	-0.057**	*(0.007)*	-0.044**	*(0.007)*
γ (t+1)			-0.176**	*(0.056)*
γ (t)			1.007**	*(0.040)*
γ (t-1)			0.065	*(0.058)*
γ (t-2)			0.185**	*(0.043)*
Long - Run Effects				
	Estimates	Standard Erro	Estimates	Standard Erro
Production	0.487**	*(0.043)*	0.515**	*(0.052)*
RTC Effect			11.795**	*(1.610)*
Regression Statistics				
SSR	91.0798		85.491	
s	0.082080		0.079534	
R^2 - adj.	0.3258		0.3670	
Log Likelihood	18 607.6		19 113.4	
LM Het. Test	541.05	[.000]	491.29	[.000]

Dependent variable : R/G (t)
15 977 Observations - 2 431 Firms - Period : 1983 - 2002.
Within estimation with a full set of time dummies.
Heteroscedasticity consistent standard error in parenthesis.
* : significant at 5 % level, ** : significant at 1 % level.
SSR : Sum of squared residuals, s : standard error of regression.
LM Het. Test : Lagrange Multiplier Test of general heterosceadsticity with p-value in squared brackets

Table 4 : Estimation of the Descriptive Models

The coefficient of the error correction terms is rather weak, even though highly significant, indicating a strong persistence in the R&D expenditure, and a very long lag in response to exogenous shocks. In fact, the first autoregressive coefficient in the ADL specification is always larger than one (around 1.15) but it is compensated by the second and third autoregressive coefficients which are always negative. However the R&D rate is strongly persistent because the error correction parameters is small (around 0.10). The level of value added has a small negative, but significant, coefficient rejecting the hypothesis of unit elasticity between output and capital stock. Many of the individual parameters are not significant due to large number of parameters to be estimated. However the short run parameters on value added are often significant, that shows a somewhat precise dynamic adjustment to output shocks.

The long run elasticities of the R&D capital to the value added are around 0.5 with a value always significantly lower than unity. If we consider the theoretical equation (3), we notice that it requires either an elasticity of substitution larger than the unit to allow a mark-up rate higher than the returns to scale, or a small elasticity of substitution, but with returns to scale higher than the mark-up rate. Both hypotheses do not make sense. However it is possible that measurement errors in expected future production bias downward this elasticity.

The long run effect of the effect of tax credit rate is positive and large with a value of 11.8. It is estimated with a good precision because it is highly significant in the second regression. But the change in this variable γ : the effect of tax credit rate is small because the nominal rate of tax credit is multiplied by a small real discounting factor :

$$\frac{\partial\gamma}{\partial\theta} = \left(\frac{\rho - \pi^{RD}}{1+\rho}\right)\left(1 + \frac{1}{2}\frac{1+\pi^{RD}}{1+\rho}\right) \approx 0.0272 \quad \text{(in 2003)}\,. \tag{15}$$

If the nominal tax credit rate increases by 10 percentage point (from 50 % to 60 %) for example, this leads to an effect on the rate of R&D of around 0.032 (= 11.8 x 0.0272 x 0.10) . The optimal knowledge capital will rise of 3.2 % for fully recipients firms which is a rather significant increase in the knowledge capital stock.

Let us note that short run coefficients are often significant, but the first coefficient corresponding to the expected tax credit of the next year rate has a small negative coefficient. This is an obvious effect with an incremental tax credit. If the firms expects that the tax credit will be higher in next period, it has an incentive to reduce the present R&D expenditures in order to benefit of a large increase in its R&D expenditure. However the estimated parameter of the current change in the tax credit effect is the larger because the firms will react strongly to the current tax credit.

4.2. The model with the user cost of capital.

In a second set of results, we analyze the effect of the user cost of capital such as it was defined in the expression (10). Thus we assume a more constrained form linking the various variables that enter its composition. An extension of this model is also presented where the decomposition of the cost of capital (11) presented in Section 3.1 is used in order to assess particularly the effect of the R&D tax credit. By assuming that the elasticity of the R&D capital optimal stock can be different for each component of this decomposition, the long run optimal capital expression becomes:

$$k = a + \theta v + \sigma \log(\omega) + \sigma' \log(\Omega) + \sigma'' \log(\psi) \tag{13}$$

where ω and Ω are respectively the user cost of capital without and with the research tax credit parameter, and $\psi = \Omega / \omega$ is the ratio of these two user cost, indicating the effect of the RTC. A formal test of the equality between the parameters of the cost of capital could be perform in order to accept or to reject the constrained form for the cost of capital or to assess whether the variables are not measured with errors. The model estimated with these various effects is as follows :

$$\begin{aligned} \frac{R_{it}}{K_{it-1}} = \alpha_i &+ \eta_1 \frac{R_{it-1}}{K_{it-2}} + \eta_2 \frac{R_{it-2}}{K_{it-3}} + \xi_0 \Delta v_{it+1} + \xi_1 \Delta v_{it} + \xi_2 \Delta v_{it-1} \\ &+ \zeta_0^{\omega} \Delta \log(\omega_{it+1}) + \zeta_1^{\omega} \Delta \log(\omega_{it}) + \zeta_2^{\omega} \Delta \log(\omega_{it-1}) \\ &+ \zeta_0^{\Omega} \Delta \log(\Omega_{it+1}) + \zeta_1^{\Omega} \Delta \log(\Omega_{it}) + \zeta_2^{\Omega} \Delta \log(\Omega_{it-1}) \\ &+ \zeta_0^{\psi} \Delta \log(\psi_{it+1}) + \zeta_1^{\psi} \Delta \log(\psi_{it}) + \zeta_2^{\psi} \Delta \log(\psi_{it-1}) \\ &+ \phi\left(k_{it-1} - v_{it} - \log(\Omega_{it})\right) \\ &+ \lambda v_{it} + \lambda^{\omega} \log(\omega_{it}) + \lambda^{\Omega} \log(\Omega_{it}) + \lambda^{\psi} \log(\psi_{it}) + \varphi_t + \varepsilon_{it} \end{aligned} \tag{14}$$

The results of estimates, as well as the regression statistics, are presented in Table 5. The first column (regression 3) takes again the estimate of the model with the demand as the only explanatory variable, without introducing the user cost. The next two columns are concerned with the user cost of capital without the tax credit parameter (regression 4) or in its complete form including the RTC effect (regression 5). Finally a model where the effect of the tax credit is decomposed into the user cost without the RTC effect and the change in user cost to the RTC, is estimated in the last column (regression 6).

When the user cost of capital is introduced in the estimation with its constrained expression, there is a statistical improvement, nevertheless modest, of the quality of the estimates, even if the best model here it does not reach the level of adjusted R^2 of the non-constrained model of the preceding Section (regression 4 : adj.R^2 = 0.3262). The user cost of capital without the effect of the tax credit (regression 4) is not better than the regression (5) without this term. It is only when the tax credit is taken into account (jointly or separately with other elements in this user cost) that the regressions become better.

The accelerator effect of the demand is very stable whatever the selected estimates with the same long run coefficient (0.50). Here again, we find a too small elasticity, which are significantly lower than one, to accept the assumption of a function of Cobb-Douglas production, or equality between the returns to scale and the mark-up rate. The short run coefficients of the value added show the same profile as in the previous regressions, while the error correcting term has a similar estimate, and thus the same slowness of the adjustment process to reach the equilibrium capital stock. In fact the mean lags computed from the estimates show a very long delay of 7 years for the demand and between 6 and 8 years for the user cost of capital, in order to have a mean effect of a permanent shock on the R&D capital stock. The R&D seems to be adapted very slowly at the firm level, or the firm smoothes its path.

If the model (4) where the user cost of capital without the research tax credit effect is introduced, its long run elasticity is negative as expected theoretically, and significant at 5 % level. But its long run effect (-0.15) is small because of either a very strong inaccuracy in the estimate of this effect because of the heterogeneity in R&D behavior, or a lack of substitution between the R&D and the other factors of production. A third reason to this small elasticity could be the measurement errors in this user cost of capital because it is difficult to compute marginal and not average interest rate, the required (adjusted for the risk) rate of return, and the rate of depreciation of R&D.

	(3)		(4)		(5)		(6)	
Parameters of Error Correction Model								
	Estimates	Std. Error	Estimates	Std. Error	Estimates	Std. Error	Estimates	Std. Error
R/G (t-1)	0.267**	*(0.058)*	0.267**	*(0.058)*	0.264**	*(0.059)*	0.249**	*(0.059)*
R/G (t-2)	0.054	*(0.036)*	0.054	*(0.036)*	0.057	*(0.036)*	0.064	*(0.039)*
Δlog(V) (t+1)	0.010**	*(0.003)*	0.009**	*(0.003)*	0.009**	*(0.003)*	0.009**	*(0.003)*
Δlog(V) (t)	-0.020**	*(0.006)*	-0.020**	*(0.006)*	-0.019**	*(0.006)*	-0.018**	*(0.006)*
Δlog(V) (t-1)	-0.014**	*(0.003)*	-0.014**	*(0.003)*	-0.014*	*(0.003)*	-0.014**	*(0.003)*
$\Delta\log(\omega)$ (t+1)			-0.003	*(0.008)*			-0.005	*(0.008)*
$\Delta\log(\omega)$ (t)			0.018*	*(0.008)*			0.010	*(0.007)*
$\Delta\log(\omega)$ (t-1)			-0.007	*(0.006)*			-0.008	*(0.006)*
$\Delta\log(\Omega)$ (t+1)					0.039**	*(0.007)*		
$\Delta\log(\Omega)$ (t)					-0.004	*(0.009)*		
$\Delta\log(\Omega)$ (t-1)					-0.006	*(0.006)*		
$\Delta\log(\psi)$ (t+1)							0.107**	*(0.029)*
$\Delta\log(\psi)$ (t)							0.128**	*(0.036)*
$\Delta\log(\psi)$ (t-1)							0.085**	*(0.023)*
Error (t)	-0.112**	*(0.007)*	-0.111**	*(0.007)*	-0.110**	*(0.007)*	-0.094**	*(0.008)*
log(V) (t)	-0.057**	*(0.007)*	-0.057**	*(0.007)*	-0.056**	*(0.007)*	-0.046**	*(0.007)*
$\log(\omega)$ (t)			-0.128**	*(0.010)*			-0.098**	*(0.011)*
$\log(\Omega)$ (t)					-0.140**	*(0.009)*		
$\log(\psi)$ (t)							-0.611**	*(0.044)*
Long - Run Effects								
	Estimates	Std. Error	Estimates	Std. Error	Estimates	Std. Error	Estimates	Std. Error
Production	0.487	*(0.043)*	0.486**	*(0.043)*	0.485**	*(0.043)*	0.515**	*(0.051)*
Cost Cap. (without RTC)			-0.148*	*(0.069)*			-0.039	*(0.082)*
Cost Cap. (with RTC)					-0.277**	*(0.073)*		
Effect RTC							-5.474**	*(0.783)*
Regression Statistics								
SSR	91.0798		90.9997		90.314		86.2814	
s	0.082080		0.082056		0.081747		0.079913	
R^2 - adj.	0.3258		0.3262		0.3313		0.3610	
Log Likelihood	18 607.6		18 614.6		18 675.0		19 039.9	
LM Het. Test	541.05	[.000]	543.72	[.000]	524.91	[.000]	502.59	[.000]

Dependent variable : R/G (t). 15 977 Observations - 2 431 Firms - Period : 1983 - 2002.
Within-Firm estimation with a full set of time dummies. Heteroscedastic conssitent standard errors in parenthesis.
* : significant at 5 % level, ** : significant at 1 % level. SSR : Sum of squared residuals, s : standard error of regression.
LM Het. Test : Lagrange Multiplier test of general heteroscedasticity.

Table 5 : Error Correction Model with the User Cost of Capital

By adding to the user cost of capital the effect of the research tax credit, the statistical quality of the estimate is improved. The assumption of a zero coefficients for the user cost of capital variables in regression (5) is clearly rejected by a Wald test. Moreover adjusted R^2 increases slightly in spite of the rise in the number of estimated parameters. The long-run elasticity of the user cost of capital including the R&D tax credit is larger than before with a value of 0.28. It indicates that the R&D tax credit improves the price reaction of the firms which increases the substitution between knowledge capital to other production factors.

The regression becomes even better when the effect of RTC is added separately from the user cost of capital in regression (6) mainly because of the change in user cost due to this RTC, which becomes highly significant. The long run elasticity of the R&D capital to its user cost (ignoring the RTC effect) is smaller, and not significant. This can be explained by the same hypothesis as before on the measurement errors at the firm level.

If the long run parameters for the change in user cost due to tax credit is interpreted like an elasticity of substitution. It seems to be unreasonable (-5.5), even if it is more precisely estimated. However we find an estimated elasticity from the coefficient of the tax credit effect that is quite close from the estimates by Bronwyn Hall (1993) for the United States[11] which goes from –2 to –2.7 for the elasticity of the R&D to the after tax price of the R&D. This can be due to a larger effect when we consider an incremental tax credit both in France and in the U.S.

In these results, we can remark that the expected change in the tax credit parameters directly (regression 6) or through the user cost ok capital (regression 5) has a negative affect on the R&D rate. This is again due to the reduction of current R&D expenditure if the firm expects that the change in future tax credit system will become more profitable. This negative effect is offset by the positive effect of a change in the current tax credit parameter. However, as for the demand effect, the cost of capital and the tax credit effects are very slow with a mean lags of about 7 years for these variables. The large reaction delays can be due to the small error correction parameters. The dynamics of adjustment is conditioned by the lags in the autoregressive form which can be biased towards zeros due to the within transformation of the autoregressive model, even with a fairly long panel[12].

5. THE EFFECTIVENESS OF R&D TAX CREDIT IN FRANCE.

[11] The comparison between our model and the model used by Hall (1993) for the U.S. is not easy beacuse she had a Euler equation specification with explicit adjustment costs, whereas we do not specify any a priori form for the adjustment process. Moreover the estimation methods are different : generalized method of moments in first difference for her study, within firm estimation method here. Finally the estimation period, the corporate tax system, and the R&D tax credit are somewhat different between France and the U.S.

[12] This is the well-known bias in dynamic panel. See Nickell (1980) for example.

5.1. The effects of an increase in the rate of tax credit.

In this last section, we study the effect of a policy aiming to boost the private R&D by changing the rate of research tax credit. To measure the impact of a legislative change in the R&D tax credit system, it is necessary to study how the effective rate and the parameter of tax credit moves when the rate of tax credit is increased. In the following of this section, it is assumed that the change is a rise in the statutory rate of tax credit by 10 points, from 50 % to 60 %. To prevent that some firms do not pass the ceiling RTC^{max} for the same level of R&D expenditure, the ceiling is also increased by 20 % : from 6.10 M€ to 7.32 M€.

Several cases should be considered : the first relates to a firm which fully benefits from the RTC. In this case, the increase in the statutory rate will reduce the user cost of capital as indicated in Table 2. The effect will be identical, although proportionally reduced, for the firms hitting the ceiling. On the other hand, if a firm is below the floor, the incentive effect will be null because it does not benefit from the RTC. In assuming such a behavior, we neglect the case when a firm changes sufficiently its R&D behavior in order to pass the floor or the ceiling. In the first case, the firm will increase, and not reduces, its R&D, and in the second, the firm increased its &D a lot to pass over the ceiling limit of the RTC.

The first model can be used directly to evaluate the effect of the rise in tax credit rate, because the considered variable is the effective rate of tax credit by 10 points. For the firms between the floor and the ceiling of the RTC, the optimal R&D capital stock will be increased by about 3.2 %. If we assume that a half of the firm is at the floor, with a decrease in R&D expenditure and a zero effect of the change in tax credit rate, and neglecting the reduced effect on the firms above the ceiling, there will be a total effect on the aggregate R&D capital by 1.6 %. The aggregate effect is then lowered to an half, but the total budget cost for the government is the same because it is only affected by a fall in corporate taxes from the firms above the floor which benefit from the RTC.

If the adjustment of optimal capital stock is immediate, a rise in the R&D expenditure of 3.2 % should be noted for the firms which fully benefit from the RTC, and of 1.6 % for the whole of the firms. In 2003, the R&D tax credit had a budgetary cost for the government of 428 M€[13], by a reduction of corporate taxes. The R&D expenditure of the firms recipients of the RTC was for the same year to 11.3 Billion Euros. Consequently, an rise in the statutory rate of tax credit, accompanied by a rise of the ceiling of 20 %, would have cost approximately 86 M€ for the government budget (20% of the previous cost). But it would have involved an increase in the R&D expenditure of 1.6 % for the recipients firms, that is to say 181 M€. The multiplier effect is far from negligible because it is larger than 2 times the amount of the budgetary cost.

In order to qualify the RTC effect, we also use the error correction model where the rate of user cost of capital is decomposed on a fist part : the rate of user cost without the tax credit effect, and a second part the change in rate of user cost due to the tax credit, as described in the long run expression (9). To determine the effect of an economic policy increasing the R&D tax credit, we must remembered that the rate of RTC appears only through the RTC parameter γ in this rate of user cost (see expression 11). Therefore the long run effect on the R&D capital stock the stock of a change in this RTC parameter γ is given by :

[13] Source : Ministry of the Research.

$$\frac{\partial k}{\partial \gamma} = \sigma'' \frac{\partial \log(\psi)}{\partial \gamma} = \sigma'' \frac{\partial \log(\Omega)}{\partial \gamma} = \sigma'' \frac{1}{\Omega}\frac{\partial \Omega}{\partial \gamma} = -\sigma'' \frac{1}{\Omega}\left(\frac{\rho + \delta - \pi^{RD}}{1-\tau}\right).$$

Using the definition of this RTC parameter $\gamma = \theta\left((\rho - \pi^{RD})/(1+\rho)\right)\left(1 + 0.5(1+\pi^{RD})/(1+\rho)\right)$ for the later period (1991-2003) in Table 2, we obtain finally the effect of a change in the rate of tax credit as :

$$\frac{\partial k}{\partial \theta} = \frac{\partial k}{\partial \gamma}\frac{\partial \gamma}{\partial \theta} = -\sigma'' \frac{1}{\Omega}\left(\frac{\rho + \delta - \pi^{RD}}{1-\tau}\right)\left(\frac{\rho - \pi^{RD}}{1+\rho}\right)\left(1 + \frac{1}{2}\frac{1+\pi^{RD}}{1+\rho}\right). \qquad (15)$$

Because this effect depends on the particular value of some variables, we evaluate it for a 10 point rise in the statutory rate of tax credit by using the 2003 average for the variables in this expression : $\rho = 0.041$, $\pi^{RD} = 0.022$, $\delta = 0.15$, $r = 0.041$ and $s = 0.38$ also enter into the computation of $\Omega = 0.161$. The corporate tax rate is taken in 2003 : $\tau = 0.354$. Finally the long run estimated coefficient of the tax credit effect is taken in the regression (8) $\sigma'' = -5.474$ to give :

$$\frac{\partial k}{\partial \theta} = -(-5.474).(0.0443) = 0.243.$$

Therefore a 10 points increase in the rate of tax credit, implies a rise of 2.4 % in the optimal R&D capital for the full recipients of this tax credit. For firms with a decreasing R&D, this policy has no direct effect because they are under the floor, and the RTC parameter γ is zero. If we assume that half of the firms fully benefits from the RTC, the aggregate effect will be a rise of 1.2 % of the R&D capital stock. This result is smaller than the one obtained with the descriptive model (1.3 %), but the difference is quite weak. This improves our confidence in the computation of the effect of the tax credit : for a budgetary cost of 86 M€, the equilibrium R&D expenditure will rise of 136 M€.

5.2. The transitory and permanent shocks on the tax credit.

The mean lags for the determinants of the R&D capital are rather long. The computation shows that for the production, it exceeds 6.7 years. It is again longer for the effect of tax credit which culminates at 6.9 years. These delays are mainly due to the high persistence of R&D expenditure, which is showed in the weakness of the estimated error correction parameter. This parameter is about – 0.09 in our preferred specification (7). It implies that only 9 % of the gap between the optimal and the actual R&D capital stock is filled each year, and thus the adjustment is relatively slow.

We present in the Figures 4 and 5, the effects of a transitory or a permanent shock on the tax credit effect variable : $\log(\psi)$ based on the estimated short run and long run coefficients of the regression (7). In these Figures 4 and 5, the 95 % confidence interval are also shown.

The Figure 4 shows the effect of a transitory shock on the tax credit variable taking effect at time $t = 0$, which goes back to the initial rate at the following periods. Let us note that the maximum effect is reached after 2 periods, then it declines slowly thereafter

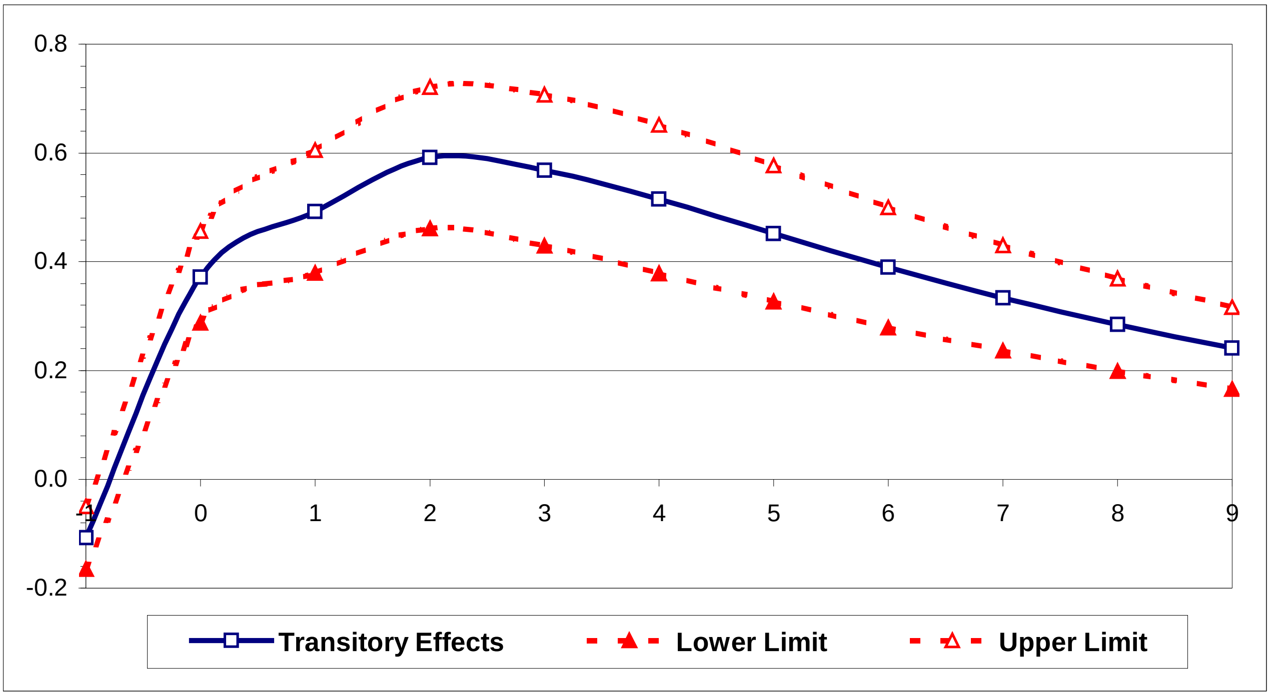

Figure 4 : Effect of a Transitory Shock on the Rate of Research Tax Credit.

An expected change in the statutory rate of tax credit at the next period has a negative and significant effect. But we need to remember that it is the expected rate in period $t+1$ which is taken into the estimation. Therefore if the firm expects a rise in this statutory rate next year, it has an incentive to reduce immediately its R&D expenditure, in order to be able to increase them next year to benefit of the future rise of the statutory rate of the incremental tax credit.

The Figure 5 present the effects of a permanent shock on the statutory rate of tax credit, which are the cumulated effect of the transitory shocks. The smooth and slow adjustment path is striking. Only the half of the adjustment will be made after 5 years. After 10 years of this permanent increase in the statutory rate, the estimated effect is only 75 % of the long run effect. There is still a large room for adjustment in the later years. This Figure also shows that a current change in the tax credit system has a direct immediate significant effect. But it is quite small. Finally the effects of a permanent shock are quite imprecise as it is indicated by the 95 % confidence interval.

The incremental R&D tax credit seems to have a strong long run incentive on the private R&D in France. Perhaps it is due to its incremental nature which acts on the increase in the R&D, and benefit only to firms which undertake a growing program of R&D. However there are very long delays for the R&D tax credit to be fully effective because of the high persistence of the R&D programs. Therefore if the R&D tax credit can help the private R&D in the long run, it does not prevent the use of alternative policies in order to boos the R&D in the short run.

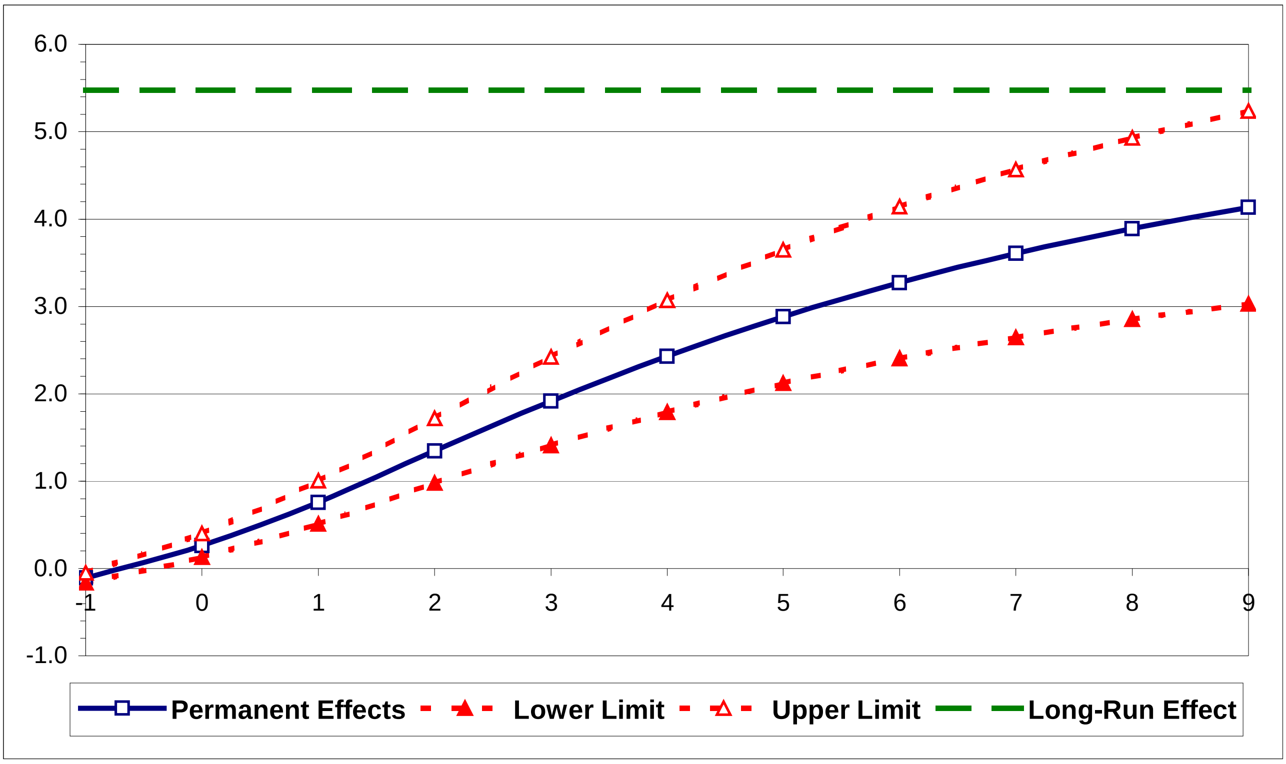

Figure 5 : Effect of a Permanent Shock on Research Tax Credit.

6. CONCLUSIONS

In this article, we develop an analysis of the effect on the R&D expenditure of the user cost of capital in an identical way as for the investment in fixed assets. In this empirical study about the R&D in France, we are interested more particularly in the incremental research tax credit introduced since 1983 which is based on the increase in R&D, in order to support the private R&D, especially for small businesses. We propose to study the effect of the research tax credit by computing a user cost of capital with or without this RTC.

A panel of French firms over the period 1979 - 2003 is used to empirically test the effects of the various determinants of the R&D expenditure, with a dynamic error correction model in order to distinguish the long-run effects from the short-run adjustment.

The main determinant of the R&D expenditure remains the output demand. On the other hand, the user cost of capital has a very weak negative effect on the optimal stock of R&D capital. However much of these components, can be badly measured at the individual level, do not have significant effects. But if we consider more particularly the research tax credit, a rather important incentive effect is found. By reducing the user cost of R&D capital, this tax credit significantly supports the firm’s R&D expenditure. If the current tax credit which is 50 % with a ceiling of 6.1 M€ is increased to a rate of 60 % (and a corresponding ceiling of 7.3 M€), that would involve an increase in the optimal stock of R&D capital of 2.4 to 2.6 %. In consequence, it also results in a rise in the equilibrium R&D expenditure of 2.4 to 2.6 %, or an increase between 136 to 181 M€ of the private R&D expenditure at a budgetary cost of 86 M€. This multiplier effect (around 2) must certainly be consolidated by other studies on French data, because it is much more important than that generally advanced by the international authorities[14].

In spite of this important effect of the research tax credit that was underlined, the principal problem resulted in slow adjustment process of the R&D to a change on these determinants. It can take many years in order to have a significant effect. Moreover, the distributive effect of the research tax credit between firms because of the floor and the ceiling in the RTC. If a firm reduces or stabilizes their R&D expenditure, there is no effect of the RTC. This threshold effect remains an important problem, which would deserve theoretical and empirical researches to qualify the distribution of the benefits of this economic policy. In the same way, deeper studies of asymmetries in the tax system, with regard to the carry forward of the losses or the unused tax credits should be undertaken later so as to refine the results obtained within this framework.

[14] See for example Hall and Van Reenen (2000) or OECD (2002) for international comparisons of empirical studies on the R&D tax credit. They concludes that these fiscal incentives lead to a rise in private R&D expenditure which is approximately equal to the budgetary cost.

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APPENDIX A :

THE SPECIFICATION OF THE USER COST OF CAPITAL

This appendix aims at specifying the derivation of the user cost of capital, i.e. the cost of implementing one unit of R&D capital during one period (one year). It is based on the assumption that the company maximizes its intertemporal value which is measured by the discounting sums of future dividends:

$$\max V_0 = \sum_{t=0}^{\infty} \beta_t Div_t \qquad \text{(A1)}$$

with a discounting rate : $\beta_t = \prod_{i=0}^{t} (1+\rho_i)^{-1}$ where ρ is the firm's net rate of return. The dividend is defined by the identity between the resources and the uses of funds, and the balance sheet identity between two periods. For the sake of simplicity, it is assumed that there are no new share issues. Retained earnings and new debts constitute the only changes of the firm's liability.

$$Div_t = OP_t - r_t D_{t-1} - T_t - P_t^{RD} R_t + D_t - D_{t-1}$$

where
$$\begin{cases} OP_t & : \text{Operating profits} \\ A_t & : \text{Depreciation allowances} \\ T_t & : \text{Coporate taxes} \\ D_t & : \text{Firm's debt} \\ R_t & : \text{R \& D expenditures} \\ Div_t & : \text{Profits distribués (Dividendes)} \end{cases}$$

The total dividend is expressed like the operating profits less the debt charges increased of the net change in firm's indebtedness, decreased of the load of the debt ($r_t D_{t-1}$), the corporate taxes and the R&D expenditure of R&D : $P_t^{RD} R_t$ which is the gross change in the R&D capital stock between two periods.

The corporate tax is taken at a constant rate constant τ on a basis where the interests and depreciation allowances are deduced. A tax credit on the R&D expenditure is also allowed as a rebate on the corporate taxes for the company. This tax credit relies either on the value of the current R&D or on the increase in R&D for an incremental tax credit. To take account of these two forms of tax credit, it is assumed that it depends on the R&D expenditures of the current year and the revaluated R&D expenditures of the two previous periods:

$$T_t = \tau_t \left(OP_t - r_t D_{t-1} - A_t \right) - \sum_{i=1}^{I} \theta_i P_t^{RD} R_{t-i}$$

with θ_i the rates of tax credit on current and past R&D expenditures. If $\theta_0 > 0$ and $\theta_i = 0$ for $i > 0$, the tax credit will relate to the total value of the current R&D investment. If $\theta_1 = -\theta_0$ and $\theta_i = 0$ for $i > 1$, there is a marginal or an incremental tax credit on the change of R&D expenditures relative to the last year. This is the French RTC before 1991. Since 1991 the incremental tax credit in France is based on the average of the last two years revaluated R&D expenditures with $\theta_1 = \theta_2 = -\theta_0/2$ and $\theta_i = 0$ for $i > 2$. All the intermediate cases can be studied within this framework like the introduction of a tax credit on current R&D expenditures from 2004 to 2006 in France.

We will not go into the details of the tax system which does not allow the negative tax or the refunding of tax credit if it would be higher than the corporate taxes, nor difficulties of the carry forward of the losses over several years in order to eliminate a taxation from the future or former profits. In the same way, the difficulties related to the possible thresholds of the tax credit will not be assessed here.

Finally the following expression for the dividends of the company can be written as:

$$Div_t = (1-\tau_t)\left(OP_t - r_t D_{t-1}\right) + \tau_t A_t - P_t^{RD} R_t + D_t - D_{t-1} + \sum_{i=0}^{I} \theta_i P_t^{RD} R_{t-i} \qquad \text{(A2)}$$

The choice of the level of debt is very simplistic in this paper because it is not determined by an arbitrage between the tax gain of the debt, the costs of bankruptcy, and the control of the company by its main shareholder. Thus the firm's indebtedness is assumed, in a first approximation, to be proportional to the value of the assets of the firm measured by the value of the capital at the replacement cost:

$$D_t = s_t P_t^{RD} K_t \qquad \text{(A3)}$$

By assumption, the depreciation allowances in one year depends only on the gap between this year and the date of the R&D expenditure : $\alpha_{t-j}^t = a_j$ with $0 \le a_j \le 1, \sum_j a_j = 1$, and thus it is constant over time (the changes in the tax policy are assumed not expected by the firm).

$$A_t = \sum_{j=0}^{\infty} P_{t-j}^{RD} R_{t-j} \alpha_{t-j}^t \qquad \text{(A4)}$$

Finally the last constraint to be taken into account is the equation of evolution of the capital stock, which depreciates economically at a constant rate δ :

$$K_t = (1-\delta) K_{t-1} + R_t \qquad \text{(A5)}$$

By substituting the expressions for the dividends (A2), the debt (A3) and depreciation allowances (A4) in the firm's maximization program (A1) and by taking account of the constraint (A5), the generalized Lagrangian is obtained for the firm's optimization problem with the Lagrange multiplier λ_{t+j} of the discounted constraint for the change in capital stock :

$$\max V_0 = \sum_{t=0}^{\infty} \beta_t \left\{ \begin{array}{l} (1-\tau_t)\left[P_t F_t(K_{t-1}) - r_t s_{t-1} P_{t-1}^{RD} K_{t-1}\right] - P_t^{RD} R_t \\ + s_t P_t^{RD} K_t - s_{t-1} P_{t-1}^{RD} K_{t-1} + \sum_{i=0}^{I} \theta_i P_t^{RD} R_{t-i} \\ -\lambda_t \left[K_t - (1-\delta) K_{t-1} - R_t\right] \end{array} \right\} + \tau_t \sum_{t=0}^{\infty} P_t^{RD} R_t \Phi_t \qquad \text{(A6)}$$

where $\Phi_t = \sum_{j=0}^{\infty} \beta_{t+j} \alpha_t^{t+j} = \sum_{j=0}^{\infty} \beta_{t+j} a_j$ represents the discounted value of the depreciation allowances for one unit of R&D expenditure at the period *t*. This variable only depends on the path of depreciation allowances (for example linear, double-declining or exponential) and on the discounting factors β_{t+j} .

The first order condition for the R&D expenditure yields an expression for the Lagrange multiplier as :

$$\lambda_t = \left(1 - \sum_{i=0}^{I} \theta_i \frac{\beta_{t+i}}{\beta_t} \frac{P_{t+i}^{RD}}{P_t^{RD}}\right) P_t^{RD} - \tau_t P_t^{RD} \frac{\Phi_t}{\beta_t} = (1-\gamma_t) P_t^{RD} - \tau_t P_t^{RD} \frac{\Phi_t}{\beta_t} \qquad \text{(A7)}$$

where : $\gamma_t = \sum_{i=0}^{I} \theta_i \frac{\beta_{t+i}}{\beta_t} \frac{P_{t+i}^{RD}}{P_t^{RD}} = \sum_{i=0}^{I} \theta_i \xi_i$ with $\xi_i = \prod_{j=0}^{i} \frac{\beta_{t+j}}{\beta_t} \frac{P_{t+j}^{RD}}{P_t^{RD}} = \prod_{j=0}^{i} \frac{1+\pi_{t+j}^{RD}}{1+\rho_{t+j}} \approx \prod_{j=0}^{i} \left(1 - \rho_{t+j} + \pi_{t+j}^{RD}\right)$ and $\pi_{t+s}^{RD} = P_{t+s}^{RD} / P_{t+s}^{RD} - 1$ is the inflation rate on R&D prices.

This Lagrange multiplier can be interpreted as the marginal value of one unit of R&D capital at the period *t*. It is equal to the price of R&D, corrected by the tax credit effect, minus the discounted value of the depreciation allowances. γ in this expression can be interpreted as the effect of tax credit on the user cost of capital. It reduces the price of one unit of R&D capital.

If there is no tax credit $\theta_i = 0$ for all *i*, the full price of the R&D is used with $1-\gamma = 1$. On the other hand, if the tax credit depends only on the current value of the R&D ($\theta_0 > 0$ and $\theta_i = 0$ for *i* > 0), the price of the R&D will be decreased by the rate of tax credit : $1-\gamma = 1-\theta_0 < 1$. For the French R&D tax credit system before 1991 : $\theta_1 = -\theta_0$ and $\theta_i = 0$ for *i* > 1, the price of the R&D will then be reduced by a factor :

$$\gamma_t = \theta_0 + \theta_1 \frac{\beta_{t+1}}{\beta_t}\frac{P_{t+1}^{RD}}{P_t^{RD}} = \theta_0\left(1 - \frac{1+\pi_{t+1}^{RD}}{1+\rho_{t+1}}\right) = \theta_0 \frac{\rho_{t+1} - \pi_{t+1}^{RD}}{1+\rho_{t+1}}$$

which is positive if we assume a nominal rate of return larger than the inflation rate. After 1991, the incremental R&D tax credit is based on the average of two last periods R&D expenditure with $\theta_1 = \theta_2 = -\theta_0/2$ and $\theta_i = 0$ for *i* > 2. the reduction in price of one R&D unit is :

$$\begin{aligned}\gamma_t &= \theta_0 - \frac{\theta_0}{2}\frac{\beta_{t+1}}{\beta_t}\frac{P_{t+1}^{RD}}{P_t^{RD}} - \frac{\theta_0}{2}\frac{\beta_{t+2}}{\beta_t}\frac{P_{t+2}^{RD}}{P_t^{RD}} \\ &= \theta_0\left(1 - \frac{1}{2}\frac{1+\pi_{t+1}^{RD}}{1+\rho_{t+1}} - \frac{1}{2}\frac{1+\pi_{t+1}^{RD}}{1+\rho_{t+1}}\frac{1+\pi_{t+2}^{RD}}{1+\rho_{t+2}}\right) \\ &= \theta_0\left[\left(\frac{\rho_{t+1}-\pi_{t+1}^{RD}}{1+\rho_{t+1}}\right) + \frac{1}{2}\left(\frac{1+\pi_{t+1}^{RD}}{1+\rho_{t+1}}\right)\left(\frac{\rho_{t+2}-\pi_{t+2}^{RD}}{1+\rho_{t+2}}\right)\right]\end{aligned}$$

Assuming a constant nominal rate of return and inflation rate, the reduction factor becomes :

$$\gamma_t = \theta_0\left(\frac{\rho-\pi^{RD}}{1+\rho}\right)\left[1 + \frac{1}{2}\left(\frac{1+\pi^{RD}}{1+\rho}\right)\right] \approx \theta_0\left(\frac{\rho-\pi^{RD}}{1+\rho}\right) \times 1.5$$

These are the expression used in Table 2 to compute the effect of the R&D tax credit. Therefore the change in tax credit rules in 1991 increases by about 50 % the effect of this tax credit on the R&D price. Let us note that the effect of incremental RTC is only due to the discounting of the stream of the tax payments by the firm. If there is no real discounting, the incremental tax credit as no effect on the price of R&D. The tax credit effect will be higher when the required rate of return is larger and the inflation rate is lower.

Now the first order condition for the R&D capital stock is obtained from (A6) for all periods as :

$$\frac{\partial V_0}{\partial K_t} = \beta_t\left[s_t P_t^{RD} - \lambda_t\right] + \beta_{t+1}\left[(1-\tau_{t+1})\left\{P_{t+1}\frac{\partial F_{t+1}(K_t)}{\partial K_t} - r_{t+1}s_t P_t^{RD}\right\} - s_t P_t^{RD} + \lambda_{t+1}(1-\delta)\right] = 0$$

This yields the expression for the after-taxes marginal productivity of the capital in value (with $\beta_t/\beta_{t+1} = 1+\rho_{t+1}$) :

$$\begin{aligned}(1-\tau_{t+1})P_{t+1}\frac{\partial F_{t+1}(K_t)}{\partial K_t} &= (1+\rho_{t+1})\lambda_t - (1-\delta)\lambda_{t+1} + (1-\tau_{t+1})r_{t+1}s_t P_t^{RD} - (1+\rho_{t+1})s_t P_t^{RD} + s_t P_t^{RD} \\ &= (1+\rho_{t+1})\lambda_t - (1-\delta)\lambda_{t+1} + \left[\left(1+(1-\tau_{t+1})r_{t+1}\right) - \left(1+\rho_{t+1}\right)\right]s_t P_t^{RD}\end{aligned} \quad \text{(A8)}$$

Let us now introduce the Lagrange multiplier found in expression (A7) into (A8) in order to obtain the after-tax marginal productivity of knowledge capital in value :

$$\begin{aligned}(1-\tau_{t+1})P_{t+1}\frac{\partial F_{t+1}(K_t)}{\partial K_t} &= (1+\rho_{t+1})(1-\gamma_t)P_t^{RD}-(1-\delta)(1-\gamma_{t+1})P_{t+1}^{RD}\\ &+\left[\left(1+(1-\tau)r_{t+1}\right)-\left(1+\rho_{t+1}\right)\right]s_t P_t^{RD}\\ &-\tau_t(1+\rho_{t+1})P_t^{RD}\Psi_t+\tau_{t+1}(1-\delta)P_{t+1}^{RD}\Psi_{t+1}\end{aligned}$$

If we assumed for simplicity that the changes between two periods in the tax credit parameter γ_t is negligible, $\gamma_t \cong \gamma_{t+1}$, as well as the change in the tax rate τ. This expression becomes approximately :

$$\begin{aligned}(1-\tau_{t+1})P_{t+1}\frac{\partial F_{t+1}(K_t)}{\partial K_t} &\cong P_t^{RD}\left[\rho_{t+1}+\delta-\pi_{t+1}^{RD}\right]-s_t P_t^{RD}\left[\rho_{t+1}-\left(1-\tau_{t+1}\right)r_{t+1}\right]\\ &-\gamma_t P_t^{RD}\left[\rho_{t+1}+\delta-\pi_{t+1}^{RD}\right]\\ &-\tau_t P_t^{RD}\Psi_t\left[\rho_{t+1}+\delta-\pi_{t+1}^{RD}\right]\end{aligned}$$

The same assumption is done for the discounted value of the tax deduction Ψ_t for one unit of R&D. In fact if the discounting factor is assumed approximately constant over the period, we have :

$$\Psi_{t+1}=\frac{1}{\beta_{t+1}}\sum_{j=0}^{\infty}\beta_{t+1+j}a_j=\frac{(1+\rho_{t+1})}{\beta_t}\sum_{j=0}^{\infty}\frac{\beta_{t+j}}{(1+\rho_{t+j+1})}a_j\cong\frac{(1+\rho_{t+1})}{\beta_t(1+\rho_{t+1})}\sum_{j=0}^{\infty}\beta_{t+j}a_j=\Psi_t$$

For the sake of simplicity, we assume that the firm's expected required rates of return ρ_t, which appears in the discounting factor are constant over time in the future. Consequently, the discounted tax deduction for depreciation of capital is be equal to

$$\Psi_t=\sum_{j=0}^{\infty}\left(1+\rho\right)^{-j}a_j\ .$$

The depreciation scheme retained here is an exponential depreciation of the R&D capital at a constant rate δ_f, such that the depreciation allowances factors $a_j=\delta_f(1-\delta_f)^j$ are introduced into the previous expression to obtain the discounted tax deduction for one unit of R&D in real terms :

$$\Psi_t=\sum_{j=0}^{\infty}\left(1+\rho\right)^{-j}\delta_f(1-\delta_f)^j=\frac{\delta_f}{\delta_f+\rho}\ . \qquad \text{(A9)}$$

This expression shows that if the required rate of return increases, the tax deduction for depreciation of the capital will be reduced. In the same way, the tax deduction increases when the fiscal depreciation rate decreases because depreciation allowances will be diluted in time.

Therefore we end up with the traditional expression for the marginal productivity in value of the R&D capital and its user cost of the capital (C) :

$$P_{t+1}\frac{\partial F_{t+1}(K_t)}{\partial K_t}=C_{t+1}=\frac{P_t^{RD}}{1-\tau_{t+1}}\left[\begin{array}{r}\left(s_t(1-\tau_{t+1})r_{t+1}+(1-s_t)\rho_{t+1}\right)+\delta-\pi_{t+1}^{RD}\\ -\tau_t\Psi_{t+1}\left(\rho_{t+1}+\delta-\pi_{t+1}\right)-\gamma_t\left(\rho_{t+1}+\delta-\pi_{t+1}\right)\end{array}\right] \qquad \text{(A10)}$$

The cost of the capital depends on the price of the R&D, which is multiplied by what we called the rate of user cost of R&D capital. This last factor can be interpreted as the annual rental of one unit of R&D (in real terms). It includes five elements: the first one is the interest rate which is a weighted average of the interest rate on the firm's debt and the yield rate, corrected for corporate, the weight is the firm's debt ratio. It can be considered as the opportunity cost of the funds raised to finance the R&D expenditure. The second element is the depreciation rate, and the third element represents the effect of the capital gains due to the inflation on R&D price. The fourth and fifth element correspond to the reductions in the cost of the capital due respectively to a possible tax credit and to the tax deductibility of depreciation of R&D capital.

This expression is closed from the one obtained by Hall and Jorgenson (1967) or King and Fullerton (1984). The only difference come from the interest rate term where the rate of return on firm's equity can be different from the firm's interest rate on its debt. If there is no leverage effect of the debt or if there is no differential between the interest rate on the debt and the required yield on equity, the cost of the capital is rewritten like the Hall and Jorgenson user cost of capital expression :

$$C_{t+1} = \left(1 - \tau_t \Psi_{t+1} - \gamma_{t+1}\right) \frac{P_t^{RD}}{1 - \tau_{t+1}} \left[\rho_{t+1} + \delta - \pi_{t+1}\right]$$

This user cost of R&D capital is also the same as the one proposed by Hall (1992) and Hall and Van Reenen (2000) which is frequently used in the empirical studies of R&D cost.

APPENDIX B :

DATA AND VARIABLES

1. *The Data.*

The empirical implementation of this study is based on a panel of French manufacturing firms over the period 1979 – 2003. The accounts and balance sheets of the companies from INSEE were merged with the data of Research and Development, collected by surveys of R&D of the Ministry of Research. As most of the firms do not answer these surveys on a regular basis, only the firms with data on R&D for at least 5 times consecutively have been kept in this paper. Consequently, we have an unbalanced sample of 25 071 observations on 2 431 companies. But only 3.2 % of the firms are present on the entire period, whereas 50 % of the firms are observed without discontinuity only during less than 9 years (see Table B1).

NUMBER	Frequency	Percent
5	341	14.0%
6	301	12.4%
7	234	9.6%
8	205	8.4%
9	223	9.2%
10	191	7.9%
11	120	4.9%
12	82	3.4%
13	113	4.6%
14	108	4.4%
15	76	3.1%
16	78	3.2%
17	99	4.1%
18	33	1.4%
19	48	2.0%
20	24	1.0%
21	27	1.1%
22	23	0.9%
23	18	0.7%
24	9	0.4%
25	78	3.2%
TOTAL	**2 431**	**100.0%**

Table B1 : Number of Observations per Firms.

These companies are mainly large-sized. Most of them have more than 500 workers on the average. The industry composition of the sample is given in Table B2. The main industries of R&D firms are the Fabricated Metals (16.5%) the Chemicals-Rubber-Plastics (14.4%), and the Electric and electronic equipments (11.6%), while Clothing and leather, Printing and Publishing, and Construction are the industries with less firms doing R&D in the sample. Let us note that the sample contains some firms in Trade or Services, mainly addressed to business.

INDUSTRY	Frequency	Percent
Food, beverages and tobacco	142	5.8%
Clothing and leather	24	1.0%
Printing and publishing	11	0.5%
Drugs, perfumes, and soap	185	7.6%
Domestic equipment	105	4.3%
Motor vehicles	75	3.1%
Aircrafts, ships and railway materials	62	2.6%
Fabricated metals	402	16.5%
Electric and electronic equipments	282	11.6%
Mining and Minerals	77	3.2%
Textiles	53	2.2%
Wood, papers ans miscellaneous	39	1.6%
Chemicals, rubber and plastics	349	14.4%
Primary Metals	164	6.7%
Electric and electronic components	171	7.0%
Energy	29	1.2%
Construction	10	0.4%
Trade	83	3.4%
Services	168	6.9%
TOTAL	**2 431**	**100.0%**

Table B2 : Industry repartition in the sample.

2. *The Variables*

We present here the main variables used in the regressions. The first one is the total R&D expenditure in real terms :

$$R_t = \frac{R\,\&\,D_t Expenditure}{P_t^{RD}},$$

the price of the R&D (P^{RD}) is computed like in Mairesse, Cette and Kocoglu (2000) as a weighted average of a wage index for R&D workers, a input prices in the R&D sector, and the price of equipment goods in this sector. The weights are computed with the total sum of these three types of expenditures in the R&D surveys for each year. This price is identical for all the firms.

The nominal production is measured by the firm's value added (*V*), while the real stock of R&D capital (*K*) is computed by the perpetual inventory method with an economic depreciation rate of the R&D capital (δ) of 15 %, which is supposed constant over time and over firms :

$$K_t = (1-\delta)K_{t-1} + R_t .$$

We will describe here the way in which the variables entering into the user cost of capital were computed from the accounting and balance sheets data of the companies.

- the debt ratio (*s*) is measured like the ratio of the total debt of the firm on the total of the firm's assets. The half sum of the debt (*DEBTS*) and the total of assets in the balance sheets (*TOTAL*) at the beginning and the end of accounting year as the year averages. The rate of debt is by definition ranging between zero and one.

$$s_t = \frac{DEBTS_{t-1} + DEBTS_t}{TOTAL_{t-1} + TOTAL_t}$$

- the apparent interest rate *r* on the firm's debts is given by the ratio of the financial fees (*FINF*) on the part of the debt bearing interest. Because of the lack of information on the firm's debt structure, we assume that only a proportion of 50 % of debts bears interest. This estimate implies a reasonable evaluation for the apparent interest rate. As previously, the average stock of debt is taken into account by the half sum of beginning and end of period indebtedness. In order to avoid abnormally high values for interest rate, the maximum apparent interest rate is set to 30%.

$$r_t = \frac{FINF_t}{0.5 \times \left(\frac{DEBTS_{t-1} + DEBTS_t}{2} \right)}$$

- the rate of return ρ is computed from the yield of the government long-term bonds (*R*) with a tax rate t_0. By an arbitrage principle, it should be equal to the net rate of return on firm's equity with tax rate which is a weighted sum of tax rate on dividends (including the imputation system : $t_d = t_{IR}(1 + t_{AF}) - t_{AF}$) and tax rate on capital gains t_p. The weights are given by the rate of distribution of dividends (*d*) out the firm's net profits.

$$\left[1 - \left(d_t . t_d + (1 - d_t).t_p\right)\right]\rho_t = (1 - t_o)R_t$$

- the rate of distribution of the dividends (*d*) is given by a 3-years moving average of the annual rate of distribution measured by the ratio of dividends (*DIVID*) on the net accounting profits (*PROFIT*) which can be distributed to the shareholders :

$$d_t = \frac{1}{3} \sum_{i=-2}^{3} \frac{DIVID_{t+i}}{PROFIT_{t+i}}$$

- the rate of inflation on the R&D expenditure (π^{RD}) corresponds to the capital gain carried out by the firm for holding one unit of R&D capital during one period. :

$$\pi_t^{RD} = \frac{P_t^{RD} - P_{t-1}^{RD}}{P_{t-1}^{RD}}$$

3. *The Tax Rate and the Rate of Research Tax Credit.*

The following table gives the tax rates of the French tax system (corporate and shareholders) during the period 1979 – 2003, provided by the Ministry of Finance.

Year	Corporate Tax Rate	Income Tax Rate on Dividends	Capital Gains Tax Rate	Income Tax Rate on Bonds Interests	Imputation Rate *"Avoir Fiscal"*	Income Tax Rate on Dividends *after imputation*	Nominal Rate of R&D Tax Credit	Ceiling of R&D Tax Credit (in thousands Euros)	Nominal Rate of Special R&D Tax Credit	Ceiling of Special R&D Tax Credit (in thousands Euros)
1979	50.0%	60.0%	15.0%	25.0%	50.0%	40.0%				
1980	50.0%	60.0%	15.0%	25.0%	50.0%	40.0%				
1981	50.0%	60.0%	15.0%	25.0%	50.0%	40.0%				
1982	50.0%	65.0%	15.0%	25.0%	50.0%	47.5%				
1983	50.0%	65.0%	16.0%	25.0%	50.0%	47.5%	25%	457		
1984	50.0%	65.0%	16.0%	26.0%	50.0%	47.5%	25%	457		
1985	50.0%	65.0%	16.0%	26.0%	50.0%	47.5%	50%	762		
1986	45.0%	58.0%	17.0%	26.0%	50.0%	37.0%	50%	762		
1987	45.0%	56.8%	17.0%	27.0%	50.0%	35.2%	50%	762		
1988	42.0%	56.8%	17.0%	27.0%	50.0%	35.2%	50%	1 524	30%	137
1989	39.0%	56.8%	17.0%	27.0%	42.6%	38.4%	50%	1 524	30%	137
1990	37.0%	56.8%	18.1%	17.0%	38.1%	40.3%	50%	1 524	30%	137
1991	34.0%	56.8%	18.1%	18.1%	31.8%	43.1%	50%	6 098		
1992	34.0%	56.8%	18.1%	18.1%	50.0%	35.2%	50%	6 098		
1993	33.3%	56.8%	18.1%	18.1%	50.0%	35.2%	50%	6 098		
1994	33.3%	56.8%	19.4%	19.4%	50.0%	35.2%	50%	6 098		
1995	36.7%	56.8%	19.9%	19.9%	50.0%	35.2%	50%	6 098		
1996	36.7%	54.0%	20.9%	20.9%	50.0%	31.0%	50%	6 098		
1997	36.7%	54.0%	26.0%	25.0%	50.0%	31.0%	50%	6 098		
1998	36.7%	54.0%	26.0%	25.0%	50.0%	31.0%	50%	6 098		
1999	36.7%	54.0%	26.0%	25.0%	50.0%	31.0%	50%	6 098		
2000	37.8%	53.3%	26.0%	25.0%	50.0%	29.9%	50%	6 098		
2001	36.4%	52.8%	26.0%	25.0%	50.0%	29.1%	50%	6 100		
2002	35.4%	49.6%	26.0%	25.0%	50.0%	24.4%	50%	6 100		
2003	35.4%	48.1%	26.0%	25.0%	50.0%	22.1%	50%	6 100		

Table B3 : Tax Rates and Research Tax Credit 1980 – 2003 (in percent)