Is Private R&D Spending Sensitive to Its Price? Empirical Evidence on Panel Data for Italy*

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Abstract

In this paper empirical evidence is presented on the elasticity of private R&D spending on its price. A censored panel-data regression model with random effects is applied to a balanced panel of 726 Italian firms over the 1992-97 period. Implied estimates point out that Italian firms' response to policy measures (including tax credits), aimed at reducing the user cost of R&D capital, is likely to be substantial (1.50-1.77). Furthermore, we also find that the elasticity of R&D spending is higher in recession (2.01) than in expansion (0.87).

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1 Introduction

There is general consensus among economists that market mechanisms fail to provide the socially optimal level of R&D spending, basically because private firms are not able to fully capture all the profits arising from the results of their R&D activity. Government intervention in this area is thus justified from an economic point of view by the market failure aspect of R&D: because the social returns to private R&D are often higher than the private returns, some research projects would benefit society but would be privately unprofitable. By lowering the cost to the firm, a subsidy can make these projects profitable as well.

There is far less consensus on how should policy bridge the gap between the private and the social rate of return. Until recently, in most European countries including Italy, direct government funding through grants or soft loans have been the prevailing types of incentives, with tax credits playing a somewhat marginal role. The standard economic rationale underlying this preference is that direct funding is discretionary as it is usually accompanied by a government project choice. In turn, this would allow policy makers to channel public subsidies towards projects where the gap between the social and the private return is perceived to be greater (see David et al., 2000). In recent years, however, a progressive shift towards tax credits has been observed in several countries. For instance, automatic tax credits reducing the cost of R&D spending were effectively introduced in Italy only in 1997. Indeed, in the present days where the blame for economic inefficiencies is more often put on government than on market failures, a tax-based subsidy seems a feasible market-oriented response since it leaves the choice of how to carry out R&D programs in the hand of the private sector.

As noted by Hall and Van Reenen (2000) in their review of the existing empirical evidence on this issue, the effectiveness of tax incentives cannot be taken for granted since it crucially depends on the tax-price elasticity of R&D private spending. If it is very low it would take an implausibly large fiscal relief to generate a sizeable effect. Incidentally, this was the overall conclusion emerging from the first wave of studies of the US tax credit program using data through 1983. More recent studies on both the US and other industrialized countries seem instead to converge in concluding that the tax price elasticity of total R&D spending is on the order of unity, maybe even higher (see Hall and Van Reenen, 2000).

The main objective of this paper is to provide econometric evidence on this unresolved issue for Italy. For this purpose we apply a censored panel-data regression model with random effects to a balanced panel of 726 Italian firms over the 1992-97 period. Compared to most of previous literature in this area which focuses exclusively on large firms, our panel has the advantage of a broader coverage, since it also includes a sizeable number of unlisted small/medium sized companies. The main result of this paper is that estimated elasticity is high, being systematically greater than 1 (1.50-1.77) in all our estimates where the elasticity parameter is assumed to be constant over time. In addition, we also find evidence that the elasticity is greater in recession (2.01) than in expansion (0.87).

The remainder of this paper is organized as follows. Next section briefly illustrates recent trends in public financing of R&D expenditures in Italy. Section 3 focuses on how our crucial variable - the user cost of R&D capital - is constructed. Section 4 describes the sample of firms used for the estimation of the empirical model and presents the relevant descriptive statistics. In section 5 the empirical model and its underlying assumptions are introduced. Section 6 discusses the econometric results and section 7 concludes.

2 Public Incentives to R&D in Italy

As already mentioned in the introduction, direct funding through grants or soft loans have been the prevailing types of R&D incentives in Italy. According to the surveys on state aids published by the European Union (EU, hereafter) Commission, in the 1992-94 (1994-96) period these instruments accounted respectively for 65.0 (85.7) and 35.0 (14.3) per cent of total R&D subsidies to the private sector. Only in more recent years (1996-98), government intervention in this field has taken the form of fiscal benefits. However, the percentage of aid granted through tax measures (5 per cent of total R&D subsidies) is still small when compared with the other more usual instruments.[1] Furthermore, as it can be seen in Table 1 where these broad figures are reported for the four large EU countries (France, Germany, Italy and the UK), the preference accorded to direct and often discretionary measures was fairly widespread in the EU in the period under study.[2]

Table 1. R&D national public incentives to private R&D

	France	Italy	Germany	UK
Annual average (1992-94)	1100.53	294.86	759.29	236.50
Types of incentives (%)				
Grants (A1)	53.1	65.0	98.1	100
Tax Exemptions (A2)	40.9	-	-	-
Soft Loans (C1)	5.9	35.0	1.9	-
Tax Deferrals (C2)	0.1	-	-	-
Annual average (1994-96)	1037.30	270.81	1090.70	176.10
Types of incentives (%)				
Grants (A1)	48.6	85.7	98.7	100
Tax Exemptions (A2)	45.3	-	-	-
Soft Loans (C1)	6.1	14.3	1.3	-
Tax Deferrals (C2)	-	-	-	-
Annual average (1996-98)	1212.30	285.87	1102.29	155.64
Types of incentives (%)				
Grants (A1)	30.0	74.4	96.8	100.0
Tax Exemptions (A2)	40.8	5.0	-	-
Soft Loans (C1)	29.2	20.6	3.1	-
Tax Deferrals (C2)	-	-	-	-
Others	-	-	0.1	-

Data in millions ECU. Source: "Fifth, Sixth and Eight Surveys on State Aid in the EU in the Manufacturing and Certain Other Sectors", EU Commission

[1] Note, however, that these figures are open to criticism. For instance, the EU Commission allocates each national aid scheme to a single objective. This might lead to underestimate the amount of R&D public incentives, if R&D programs specifically directed towards small firms (or to firms located in less favored regions) are allocated under the SME (or regional aid) heading and therefore are not included in the R&D total.

[2] In Table 1, A1+A2 represent aids which are transferred in full to the recipient. A1 means that aid is granted though the budget (grants + direct interest subsidies). The aid is denoted as A2 if it is given through the tax or social security system. C1+C2 are transfers in which the aid element is the interest saved by the recipient during the period in which the capital transferred is at her/his disposal. The financial transfer can take the form of a soft loan (C1) or tax deferral (C2).

These figures obviously reflect the characteristics of the Italian legislation on public incentives to R&D and its evolution over time.[3] In fact, grants and soft loans are the financial instruments used by the main R&D program (law 46/82) operating consistently through the nineties to channel public funds to private R&D projects. Even if this program has been recently amended to fulfill EU requirements, its main features have remained broadly unaltered over the decade. Roughly speaking, firms apply for the financing of R&D expenditures (including labor, equipment and other current costs). If the proposed project is accepted, firms benefit from both types of incentives (grants + soft loans) to cover up to a maximum share of planned R&D costs. Additional benefits to small firms and/or to firms localized in less developed areas (i.e. Southern Italy) are provided, the rationale here being that these types of firms are likely to face more severe market imperfections in financing their R&D activities. As it will become apparent in the next section, these differences across firms will be exploited in the construction of the user cost of capital variable. For this reason, Table 2 reports in details the amount of incentives available to different types of firms in the sample period used for estimation.

Table 2. Characteristics of Law 46/82 (1992-97)

	All firms (base)	SMEs	Less Developed Areas
Law 46/82	Eligible expenditures = 60% of expenditure[a]		
Grant[1]	20%	30%	30%
Soft Loan[2]	40%	50%	75%

1 size of the grant as a percentage of eligible expenditures.
2 discount on the market interest rate.
a Current expenditure and equipment

Specific fiscal incentives to R&D were introduced in Italy in 1991 as part of a more comprehensive program (law 317/1991) aimed at fostering the development of small and medium sized firms. A tax credit of 30 per cent on all R&D expenditures was given to small and medium sized firms (50 per cent for SMEs localized in less favored areas). However, mainly because of a legislative conflict

[3] Given the well known complexity of Italian legislation, providing a comprehensive picture of all programs where a R&D aid element is present goes far beyond the purpose of this paper. For more details see CER/IRS (1993) and Aronica et al. (1995).

with the EU on definitions and parameters, planned measures providing automatic tax credits were not implemented until 1995. Furthermore, this program was discontinued as soon as the end of 1996, see Aronica et al. (1995). In 1997, however, two new programs were introduced with the purpose of stimulating private R&D activities (law 140/1997 and law 449/97). As a confirmation of the recent trend towards tax-based subsidies, both programs make use exclusively of the tax credit instrument. In particular, whereas law 140/97 applies only to small and medium sized firms and is confined, almost exclusively, to the hiring of new R&D personnel, law 449/97 extends the availability of fiscal benefits to all firms and applies to labor, equipment and other current expenditures. The tax credit rate varies according to the usual size and location criteria, ranging from 10% for large firms located in Northern Italy to 30% for small firms located in Southern Italy.[4]

3 User Cost of R&D Capital

As stated in the introduction, the main objective of this paper is to estimate the response of R&D demand to its user cost. Among other things, this exercise is potentially useful in assessing the ex-ante expected impact of the recent tax credit measures introduced in 1997 but actually implemented from 1998. Since available data on firms' R&D expenditures cover only the 1992-97 period, an ex-post quasi-natural experiment cannot be performed. Nevertheless, even if the price variable does not incorporate the measure of the tax subsidy, the estimated elasticity can still be used to estimate the effect of a given policy change (e.g. the new tax credit) insofar as firms' response is not altered by the new policy.

In this paper, the user cost of R&D is calculated using the approach pioneered by Hall and Jorgenson (1967) and King and Fullerton (1984). The aim of this approach is to derive for any given investment project the minimum pre-tax real rate of return in order to provide the saver lending money to the firm with the same post-tax return he would receive from lending at the market interest rate.

[4] According to 1997 criteria, a firm is defined as small if it has a maximum of 50 workers, no more than 7 millions Ecu in sales or 5 millions Ecu in total assets, and if it is not owned by one or more firms defined as large. A firm is defined as medium if it has a maximum of 250 workers, no more than 40 millions Ecu in sales or 27 millions Ecu in total assets, and if it is not owned by one or more firms defined as large. This is in line with the 1996 EU directive.

In order to achieve identification of the price elasticity, variation of the R&D user cost across firms and/or over time is required. In most of previous literature this is obtained by relying mainly on differences in tax treatment, usually induced by differences in the implicit subsidy given by the tax system to R&D. As it should have become apparent from the previous section, this is unlikely to be a promising identification strategy in our case. In fact, not only R&D tax credits were relatively unimportant in the period under study (1992-1997), but also reliable firm level information on tax position is not available. This would leave us only with changes of the general tax legislation over time, a very thin reed on which to base the estimation of the price elasticity of R&D demand. For this reason, we complemented it with three additional sources of across-firms variation: differences in market interest rates (depending on firm's location and size), in firm's optimal capital structure, and in the amount of discretionary subsidies potentially accorded by the main R&D program (law 46/82) implemented in the 1992-97 period (again depending on firm's location and size). On the contrary, since firm level information on R&D composition is not available, it is assumed to be constant across firms and made by 90% as of current expenditures (personnel), 6.4% as of machinery and equipment, and 3.6% as of buildings (see OECD, 1996b).

Given the availability of direct and discretionary subsidies in the sample period used for the estimation (1992-97), a preliminary methodological issue has to be faced at this stage. In particular, since these incentives do not apply automatically to all eligible firms but are both discretionary and subject to budget constraints, it is not obvious how they should enter in the computation of the R&D user cost of capital. To circumvent this problem we have computed two alternative measures for the user cost. The first measure (User Cost without Incentives) does not take into account the potential availability of direct subsidies and is therefore likely to overestimate the "true" user cost faced by each firm. The second measure (User Cost with Incentives) incorporates existing subsidies (grants and soft loans) as if they were automatically and fully available to all eligible firms. In bold we highlighted the effect of soft loans in eq.1 in reducing the financial cost of debt and of subsidies in eq.3-4 in "implicitly" raising depreciation allowances (so reducing the user cost). Obviously this alternative is instead likely to underestimate the "true" cost. In the econometric exercise presented in section 6, we experiment with both definitions in order to check whether the estimated demand elasticity is sensitive to changes in the definition of the user cost.

As it is well known, the first step in measuring the user cost of capital is to compute the financial cost for each available form of financing: retained earnings, new debt, and new share issues. Financial costs are derived from the following set of equilibrium conditions between the opportunity cost of investing in the project and a safe investment:[5]

$$\rho^k = \begin{cases} r(1-t)\frac{(1-ti)}{(1-tp)}(\mathbf{1}-\mathbf{e}*\mathbf{slr}) & k = \text{debt } (de) \\ tk + r\frac{(1-ti)}{(1-tc)} & k = \text{retained earnings } (re) \\ tk + r\frac{(1-ti)}{z(1-td)} & k = \text{new shares } (ns) \end{cases} \tag{1}$$

As already mentioned, we allow the market interest rate, r in eq.1 to vary both over time and across firms. The rationale for this is that different types of firms are perceived to face different lending conditions depending, among other things, on location and size. To capture the location effect we used the Bank of Italy's yearly active rates on cash financing disaggregated by geographical areas ("North West", "North-East", "Center", "South"), reported in the supplement to the Statistic Bulletin. Unfortunately, similar data disaggregated according to firm size are not available. In order to capture the size effect, we computed instead an implicit cost of debt for each firm-year in the sample by using balance sheet data. To minimize accounting as well as endogeneity problems, we then computed median values (both across firms and over time) for three different firm size classes ("Small", "Medium", and "Large"). Finally, we applied differences between size classes proportionately to the - location specific - yearly active rates on cash financing. The final result is a set of twelve different market interest rates (one for each size-location) for each year.

Financial costs are then used to compute the user cost of capital, p^k specific to each form of financing. This is a weighted average of prices of the different components of R&D expenditure and also depends on economic depreciation (δ), inflation (π), corporate tax (t) and depreciation allowances as follows:

[5] The notation adopted in this section as well as the numerical values for the parameters used in computing the R&D user cost of capital are reported in Appendix 1.

$$p^k = \sum_s \omega_s \left[\frac{(1-\mathbf{A_s^k})(\rho^k+\delta^s-\pi)}{(1-t)}\right] \quad (2)$$
$$s = \text{current, machinery, buildings}$$
$$\omega_{ce} = 90\% \qquad \omega_{me} = 6.4\% \qquad \omega_b = 3.6\%$$

A_s^k is the present value of depreciation allowances and for convenience it also includes taxable grants (in bold in eq. 3-4). We allow only current expenditure and machinery/equipment to benefit this grant, as indicated in the relevant program (law 46/82). Note in eq.3-5 that machinery and buildings are depreciated over a specified number of time periods according to appropriate fiscal depreciation rates (0.15 and 0.04 respectively), while current spending is fully depreciated in the same fiscal period of the investment.

$$A_{ce}^k = \phi^{ce}t + \mathbf{g(1-t)} \quad (3)$$
$$A_{me}^k = \phi^{me}t + \frac{2\phi^{me}t}{1+\rho^k} + \frac{2\phi^{me}t}{(1+\rho^k)^2} + ... + \mathbf{g(1-t)} \quad (4)$$
$$A_b^k = \phi^b t + \frac{2\phi^b t}{1+\rho^k} + \frac{2\phi^b t}{(1+\rho^k)^2} + ... \quad (5)$$

Finally, to compute the R&D user cost of capital faced by each firm, it is necessary to weight the user costs specific to each form of financing as follows:

$$p = \sum_k \omega_k p^k \qquad \text{k = debt } (de)\text{, retained earnings}(re)\text{, new shares } (ns) \quad (6)$$

In this paper we allow firms to differ in their optimal financial structure and compute it as the average share (over the sample period) of the different financial sources as reported in balance sheet data (see also next section).

4 Sample Characteristics and Descriptive Statistics

The data come from the 6th and 7th surveys "Indagine sulle Imprese Manifatturiere" by Mediocredito Centrale, MCC from now on.[6] These are two surveys

[6] The surveys are run by the "Osservatorio sulle Piccole e Medie Imprese" (*Observatory over SMEs)*, a body of Mediocredito Centrale, an Italian investment bank. More detailed information about the surveys is found in the Mediocredito Centrale publications (see for example Ministero dell' Industria - Mediocredito Centrale, 1997) and its web site www.mcc.it.

conducted in 1995 and 1998 through questionnaires handed to a representative sample of manufacturing firms within the national borders and supplemented with standard balance sheet data. In each wave the sample is selected with a stratified method for firms with up to 500 workers, whereas firms above this threshold are all included. Strata are based on geographical area, industry and firm size. Each survey contains about 5000 manufacturing firms. Questionnaires collect information over the previous three years. We merged the two MCC's samples and obtained a reduced sample of 941 firms, keeping only those firms answering to both questionnaires and therefore with complete observations over the 1992-1997 period. The criterion used to merge is based on available fiscal codes and firms' identification numbers. We further reduced the sample according to R&D data quality. In particular we cross-checked answers and excluded those firms which said to have spent on R&D in the questionnaire and gave no amount whatsoever. Analogously, we deleted those firms not mentioning whether they invested or not and yet giving some amount, the fact being dubious. We also eliminated those firms with all missing values on R&D spending. Finally, we had to eliminate 40 firms lacking the balance sheet information needed to build weights in the user cost of R&D capital. The final sample contains 726 firms, 27.8% of which spent on R&D in each sub-period (1992-94 and 1996-97), and 60.2% spent on R&D in at least one period.[7]

Table 3 reports the (percentage) distribution of the final sample of firms by industry, size and area. As in Archibugi and Ceccagnoli (1995), we used the ISTAT (the Italian Statistical Bureau) industry classification scheme and accordingly we grouped firms in 21 two-digit manufacturing industries. Size is defined as end-of-year number of employees. By using the EU classification (see footnote 4) we partitioned firms in three size classes: "Small" (up to 50 workers),"Medium" (between 50 and 250), and "Large" (above 250 workers). Finally, by exploiting available information on head quarter localization, firms were also classified in one of the following four geographical areas: "North West", "North East", "Center", and "South". As it can be seen in Table 3 "Medium" firms make 43.6% of the sample whereas the shares of "Large" and "Small" firms are respectively

[7] More detailed information on the effects of merging and cleaning procedures on the size/location distribution of firms can be found in Appendix 2.

24.7% and 31.7%. All industries are represented with "Mechanics" (23.4%) and "Textiles" (13.5%) ranking respectively first and second. Finally, about three quarters of sample firms are localized in Northern Italy (54.6% in the "North West" and 25.3% in the "North East"). More importantly for the purpose of the present paper, these figures indicate that only 29.8% of sample firms falls under the "default" category (large firms not located in Southern Italy) as defined by law 46/82, whereas additional benefits were potentially available to 64.8% (SMEs not localized in the "South") and, even more generously, to 5.4% (firms localized in Southern Italy) of the full sample.

Table 3. Firms by size, industry and area in % of total sample

	North W			North E			Center			South			
	S	M	L	S	M	L	S	M	L	S	M	L	Total
Food	0.83	1.10	0.14	0.27	0.68		0.27	0.41		0.27	0.55		4.6
Textiles	2.07	4.27	3.03	0.27	0.55	0.41	1.79	0.55		0.14	0.41		13.5
Clothing	0.14		0.41	0.14	0.14	0.27	0.14	0.14	0.41		0.27		2.1
Leather	0.14	0.27			0.55	0.14	0.14	0.27				0.14	1.7
Wood	0.68	0.55		0.27	0.55		0.27						2.3
Paper	0.68	0.55	0.41	0.27	0.55	0.14	0.41	0.83	0.27				4.1
Printing	1.79	0.55	0.27	0.83	0.14	0.14	0.41			0.14	0.14		4.4
Oil refining	0.14						0.14			0.14			0.4
Chemicals	0.55	0.83	0.96	0.55	0.27		0.41		1.10	0.27			4.0
Rubber, plastics	2.20	2.34	0.27	0.41	0.83	0.14	0.41	0.41				0.14	7.2
Non-metal miner	0.83	0.55	0.55	0.96	1.10	0.83	0.68	0.41		0.41	0.41	0.14	6.9
Metals	0.68	2.34	1.10	0.27	0.41	0.41	0.14	0.14		0.14	0.14	0.14	5.9
Metal products	0.27	1.65	0.55	0.55	0.55		0.14	0.14				0.14	4.0
Mechanics	2.48	7.30	3.30	1.52	3.86	2.62	1.38	0.27	0.27	0.14	0.14	0.14	23.4
Office machinery		0.41	0.14									0.14	0.7
Electronics	0.68	0.68	0.55	0.27	0.27	0.41		0.14	0.41	0.14			3.6
TV, radio	0.41	0.14	0.83				0.14		0.14				1.6
Medical instrum	0.14	0.14	0.14	0.14		0.27							0.8
Vehicles	0.41	0.83	1.10	0.14	0.55	0.41		0.14	0.14		0.27		4.0
Other transport	0.14	0.41	0.14						0.27	0.14		0.14	1.2
Furniture		0.27	0.14	0.41	0.55	0.27	0.27	0.55	0.14				2.6
Total Size	15.3	25.2	14.1	7.3	11.6	6.4	7.2	4.4	3.1	1.9	2.4	1.1	
Total Area			54.6			25.3			14.7			5.4	100

Table 4 below shows descriptive statistics for R&D intensity over time. R&D intensity is defined as the ratio between R&D spending and sales (in percentage terms). In both questionnaires a detailed definition of R&D activity is given.[8]

[8] Questionnaire 1998 precisely defines: "*La Ricerca e Sviluppo include tre attivita': Ricerca*

The second column of Table 4 reports the number of firms in the original panel (941 firms) spending a positive amount on R&D in each year. The third column reports the same information after cleaning the sample, and in parentheses there are percentages with respect to final sample size (726). For our sample the share of R&D active firms ranges from 41.9% in 1995 to 45.0% in 1993-94. Conditional on performing R&D activity, fourth to sixth columns report quartiles of R&D intensity distribution. Seventh and eighth report mean values and standard deviation respectively. Two data features are worth commenting upon. Firstly, by comparing the quartiles for the first sub-period (1992-94) with those for the second sub-period (1995-97), it can be noted that the latter are systematically lower. This feature of our data-set is roughly consistent with macroeconomic evidence on the negative R&D growth rate in Italy (-0.8%) between 1991 and 1996 (OECD, 1996a, 1998). Also, it must be taken into account that 1994-97 were expansionary years whereas in 1992-93 the Italian economy was in deep recession. Since sales tend to be more volatile than R&D expenditures, this explains, at least partially, the observed downward trend for our R&D to sales variable. Secondly, conditional distributions are skewed to the right with a limited number of firms investing a relatively large amount of resources in R&D.

Table 4. R&D intensity over time

	R&D Firms		R&D intensity (% of Sales)				
	941 firms	726 firms	1st Q	Median	3rd Q	Mean	St.D.
1992	356	322 (44.4)	0.43	0.99	2.18	1.88	2.62
1993	366	327 (45.0)	0.46	1.03	2.56	2.31	5.97
1994	381	327 (45.0)	0.47	1.05	2.26	1.86	2.29
1995	369	304 (41.9)	0.26	0.66	1.63	1.57	3.19
1996	376	305 (42.0)	0.30	0.70	1.64	1.66	3.22
1997	391	317 (43.7)	0.28	0.75	1.70	1.51	2.60

Given the crucial role played by the user cost of capital variable in allowing the identification of the R&D price elasticity, in Table 5 basic descriptive statistics are

di base, Ricerca applicata, Sviluppo sperimentale. Per Ricerca di base si considera un'attivita' sperimentale o teorica avente come scopo l'allargamento dei limiti della conoscenza in cui si prevede una specifica applicazione o utilizzazione; per Ricerca applicata si intende quella originale svolta per ampliare i limiti della conoscenza, ma anche e principalmente allo scopo di una pratica e specifica applicazione; per Sviluppo sperimentale si intende un'attivita' destinata a completare, sviluppare o perfezionare materiali, prodotti e processi produttivi, sistemi e servizi attraverso l'applicazione e l'utilizzazione dei risultati della ricerca e dell'esperienza pratica." This definition is in line with the EU directive of May 1992.

reported for our two alternative measures, respectively excluding and including the potential benefits deriving from existing government incentives. The impact of grants and soft loans is to reduce both the mean (as obviously expected) and the overall standard deviation (respectively from 0.342 to 0.242 and from 0.027 to 0.024). More importantly for our purposes, we have also computed within- and between-firm standard deviations. Given our sources of variation (especially differences in market interest rates, in financial structures and, when appropriate, in the amount of available subsidies), it is probably not surprising that variation between firms dominates variation within firms (but over time). This happens to be the case particularly when the user cost with incentives is considered.

Table 5. Descriptive statistics for the User Cost of R&D Capital

	Mean	1st Q	Median	3rd Q	St. D.	Within	Between
User Cost without Incentives	0.342	0.309	0.339	0.378	0.027	0.016	0.022
User Cost with Incentives	0.242	0.212	0.240	0.275	0.024	0.011	0.021

Finally, Table 6 reports summary descriptive statistics on the weights (ω_{de}, ω_{re},and ω_{ns}) used to compute eq. 6 for each firm in the sample. These weights are obtained by exploiting available stock balance sheet data. For each firm yearly weights are firstly computed. Subsequently, firm level yearly weights are averaged over time with the purpose of controlling for short run deviation from the optimal financial structure. Therefore, financial structures are allowed to vary across firms but not over time. On average, equity capital (retained earnings and new share issues) accounts for slightly more than 50% of total liabilities.

Table 6. Weights in finance structure

	1st Q	Median	3rd Q	Mean	St.D.
Debt	0.31	0.51	0.68	0.49	0.23
Retained Earnings	0.12	0.26	0.47	0.31	0.24
New Share Issues	0.10	0.17	0.27	0.20	0.13

5 Methodology

As already mentioned in the previous section, only 1,902 firm-level observations out of 4,356 (43.7%) show a positive amount of R&D spending. This feature of the data makes conventional linear panel data methods inappropriate to estimate the elasticity of R&D spending to its user cost. For instance, applying the within-group estimator only to the observations with positive R&D will yield biased and inconsistent estimates of our parameter of interest because of the standard omitted variable problem. On the other hand, applying the same estimation method to all observations fails to account for the potential qualitative difference between zero and positive observations. Furthermore, this is simply not feasible in our framework because of the logarithmic transformation of the relevant variables implied by the maintained assumption of constant elasticity.

The fact that the dependent variable is zero for a significant fraction of the observations makes it natural to model the overall R&D decision as a single equation with a censoring rule (tobit model):

$$
\begin{aligned}
y_{it}^{*} &= \pi p_{it} + x_{it}^{'}\beta + u_{it} \qquad (7)\\
(i &= 1,...,n;\;\; t = 1,...,T)\\
y_{it} &= \max\{y_{it}^{*}, 0\}\\
u_{it} &= \eta_i + \nu_{it} \qquad (8)
\end{aligned}
$$

where y_{it}^{*} is a latent variable measuring the (log of the) amount firm i is willing to invest in R&D at time t.[9] What we observe instead is $y_{it} = y_{it}^{*}$ only if $y_{it}^{*} > 0$ and we set $y_{it} = 0$ otherwise. p_{it} is the (log of the) user cost of R&D capital as measured in the previous section. $x_{it}^{'} \in \Re^{k}$ is a vector of other firm characteristics including size, location and cash-flow. Furthermore industry and time dummies are included in the specifications presented in the next section. Finally, since firms are likely to be characterized by unobservable variables which affect their risk aversion and their information set, and therefore their propensity to invest in R&D capital, we allow for individual heterogeneity by assuming that the error term u_{it} contains an individual specific component, η_i. Contrary

[9] By using this approach we are ruling out the possibility that the selection equation (the decision to engage in R&D activity) is different from the R&D spending equation (conditional on the decision to do R&D). On this issue see also section 6.

to linear panel data models, the assumption of fixed η_i does not lead to simple estimation procedures, since the individual specific effect does not enter linearly or multiplicatively and therefore it is not possible to difference it out.[10]

In this paper we assume that the individual effect is random. Maximum likelihood estimation of censored panel data models with random effects is possible but computationally very cumbersome if restrictions on the distribution of individual effects and time varying terms are not imposed. Strict exogeneity of the observables with respect to η_i and ν_{it} and $u_{it} \sim idN(0, \sigma_\eta^2 \iota\iota' + \sigma_v^2 I_T)$ are therefore assumed. In fact, under these restrictions, maximization of the likelihood requires only unidimensional numerical integration.[11]

A final issue which is worth mentioning at this stage refers to the interpretation of the estimated coefficients. It is well known that π (and the same obviously applies to each element of the β vector) measures $\frac{\partial E(y_{it}^* | x_i, p_i)}{\partial p_{it}}$ which is of limited interest since y_{it}^* is not observable. Since y_{it} is equal to the log of R&D spending if it is positive and zero otherwise, also the following alternative measure:

$$\frac{\partial E(y_{it} \mid x_i, p_i)}{\partial p_{it}} = \pi \Pr(y_{it}^* > 0) \tag{9}$$

is not very meaningful. In order to make our results comparable with those obtained in previous literature (where only firms with positive R&D are usually included) what we are really interested in is $\frac{\partial E(y_{it} | x_i, p_i, y_{it}^* > 0)}{\partial p_{it}}$, that is the elasticity of R&D spending on its user cost conditional on performing R&D activity. By exploiting the McDonald and Moffitt (1980) decomposition of $\frac{\partial E(y_{it} | x_i, p_i)}{\partial p_{it}}$, it can be proved that this measure can be computed as:

$$\begin{aligned} \frac{\partial E(y_{it} \mid x_i, p_i, y_{it}^* > 0)}{\partial p_{it}} &= \pi \left[1 - \frac{\pi p_{it} + x_{it}^{'} \beta}{\sigma_u} \lambda - \lambda^2 \right] \\ \lambda &= \frac{\phi(\frac{\pi p_{it} + x_{it}^{'} \beta}{\sigma_u})}{\Phi(\frac{\pi p_{it} + x_{it}^{'} \beta}{\sigma_u})} \end{aligned} \tag{10}$$

[10] See however the estimator proposed in Honoré (1992) where the dependent variable is artificially censored in such a way that the individual effect can be differenced out. See also Honoré and Kiriazidou (1999) and Arellano e Honoré (1999).

[11] To test for the robustness of our estimates of the price elasticity of the R&D user cost of capital to the strict exogeneity assumption on the x vector, in section 6 we will alternatively assume that $\eta_i = \overline{x}_i^{'} \lambda + \varepsilon_i$ with $E(\varepsilon_i v_{it}) = 0$ (see also Wooldridge, 1995).

where λ is the inverse Mill's ratio and ϕ and Φ denote respectively the standard normal density and cumulative density functions. In addition, the effect of a change in the user cost of R&D capital on the probability that an observation will be positive - i.e. that a firm will engage in R&D activity - can also be computed as follows:

$$\frac{\partial prob(y_{it}^{*} > 0)}{\partial p_{it}} = \frac{\pi}{\sigma_u}\phi(\frac{\pi p_{it} + x_{it}^{'}\beta}{\sigma_u}) \tag{11}$$

Given that these two parameters vary with firms and over time, we will calculate them by taking the predicted value of the regression on the means, $\pi\overline{p} + \overline{x}^{'}\beta$.

6 Results

Our findings are summarized in Tables 7 and 8. The results of alternative estimates of the coefficients of eq.7 are shown in Table 7 with attached standard errors and summary statistics (from column 1 to column 5) whereas Table 8 reports implied elasticities (see eq.10) and changes in probability (see eq.11). In all columns of Table 7 the dependent variable is equal to zero if the amount of R&D spending is zero and to the log of real R&D expenditure otherwise. Column 1 is our benchmark model which includes as explanatory variables the (log of the) user cost variable with incentives together with real sales and operational cash flow gross of R&D costs (both in log) as control variables. The sales variable is a proxy for size and is expected to be positive given the greater R&D financing possibilities for large firms and the perspective of higher returns to R&D associated with larger markets. It is instead an open question whether the elasticity of R&D effort to size is expected to significantly differ from 1. The cash flow variable is also expected to be positively signed. However, the economic interpretation is dubious since a positive sign is consistent both with contemporaneous cash flow being a signal for future investment opportunities or with cash flow signalling imperfect substitutability between internal and external financial sources.[12] Location ("North-East", "Center", and "South"), time and two-digit

[12] For empirical evidence on the role of cash flow in R&D investment equations see Himmelberg and Petersen (1994) on the US, Mulkay et al. (2000) on France and the US, and Bond et al. (2000) on the UK and Germany.

industry dummies are also included as additional control variables. Time dummies capture macroeconomic demand shocks whereas industry dummies control for time-invariant industry-specific factors including the available set of localized technological opportunities.

Estimates reported in columns 2-5 are meant to provide a series of alternative robustness checks of our basic results.[13] In column 2 the user cost of capital without incentives replaces the user cost with incentives as a regressor. As already mentioned in section 3, comparing the two estimated elasticities provides a straight robustness test to alternative definitions of our crucial variable. In column 3, instead, we have re-estimated our basic model only on the sub-sample of firms operating in high-tech industries.[14] Since the majority of R&D active firms is concentrated in a limited number of industries it might be argued that potential differences between R&D performing and R&D non-performing firms merely pick up structural differences across industries and not differences between R&D and non-R&D firms. To rule out this alternative explanation we have therefore checked whether our implied elasticities are substantially different when estimated on the sub-sample of high-tech industries. In column 4 we address the endogeneity issue by allowing the individual effect to depend linearly on $\overline{x}_i$, the objective being to test whether our estimates of the R&D price elasticity are sensitive to the assumption of strict exogeneity on the x vector. Operationally, this implies that our basic model has to be extended by including two additional regressors, that is the within-firm means for real sales and operational cash flow. Building on column 4, column 5 tests whether the R&D price elasticity is constant over time or if it varies according to the general stance of the Italian economy. For this purpose two dummy variables EXP and REC are interacted with the user cost of capital variable. EXP (REC) takes the value of one if the economy is in expansion (recession) and zero otherwise.[15]

In all columns our main variables have all the expected sign. In particular, sales

[13] If the tobit specification is correct, then the probit estimators should be consistent for $\frac{1}{\sigma_u}\begin{bmatrix}\pi \\ \beta\end{bmatrix}$ from the tobit model. Therefore, to check for misspecification of the tobit model we also run probit equations. Overall results confirm all our basic findings.

[14] High-tech industries include Chemicals, Mechanics, Office machinery, Electronics, TV and radio, Medical instruments, Vehicles, Other transport.

[15] A recessionary year is defined as one in which there has been more than one quarter of negative GDP growth. Recessionary years in our sample period are 1992 and 1993.

and cash flow coefficients are positively signed and significant at the conventional statistical level and the user cost variable is negative and highly significant. Furthermore, the "South" dummy is negative and significant with the exception of column 3 where parameters are estimated on the sub-sample of high-tech industries.

Table 7. Tobit on R&D spending with random effects

	FS	FS	HT	FS	FS
Sales	1.28*	1.36*	1.41*	1.02*	1.04*
	(0.068)	(0.079)	(0.081)	(0.219)	(0.218)
average Sales				0.34	0.39*
				(0.233)	(0.233)
Cash Flow	0.20*	0.20*	0.15*	0.20*	0.21*
	(0.026)	(0.027)	(0.029)	(0.030)	(0.030)
average Cash Flow				-0.01	-0.04
				(0.058)	(0.059)
User Cost with Incentives	-5.18*		-3.32*	-4.58*	
	(1.136)		(1.092)	(0.937)	
User Cost without Incentives		-5.26*			
		(0.858)			
User Cost with Incentives*EXP					-2.71*
					(1.076)
User Cost with Incentives*REC					-6.24*
					(1.245)
North-East	0.41*	0.18	-0.28	0.37*	0.26
	(0.205)	(0.227)	(0.222)	(0.191)	(0.205)
Center	0.09	-0.44	-1.85*	0.16	-0.19
	(0.259)	(0.286)	(0.355)	(0.299)	(0.276)
South	-1.08*	-0.70*	2.44*	-1.04*	-0.61
	(0.398)	(0.425)	(0.500)	(0.414)	(0.410)
$Var(\eta_i)$	4.41*	4.19*	3.80*	4.48*	4.36*
	(0.131)	(0.122)	(0.139)	(0.130)	(0.119)
$Var(\eta_i)/Var(u_{it})$	0.72*	0.70*	0.72*	0.73*	0.72*
	(0.012)	(0.012)	(0.015)	(0.011)	(0.011)
log-L	-6111.23	-6105.30	-3053.54	-6096.11	-6084.24
proportion of $y_{it} > 0$	.437	.437	.596	.437	.437
N. observations	4356	4356	1758	4356	4356

FS: full sample. HT: high-tech firms only. A test of significance for $Var(\eta_i)/Var(u_{it})$ rejects the null. * means 10% significance.

Table 8. Elasticities and changes in P(y>0) for main variables

	FS	FS	HT	FS	FS
Elasticities					
Sales	0.41	0.46	0.71		
Cash Flow	0.06	0.07	0.07		
User Cost with Incentives	-1.67		-1.66	-1.50	
User Cost without Incentives		-1.77			
User Cost with Incentives*EXP					-0.87
User Cost with Incentives*REC					-2.01
Changes in P(y>0)					
Sales	0.10	0.11	0.11		
Cash Flow	0.01	0.02	0.01		
User Cost with Incentives	-0.39		-0.25	-0.34	
User Cost without Incentives		-0.42			
User Cost with Incentives*EXP					-0.21
User Cost with Incentives*REC					-0.48

FS: full sample. HT: high-tech firms only.

As already explained in section 5, estimated coefficients are economically not very meaningful. What we are really interested in is to recover estimates of the relevant elasticities conditional on performing R&D activity. For this reason Table 8 reports mean estimates of eq.10 (upper part of the Table) and eq.11 (lower part of the Table) with respect to the continuous explanatory variables included in our specification. Conditional on doing R&D, implied elasticities with respect to contemporary sales and cash flow are respectively 0.41-0.46 and 0.06-0.07 when estimated on the full sample of firms. Furthermore, the R&D elasticity to sales is substantially higher (0.71), but still below 1, when estimated on the sub-sample of firms operating in high-tech industries. More importantly for the purpose of the present paper, the conditional elasticity of R&D to its user cost turns out to be high since it ranges from 1.50 to 1.77 in absolute value when estimated on the full sample period. This result should be compared and contrasted with the available empirical evidence for other countries (especially the US) where variability in the user cost is obtained trough variation in the tax treatment across firms and over time. For instance, recent work using US firm level data reaches the conclusion that the tax price elasticity of total R&D spending during the eighties is on the order of unity, maybe higher (see Hall and Van Reenen, 2000). Finally, we also find evidence of instability over time of the elasticity parameter, which turns out to be greater in recessionary years (2.01) than in expansionary years (0.87).

7 Conclusion

In this paper empirical evidence is presented on the elasticity of private R&D spending on its price. Implied estimates point out that Italian firms' response to policy measures (including tax credits) aimed at reducing the user cost of R&D capital is likely to be substantial. Taken to its face value, other things being equal, our finding implies that a 5 per cent reduction in the user cost is expected to increase the spending of R&D active firms by as much as 7.5-8.8 per cent. Of course this is not the full effect. In fact, a reduction in costs will also affect firm's output thus amplifying the R&D expansionary effect. Furthermore, it will also increase the probability that new firms will start investing in R&D activity.

However, some cautionary remarks are necessary. First, one has to recognize the limitations in the used econometric technique. These limitations are a direct consequence of the difficulties in estimating fixed effects versions of censored and, more generally, of non-linear models on the one hand and of the strong assumptions that has to be taken in a random effects approach on the other hand. Second, and possibly more important for policy perspectives, it must be recognized that identification of the elasticity parameter has been mainly achieved through size and location variability in market interest rates. This might lead to overestimate the price elasticity to the extent that variability in market interest rates captures additional size or location disadvantages not fully controlled for by the sales and the location dummy variables.

Obviously, to shed further light on this issue alternative identification strategies have to be pursued. This might become possible in the future when more recent data with detailed firm level information on tax credits, following the implementation of the 1997 programs, will become available.

A Appendix 1

Following is the legend of the parameters used in the calculation of the R&D user cost of capital in Section 3. It also includes the notation for public aid elements derived from Table 2 in Section 2. Finally, last columns of the table contain the values given to fiscal and economic parameters as reported in Gandullia (2000).

Symbols	Definitions	92-93	94-95	96-97
k	debt (de), retained earnings (re), new shares (ns)			
ρ^k	financial cost for k method of R&D financing			
p^k	R&D price by k-type method			
ω_k	weight for k-type method			
s	current expenditure (ce), machinery (me), buildings (b)			
A_s^k	depreciation allowances for (s, k)-type			
δ^{ce}	economic depreciation for ce	0.30	0.30	0.30
δ^{me}	economic depreciation for me	0.1264	0.1264	0.1264
δ^b	economic depreciation for b	0.0361	0.0361	0.0361
ϕ^{ce}	fiscal depreciation for ce	1	1	1
ϕ^{me}	fiscal depreciation for me	0.15	0.15	0.15
ϕ^b	fiscal depreciation for b	0.04	0.04	0.04
ω_s	weight for type s of R&D expenditure			
r	market interest rate			
π	rate of inflation			
t	corporate tax rate	0.522	0.532	0.532
ti	tax rate on public bonds	0.125	0.125	0.125
tp	tax rate on private bonds	0.30	0.125	0.125
tk	tax rate on firm equity ($k = re$)	0.0075	0.0075	0.0075
tk	tax rate on firm equity ($k = ns$)	0.0075	0.0075	0.0
tc	tax rate on capital gains	0.10	0.10	0.10
z	tax credits on dividends	1.5625	1.5625	1.5625
td	personal tax rate	0.42	0.42	0.42
p	user cost of R&D expenditure			
e	allowable share of R&D expenditure			
g	taxable grant			
slr	discount on market interest rate (soft loan)			

Government parameters for grants and soft loans

South			North-Centre			
e	g	slr	e	g	slr	
0.6	0.3	0.75	0.6	0.3	0.5	SME
			0.6	0.2	0.4	Large

B Appendix 2

Tables A2.1 and A2.2 show the distributions by size and area of the firms in the original survey samples as well as of the firms in the selected samples after merging the cross sections and cleaning data. We used the number of workers at the end of each year to build a "size" class. If the firm reported less than 51 workers, it was considered "Small", if it had at least 51 workers but less than 251, it fell into "Medium" size and with more than 250 workers it was considered "Large". We used MCC variable "Area" to locate firms in one of the main geographical areas (macro regions).

MCC selects firms in the surveys with up to 500 workers through stratification by area, industry and size. Firms with at least 500 workers are all included. In 92-94 survey, 46% of the firms are small and 85% are SMEs. In 95-97 survey, 64% of the firms are small and 90% are SMEs. The higher number of small firms in the second survey is likely to be due to the fact that those ones especially addressed MCC for financial support in more recent years.[16]

In order to build a balanced panel for the 6 years of observation, we merged the two cross-sections by firms' MCC identity number and fiscal code, keeping 941 firms. We needed a further cleaning because of inconsistencies in firms' answers about their R&D activity. For example, we excluded firms indicating to have spent on R&D and yet reporting missing or zero amount. We also excluded firms without balance sheet information on their financial structure.

By comparing the columns in the Table A2.1 large firms are over-represented and small firms are under-represented both in the merged panel and in our final sample of 726 firms. This is mainly due to the MCC criterion to select the universe of firms with more than 500 workers, all falling into our "Large" class. Indeed, conditional on surviving, the probability of belonging to both surveys for large firms is equal to one whereas it is lower than one for firms in the other classes and it depends on sampling procedures. Since large firms are mainly located in the North West, after sample selection the North West is over-represented at the expense of the other three geographical areas (see Table A2.2).

[16] See footnote 6.

Table A2.1. Firms distribution by size in each sample, %

	1992-94 (5415)	1995-97 (4497)	Panel (941)	Panel (726)
Small	45.6	64.1	34.9	32.2
Medium	39.1	25.4	39.4	44.3
Large	15.3	10.5	25.7	23.5

Table A2.2. Firms distribution by area in each sample, %

	1992-94 (5415)	1995-97 (4497)	Panel (941)	Panel (726)
North West	42.3	39.4	53.3	54.6
North East	31.4	29.7	26.5	25.3
Centre	17.1	16.9	13.7	14.7
South	9.2	14	6.5	5.4

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