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Do Canadian Firms Respond to Fiscal Incentives to Research and Development?*

Marcel Dagenais†, *Pierre Mohnen*‡, *Pierre Therrien*§

Résumé / Abstract

Cet article étudie l'effet des incitatifs fiscaux à la R&D à partir d'un échantillon non cylindré de 434 firmes canadiennes (dont certaines ne font pas de R&D). Avec les données de Compustat, nous estimons un modèle Tobit généralisé (à effet fixe). Ce modèle détermine notamment l'effet du prix effectif de la R&D (indice-B tenant compte des différents plafonds dans l'utilisation des incitatifs fiscaux) sur le stock de la recherche. En augmentant d'un pourcent le crédit d'impôt fédéral à la R&D, nous obtenons en moyenne 0,98$ de dépenses additionnelles de R&D par dollar de dépense fiscale (firme ayant un plafond d'utilisation du crédit fédéral). Ce résultat est majoré à 1,04$ pour les firmes pouvant utiliser la totalité du crédit fédéral. Le transfert fiscal représente plus de 80 % du cout du soutien à la R&D par le gouvernement.

This study examines the effectiveness of R&D tax incentives using an unbalanced panel of 434 Canadian firms. Not all firms in the sample are R&D performers. A B-index summarizing the various tax incentives for R&D is constructed for each firm, taking into account individual ceilings in the use of the relevant tax incentives. A generalized Tobit model with fixed effects is estimated. A one percent increase in the federal tax credit to R&D yields an average of $0.98 additional R&D expenditure per dollar of tax revenues foregone (for firms with a ceiling in their use of federal tax credit). Using the same measure on firms which are not subject to a ceiling, we obtain $1.04. Tax transfers represent more than 80% of the cost of government support to R&D.

Mots Clés : Incitatifs fiscaux, R&D, modèle Tobit généralisé, Canada

Keywords : Tax incentives, R&D, generalized Tobit panel, Canada

JEL : H32, O31, O38

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1 Introduction

Many empirical studies have shown that research and development (R & D) yields an above-average private rate of return and that the social rate of return exceeds the private rate of return. These two propositions suggest that it is in the interest of policy makers to encourage R & D. In light of this, governments have adopted a number of fiscal measures to encourage research and development. These incentive packages involve substantial amounts. In 1992 in Canada, federal tax credits for R & D (excluding provincial tax breaks) amounted to $1.1 billion, accounting for about 20% of R & D expenditures by Canadian firms[1].

Governments have been questioning whether these expenditures on research are a wise use of taxpayers' dollars. This question is particularly pertinent for Canada, with one of the lowest R & D/GDP ratios of the OECD countries along with the most generous R & D incentive programs, especially in Quebec[2]. The goal of this study is to verify whether Canadian firms respond to tax incentives to R & D and, if so, to what extent? A number of studies have examined this issue, but the results are ambiguous. We shall re-examine this question using data on Canadian firms from the Compustat data bank. Firm-level data are particularly appropriate since tax incentives vary between firms. Therefore, these data allow us to distinguish between different firms' capacity to benefit from them.

In the next section we present the framework of tax incentives to R & D in Canada. In section 3 we review the results of earlier studies. Section 4 presents the results of our research, while section 5 discusses the econometric specification of the model. In section 6 we interpret our results, and section 7 examines the limitations of our study. Section 8 provides a concluding look at the policy implications of our work. Finally, the appendices contain a list of the industries from which the firms in our sample are drawn, definitions and data sources, details of the construction of the tax-incentives index, and a more in-depth presentation

[1] Source: Revenue Canada, Statistical Services Division and Statistics Canada, cat. 88-202.

[2] Canada is one of the most generous providers of tax incentives to R & D. To illustrate, for 1993-4 Warda (1994) calculated a B-index, measuring the present value of pre-tax revenue necessary to recover the cost of one dollar of R & D, of 0.691 for Canada, 0.770 for Australia, 0.893 for the U.S., 0.910 for France, 1.00 for Japan and the U.K., and 1.057 for Germany. Among Canadian provinces, Quebec's tax laws are the most propitious to research. A Deloitte and Touch (1995) study found that for large corporations in 1995 the net after-tax cost of a dollar of R & D was $0.364 in Quebec while it was $0.401 in Ontario and $0.381 in the other Canadian provinces. For small companies the difference is greater: the numbers being $0.279, $0.427, and $0.426 respectively.

of the data.

2 Construction of an Aggregate Index of Tax Incentives to R & D

Over the years government support for scientific research and experimental development (R & D to simplify) has assumed many forms: immediate deduction of R & D expenditures, federal and provincial tax credits, tax credits on incremental research, partial reimbursement, provision for carry forward and carry back and transfer to associate partners of unused tax credits, and many more. These incentives have varied with the region in which the R&D is done, the size of the firm, and the firm's capacity to use them.

Let us briefly summarize tax incentives to R & D in Canada. At the federal level, deductibility of R & D has always been a feature of the fiscal system, with some variations in the criteria for eligible expenditures. Since the mid 1970-s, the research tax credit has been used extensively, and its scope has been extended several times. The incremental research tax credit was introduced in the early 1960-s. It was abandoned in 1983 with the introduction of the scientific research credit transferable to investors. This rule gave rise to abuses, however, and two years later was replaced with a partial reimbursement mechanism and formulae for carrying unused credits forward. In recent years, the Quebec, Ontario, Nova Scotia, New Brunswick and Manitoba provnces have introduced their own tax credits on the level or the growth of R & D, which may, or may not, reduce eligibility to federal tax credits.[3]

We constructed an index of R & D-related tax incentives comprising all the determinants we were able to quantify. However, some measures could not be included because we did not have the necessary data: i.e. streamlined processing of tax credits since 1988, differential treatment of R & D expenditures in other countries, reduced tax-credit eligibility due to government assistance or contractual payments, or differential tax credits applied to certain types of R & D, such as fundamental research, R & D joint ventures or environmental research[4]. Our index measures

[3]For further information on the history of tax incentives to R & D in Canada we direct the reader to the following sources, on which we drew, for the regulations and the fiscal parameters: Doern (1995), Clark et al. (1993), Warda (1990), Warda (1994), McFetridge and Warda (1983), Deloitte & Touche (1995), Conseil de la science et de la technologie (1996), Department of Finance and Revenue Canada (1994), Lalonde (1983). Corporate income tax rates by province are from Williamson and Lahmer (1982, 1986, 1992), Sweeney and Robertson (1989), Lord and Gagné (1989).

[4]Note that tax credits to R & D based on wages, which we consider, represent the

the ratio of the net cost of a dollar spent on R & D, after all quantifiable tax incentives have been accounted for, to the net income from one dollar of revenue[5]. For example, if R & D outlays are entirely deductible from taxable income, and if the corporate income tax is 50%, then the effective cost of a dollar of R & D is $0.50. One dollar of sales revenue also yields $0.50. Consequently, the tax incentives to research index is equal to one: one dollar of pre-tax income is required to recuperate the cost of investing one dollar in research. If the tax-credit rate is 20%, and if the proportion of R & D deductible for tax is reduced by the amount of this credit, the effective cost of one dollar of R & D falls to $0.40, which yields a ratio of 0.8 given a corporate tax rate of 50%. The formula we used to calculate the global rate of incentives to R & D is described in appendix C.

3 Review of the Literature

Ideally, the efficacy of tax incentives to R & D would be evaluated using cost-benefit analysis, i.e. comparing the social cost of foregoing the additional tax (or shifting it from one use to another) with the social benefit of additional R & D expenditure attributable to these measures. This type of analysis requires detailed information on alternative uses of the taxes dedicated to R & D and the benefits which are sacrificed in consequence, as well as a knowledge of all indirect fallouts from the ensuing research and the administrative costs of a research-support policy. In the absence of this information, the alternative approach used in the literature consists of estimating how much R & D is generated per dollar of tax expenditure. If the extra R & D exceeds the forgone tax revenue, then, as a first approximation, this policy is preferable to direct research funding by the government[6].

A first method of analyzing the efficiency of tax incentives to R & D relies on factual observation. Thus, Lebeau (1996) and Grégoire (1995), using a sample of Quebec firms contributing over 75% of the province's R & D effort, notice that after 1986 the value of R & D increases much more than the tax credits given to Quebec companies during this pe-

largest share of research tax credits. In Quebec, in 1994, they represented about 83% of the total.

[5]Our measure corresponds to the B-index proposed by McFetridge and Warda (1983).

[6]Otherwise, the government assumes responsibility for research and performs an amount of research at least as great as that represented by the forgone taxes. Again, to justify this reasoning, research financed by the government must yield social benefits at least as great as that performed by private firms.

riod. They observe an increase of over 100% in the number of small and medium-sized firms performing R & D in Quebec between 1986 and 1992 (which, incidentally, coincides with an eleven percent decrease among large companies performing R & D). Finally, they find a lengthening of the time horizon of research projects and a growth in R & D from foreign sources. Clearly, as informative as these data are, they do not allow us to attribute full credit for this increase in R & D to tax incentives. The effects of other pertinent variables must be netted out[7].

A second approach consists of surveying firms. Mansfield and Switzer (1985) conducted a survey of 55 Canadian companies. The composition of their sample is representative of the set of all firms in Canada performing R & D. The results reveal that R & D generated by tax incentives did not amount to more than 40% of the lost tax revenue. An econometric regression of R & D expenditures, where the exogenous variables contain dummies identifying different fiscal periods, confirm the results of these surveys. However, a survey by the Conference Board (Warda and Zieminski (1995)) reveals that the R & D tax credit constitutes a more important source of funds for smaller firms. An Australian study (Bureau of Industry Economics (1993)) reveals that only 17% of Australian R & D is performed in response to tax incentives, equivalent to incremental growth of research between $0.60 and $1.00 per dollar of tax expenditure.

The third approach to the problem consists of performing an econometric estimation of the relationship between R & D and tax incentives. We can further divide this procedure into three groups. The first group comprises studies in which the explanatory variables include a dichotomous variable assuming the value one if there was a usable tax credit to R & D (cf. Berger (1992) and Baily and Lawrence (1992)). This is a rough approach, as it makes no allowance for differences in the level of credits between firms. The second group of econometric studies regresses R & D expenditure on a number of explanatory variables including the effective price of R & D, which varies with tax incentives (Baily and Lawrence (1992), Hines (1993), Hall (1993), Bloom, Griffith and Van Reenen (1997)[8]). This approach has the shortcomings of not being founded on a structural model and ignoring the stock aspect of knowledge associated with R & D[9]. Studies in the third group specify a

[7]The evidence from the U.S. reported by Cordes (1989) is also essentially of a factual nature.

[8]The Hall (1993) and Bloom, Griffith and Van Reenen (1997) studies focus essentially on flow elasticities.

[9]There is a further literature on the effectiveness of subsidies to R & D. In this vein, Pagé (1995) estimates that direct assistance to R & D received by a sample of Quebec

demand equation for the stock of R & D that depends on fiscal parameters through the user cost of capital (Bernstein (1986), Hines (1993), Mamuneas-Nadiri (1993), and Shah (1994)). Whichever approach is adopted, it is important to clearly distinguish between elasticities with respect to fiscal parameters relating to stocks and to flows of R & D.

Table 1 summarizes the principal empirical studies on the effectiveness of tax incentives to R & D[10]. Flow elasticities are generally greater that stock elasticities. Baily and Lawrence (1992) report a short-term elasticity of −0.95, Hines (1993) finds −1.6 and Hall (1993) elasticities between −0.8 and −1.5 in the short run and between −2.0 and −2.7 in the long run. Only Bloom, Griffith and van Reenen (1997) obtain fairly low elasticities (−0.10 in the short run and −0.79 in the long run). The first studies to estimate a demand elasticity for the stock of R & D with respect to its user cost were based on an ad hoc dynamic specification with distributed lags. Goldberg (1979) estimates −0.39 for the short-term elasticity and −0.92 for the long-term elasticity on panel data from American manufacturing industries. Nadiri (1980) finds an elasticity of −0.16 in the short term and unity in the long term for the entire U.S. manufacturing sector. Some subsequent studies refine the specification of the R & D demand equation using dynamic models of factor demand based on the notion of adjustment cost. Cardani and Mohnen (1984) and Mohnen, Nadiri and Prucha (1986) estimate the own-price elasticity of R & D from time-series on manufacturing in five countries of the G-7. Their estimates are between −0.04 and −0.10 in the short run (defined as the first stage of the adjustment process) and between −0.25 and −0.55 in the long run. Bernstein (1986) finds short-term elasticities of −0.13 and long-term values of −0.32 for Canadian firms. Nadiri and Prucha (1990) arrive at short-term elasticities of −0.03 and long-term elasticities of −0.12 for the Bell company in the United States. Using panel data on firms, Bernstein and Nadiri (1995) derive long-term elasticities between −0.43 and −0.50 estimated separately for four research-intensive U.S. industries. Hines (1993) obtains an own-price elasticity for research financed by firms of −1.2, and Mamuneas and Nadiri (1995) of −1.0. Estimates based only on R & D funded by private firms seem higher than those which also include R & D financed from public funds.

As to the evaluation of additional research per dollar of tax expenditure, results are divided. Eisner, Albert and Sullivan (1983) stress the fact that few firms were able to take advantage of tax credits for incre-

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firms, operating exclusively in Quebec (thus essentially small firms), generates $1.89 of additional R & D for every dollar received.

[10]For a more comprehensive list of empirical studies on the efficectiveness of R & D tax incentives, see Office of Technology Assessment (1995).

mental research in the U.S., and that in some cases the effect could even be perverse. They further fail to find a significant effect on R & D expenditure attributable to this policy. Mansfield and Switzer's survey (1985) finds that for each tax dollar forgone because of R & D tax incentives only $0.40 in additional R & D is generated. Combining the effects of a change in the fiscal parameters on the user cost of R & D and of a change in this cost on the demand for R & D, Bernstein (1986) calculates that a forgone dollar of tax revenue generates $0.80 of new R & D, if output is maintained constant, and between $1.05 and $1.70 if the spillover impact of output on R & D is considered. Using the same procedure, the General Accounting Office (1989) estimates that the multiplier effect is only $0.35. In contrast, Manuneas and Nadiri (1993) derive $0.95, Hines (1993), $1.20 to $1.90, Shah (1994) $1.80 and Berger (1993) $1.74.

Various reasons may account for the differences in these estimates. The price-elasticity estimates may vary depending on whether the specification is on R & D stocks or flows, whether the estimates are for long- or short-term elasticities, whether we are examining total R & D or only R&D financed by firms. The differences also depend on how the cost of the incentive packages to the government are calculated. It may be the observed cost of a policy or the one reported by the implementing agency (Berger (1993), Mansfield and Switzer (1985), Shah (1994)). It may be estimates or simulations of the changes in costs that firms face following a tax credit (Bernstein (1986), Mamuneas and Nadiri (1993), Hall (1993), Hines (1993)). Finally, it must be borne in mind that all incentive policies are not equal, and may thus yield different results. For example, Hines (1993) simulates the effect on American firms of a 100% deductibility from revenues for R & D expenditures as opposed to deductibility prorated to domestic sales. Other American studies have largely focused on tax credits for incremental research, while Canadian studies tend to examine the global effect of various means of tax support for R & D in Canada.

Table 1: Empirical studies of the effectivenessof tax incentives to R & D

Authors	Data	price elast. of R&D[a]	R & D/$tax	Cost to govt.	Approach
Mansfield & Switzer (1985)	Canada firms survey	Survey responses	0.4	observed	flow
Bernstein (1986)	Canada firms panel	−0.13 (ST) −0.32 (LT)	0.8	elast: cost/ fisc. param.	stock
Shah (1994)	Canada industries panel	−0.16 (ST)	1.8	observed	stock
Baily & Lawrence (1992)	United States industries time-series	−0.95 (ST)			flow
Hines (1993)	United States firms panel	−1.2 (stock) −1.6 (flow)	1.2 (stock) 1.9 (flow)	individually simulated	stock flow
Hall (1993)	United States firms panel	−0.8 to −1.5 (ST) −2.0 to −2.7 (LT)	2.0	individually simulated	flow
Mamuneas Nadiri (1993)	United States industries panel	−1.0 (ST)	0.95	elast: cost/ fisc. param.	stock
Berger (1993)	United States firms panel	dichotomous variables	1.74	observed	flow
Asmussen Berriot (1993)	France firms	R & D w/t increm. R&D tax credit elast. = 0.013	0.26	observed	flow
Bureau of Ind. Economics (1993)	Australia Enterprises Survey	Survey responses	0,6 to 1,0	observed	flow
Bloom, Griffith and van Reenen (1997)	Panel of 8 countries aggregates	−0.10 (ST) −0.79 (LT)			flow
ST = short-term			LT = long-term		

a) A R & D flow or stock-price elasticity, depending on the study referred to.

4 Data

Our study is unique in that it uses firm-level data, assigning a specific effective price of research to each firm taking into account its particular situation and relevant tax-credit ceilings.

We use annual firm data for the period from 1975 to 1992 drawn from Standard and Poor's Compustat (Canadian file) database[11]. This data contains a good deal of information, including expenditure on R & D and some technological and financial characteristics of the firm. The database features the largest firms (in terms of revenues or capitalization) traded on the major U.S. exchanges (New York Stock Exchange,

[11]The production deflators from the input-output tables for 1993 were not yet available when we began our study. For 1994, there were many holes in the Compustat database.

American Stock Exchange, and NASDAQ) as well as those belonging to the TSE300 on the Toronto Stock Exchange. The information is drawn from annual reports and from the 10K reports submitted to the Securities and Exchange Commission (SEC) in the United States (the American equivalent to Canada's provincial securities commissions).

The Compustat database has been extensively used to study U.S. firms, but not Canadian firms. It contains several selection biases as it comprises primarily large, publicly-traded firms with substantial capitalization. To our knowledge, however, there exists no publicly available database of Canadian companies which is more complete.

To obtain reliable empirical results, we first needed to clean the data, eliminating firms with anomalous characteristics. First, we removed companies we suspected of receiving direct R & D subsidies, either from government or from other firms. Tax incentives have little if any influence on these firms, and hence we chose to withdraw them from our sample. We used two methods to identify such firms. First, sometimes the database itself indicated that they received subsidies from government or other sources. Second, if the variable "revenues before extraordinary items" plus R & D expenditures was negative for three consecutive years, we eliminated all data relative to the firm in question. This criterion is based on the notion that a business cannot for a long time stay alive while running deficits. These firms may belong to corporations which under the Canadian Income Tax Act and the Quebec "loi de l'impôt sur le revenu" may impute part of their tax credits to associated companies (sponsors) who can reduce their tax bill. Not having the necessary information to trace the associated companies, we chose to drop those firms. It is conceivable that a firm may have received government subsidies for a single year. In this case, we compared its R & D intensity (R & D/sales) before and after the subsidy. In the absence of a significant change, we retained the company, assuming the subsidy to be minimal. Otherwise, the observation was dropped, along with all preceding and subsequent ones, if there were three or less. In a very few cases we dropped a single observation in the middle of the sample, treating the remaining series as two companies (in order to have continuous data).

Our second selection criterion dealt with the definition of R & D expenditures. Compustat informs us that for some years certain firms inflated their R & D expenditures with "engineering"-type spending. These outlays are by definition fairly routine, and should be classified as operating costs rather than as R & D. Moreover, they are not eligible for R & D tax credits. We eliminated these firms, as we were unable to determine the proportion of spending attributable to engineering in overall R & D expenditures. However, this "inflating" was an occasional occurrence, and if we were unable to detect a significant change induced in the R & D intensity, either before or after, we retained the firm[12].

The third exclusion criterion was based on the R & D intensity variable. We expect this ratio to be less than one. Simple accounting principles imply that expenditures in this field cannot exceed the firm's total revenue. However, this ratio may exceed unity in the case of new firms, which may not immediately generate sufficient revenue to cover their research costs. Nonetheless, a firm will not be viable if it consistently has an R & D intensity greater than one. In fact, the companies we eliminated on these grounds belonged to the set of companies suspected of receiving subsidies.

Our fourth exclusion criterion dealt with holding companies. We eliminated seventeen firms on this basis, including BCE Inc., which incorporates Bell Canada, Northern Telecom, and Bell Mobility in our sample.

Finally, to ensure a sufficiently long time horizon for the retained firms, we dropped those with fewer than four observations.

Thus, of the 5642 observations on 573 firms in the initial sample, we retained an unbalanced panel of 434 firms for a total of 4859 observations in the restricted sample. Table A4.1 (in the appendix) reveals that 86 firms were eliminated because of insufficient observations. From the 487 companies not eliminated on this basis, 49 were dropped on the basis of one or several of the other criteria.

We used the database *Cancorp plus* from Disclosure Inc. (1995) as well as an internal database from Industry Canada, Bureau of Corporate Affairs and Legislative Policy to locate the firms, as the effective price of R & D varies across provinces. Since we had no information on where each firm conducted its R & D, we assumed that it was distributed uniformly among those provinces in which the firm was active[13].

The country of origin of the controlling entity was found in the Statistics Canada publication "Inter-corporate ownership", catalogue 61-517[14]. We deflated sales data using the implicit production price by

[12]Even the criteria established by Revenue Canada and Statistics Canada to distinguish R & D from other innovation related activities are not necessarily clear to accountants or to respondents of the questionaire of the R & D survey. For example, routine testing, minor product adaptations and corrections are not recognized as R & D for purposes of the Income Tax Act.

[13]Regressions using the alternative hypothesis that the firms performed all of their R & D in the province in which they were incorporated did not produce significantly different results. Fifteen of them conducted their research in several provinces and five in a province other than the one in which they are incorporated.

[14]Owing to a lack of resources, we only gathered this data for the years 1982 and 1992. Notice that the structure of foreign ownership of the firms in our sample

industry from Statistics Canada's input-output tables, catalogue 15-201 and 15-202. The industry to which each firm is deemed to belong is the Canadian equivalent of the industry associated with it by Compustat.

Together with Statistics Canada we constructed R & D deflators for 39 industries. These deflators are chain Laspeyres indices based on the implicit research-personnel wage-and-benefits index for the research staff and on the implicit GDP price-index for other current expenditures, as well as for plant and equipment used for R & D. Data on R & D, R & D personnel and R & D labor costs for each industry were drawn from the survey on industrial R & D from Statistics Canada (cat. 88-202). About 60% of research costs are industry specific. As to the remainder, it appeared plausible to us to assume that these costs do not vary much between sectors, and thus the GDP price-index serves as a representative mean price[15]. Complete surveys of industrial R & D were only performed in odd years between 1973 and 1981. Statistics Canada estimated total R & D for even years during this period using data from a smaller survey, but data on wages and staffing for R & D from these surveys are not very reliable. Data on the wage index for R & D staff for even years between 1973 and 1981 were constructed by interpolating the ratios (research-labor cost)/(total R & D) and (research personnel)/(total R & D) and relating them to total R & D estimates for the even years.

The initial stock of R & D was constructed on the assumption that it accumulated over the entire sampling period at the same average rate as gross production[16]. This procedure yields an initial stock unique to each firm. For the other years, the R & D stock accumulates according to the permanent inventory formula. The user cost of research is defined as the effective price multiplied by the sum of the interest rate (we used ten-year and longer government bonds from the Bank of Canada), and of the depreciation rate of R & D, fixed at 10%.

Before proceeding to describe the model, we shall present some characteristics of our data (a more detailed analysis can be found in appendix D). Among the 434 firms in our sample (after eliminations), only 108 perform, or declare performing, R & D. For about 70 of these we have data

remained very stable. Only seven firms changed country of control between these two years. We used foreign-ownership data for 1992.

[15]Our R & D deflator is similar to that used by Jaffe and Griliches (cf. Bureau of Labor Statistics (1981)).

[16]The initial stock is constructed from the equation:

$$R_{i0} = \frac{\sum_t^T I_{it} (1-\delta)^{T-t}}{(1+\gamma_i)^T - (1-\delta)^T},$$

where γ_i is estimated by the regression $\ln(Q_{it}) = [\ln(1+\gamma_i)]\, t + \ln(Q_{i0}) + \epsilon_{it}$.

for ten consecutive years or more. Companies conducting R & D are relatively over-represented in our sample, as for the Canadian economy as a whole only 0.3% of firms performed research in 1980 (Department of Finance (1983)).

The fact that the R & D figures reported in Compustat include R & D performed outside of Canada matters only to the extent that support for this research is more limited (for example, it is limited to current expenses and not supported by provincial tax credits). Overall, our sample of 416 firms, of which 78 performed R & D, represents 39% of all R & D in the Statistics Canada survey for 1989. This percentage does not include the major R & D performers in Canada since, in 1992, 25 Canadian firms conducted 45% of total research there (Statistics Canada, cat. 88-202)[17]. Small and medium-sized companies are also under-represented. Among firms which declare employment (this data is missing for several firms), only 25% have fewer than 200 workers. Thus we have a truncation at both extremes of the distribution of firms.

The index of tax incentives ($F1$) ranges from 0.5 to 1.8 for different firms. A large part of this variation derives from ceilings on the use of tax incentives unique to each firm. Thus, for 20% of the observations on firms performing R & D, these expenditures could not be deducted entirely because the tax bill was not high enough in the year in which they were incurred ($\delta_0 < 1$, cf. the appendix). In only 11% of cases tax credits could not be entirely claimed in the year in which the R & D was performed ($H < 1$). For 22% of observations with R & D, tax credits for incremental research could not be claimed ($\phi = 0$).

5 Econometric Specification

We have a number of firms, some of which perform R & D while others do not, or do not declare it. Firms listed on U.S. exchanges are obliged to report their R & D expenditures to the SEC if these are substantial or exceed one percent of gross revenues. For these firms we may assume that if no R & D expenditures were declared, or if the data is missing, then none was performed[18]. About half of the firms in our sample did not submit a 10K report to the SEC. Numbers published by Compustat

[17]Comparing the top 100 Canadian companies in terms of R & D budget from Research Money (June 1995) and from the TSE300 list, we notice that the R & D firms not included in our sample are also not in the TSE300. We thus have a selection bias toward firms which are heavily capitalized.

[18]Bound et al. (1984) make the same assumption. As these authors indicate, it may be the case for some missing data that Compustat either did not obtain the information, or deemed it not to be true R & D.

for these companies are retrieved from their annual reports. In large part these are Canadian firms belonging to the TSE300, i.e. not traded on American exchanges. We are confident that the R & D disclosed in these companies' annual reports is relatively complete for the following three reasons. First, the proportion performing R & D is about the same as for the entire sample, so there does not seem to be a systematic bias toward not declaring R & D among these firms. Second, according to Canadian accounting standards, firms are expected to report R & D in their financial statements[19]. Third, in our sample all but three of the top 100 R & D performing firms declare R & D operations[20].

Our data is thus well suited to the application of the generalized tobit model. Firms perform research if $g\left(z_{it}\right) + u_{2,it} > 0$, where z_{it} is a vector of variables determining the threshold below which firms perform no R & D, and $u_{2,it}$ is a random term. We assume that $g\left(\cdot\right)$ is a logarithmic function. If $g\left(z_{it}\right) + u_{2,it} \leq 0$, firms do not engage in R & D. For those that do, the potential investment is realized. Since R & D expenditures constitute an investment in intangible capital, it is more satisfactory from a theoretical standpoint to specify a capital accumulation equation rather than a simple investment function. We further assume that depreciation occurs at a rate δ, set equal to 10%[21]. Moreover, many empirical studies have shown that there are adjustment costs associated with the accumulation of the stock of R & D (organizing the research team, project financing, elaboration of the research program). Nonetheless, instead of specifying an adjustment-cost function, we opted to use a partial stock-adjustment formulation, which is consistent with the adjustment-cost model (on net investments as well as on replacement investments) (cf. Lucas (1967)). The complete model is thus:

$$\begin{cases} [R_{it} - (1-\delta)R_{i,t-1}] = 0 \\ if \;\; g(z_{it}) + u_{2,it} \leq 0 \\ [\ln R_{it} - \ln R_{i,t-1}] = \alpha[\ln R^{*}_{it}(x_{it}) - \ln R_{i,t-1}] + u_{1,it} \\ if \;\; g(z_{it}) + u_{2,it} > 0 \end{cases} \tag{5.1}$$

where R^{*}_{it}, the desired stock of R & D at time t, is a double logarithmic function of the variables x_{it}, R_{it} is the actual stock of R & D at the

[19]See the Canadian Institute of Chartered Accountants Handbook, Accounting Recommendations, updated as of June 1995, section 3450, research and development costs.

[20]The three firms from Research Money (1992) for which we do not have R & D data are Seagram, Xerox, and Repap. These are all multinationals with foreign offices, and it is possible that their R & D is not accounted for in the Compustat Canadian file.

[21]In the literature, this rate varies between 10% and 25%.

end of period t, α is the proportion of the adjustment realized at time t, and where the random variables $u_{1,it}$ and $u_{2,it}$ have a normal bivariate distribution with mean zero and covariance matrix Σ. We chose a double logarithmic formulation because it yielded the best results and had the further advantage of reducing the possibility of heteroscedasticity in the error terms. We also postulated independence between observations[22]. Estimation of this type of model using maximum likelihood yields consistent estimators (cf. Maddala (1983), Gourieroux (1989)).

Among the variables x_{it} and z_{it} which determine the existence and level of R & D activity, we are primarily interested in the effective price of research, which is the research deflator divided by the sales price and multiplied by the B-index, defined in appendix C. A simultaneous equation bias may exist to the extent that tax incentives vary with the level of research and that firms hit ceilings on deductions and tax credits. This bias should be small, since our sample is biased toward large firms which in general do not benefit from the most generous tax breaks and have sufficient income not to be affected by these ceilings. To make the demand for R & D homogeneous of degree zero in prices, we deflated the effective price of R & D by the sales price rather than a particular input price, since the sales price acts as a general index of the input prices (even when it incorporates a constant mark-up over the average production price).

Several other R & D determinants must be considered to net out their effects on the amount of R & D undertaken[23] [24]. These are in

[22]Since $I_{it} = R_{it} - (1-\delta)\, R_{i,t-1}$, we see that our stock model simplifies to a flow model if depreciation is immediate $(\delta = 1)$.

[23]As mentioned below, the introduction of dummy variables for years and industries among the explanatory variables renders the assumption of independence of error terms between observations more acceptable. We could also have accounted for variability in the tax incentives, which Hall (1983) found significant for the United States. However, Canadian policy in this area has been more stable than that of the U.S. To neutralize the effect of firms performing R & D in other countries which, on one hand, benefit less from Canadian tax incentives and, on the other hand, may benefit from such arrangements in the host country, we could have included a variable for foreign holdings or, better yet, indices of tax incentives for these countries. Constructing such a variable was beyond the scope of this study.

[24]Because of the unavailability of data, we were not able to account for growth prospects. These could be measured by observed growth (assuming perfect foresight), or by Tobin's q but at the cost of losing quite a number of observations. Also, we chose not to include the variable "age of the firm" in the regression despite the fact that we often observe a considerable drop in the R & D/sales ratio after the first few observations (for aforementioned reasons). For one, we must not assume that firms newly included in Compustat are necessarily new firms: they appear in this listing when they have achieved a certain degree of capitalization. Second, exploratory regressions did not yield a significant coefficient for this variable.

order:

1. Year dummies— These capture technological progress or other time-specific effects, such as changes in R & D tax incentives which we were not able to incorporate into our B-index of tax incentives.

2. Industry dummies — They capture all industry-specific factors not accounted for by the other variables, such as the degree of concentration and technological opportunities.

3. R & D level for the industry — A positive impact indicates a spillover effect, a strategic complementarity between the firm's research and that of other companies in the industry. This may be due, for example, to the need for R & D to absorb within-industry technological externalities. A negative impact reveals a substitutability between the firm's own research and that of its competitors. Most studies have found complementarity for large firms and for hi-tech. firms and substitutability for the others (Mohnen (1996)).

4. Accumulated retained earnings — In order to protect their trade secrets as much as possible, companies prefer to finance research from their own funds rather than borrowing from banks or financial markets (Himmelberg and Peterson (1994)). Thus, R & D expenditures are more likely to occur when internal financing is available (Berger (1993)).

5. Size — Because of returns to scale in R & D, greater R & D financing possibilities for large firms and the perspective of higher returns to R & D associated with larger markets, one would expect size to be positively correlated with R & D effort. On the other hand, larger firms tend to be burdened with bureaucratic decision-making processes, which may attenuate this advantage. The empirical evidence on this matter is ambiguous. Scherer (1980) cites studies which have established the existence of a threshold, above which R & D grows more slowly than sales. Other studies have shown that the relationship between sales and research intensity has an inverted U-shape, with the most active firms being medium sized. Bound et al. (1984) found a U-shaped relationship. We measure size by total sales[25].

[25]Data on employment was missing for too many firms to be a useful measure of size.

6. The nationality of the firm's head office — It is often claimed that Canada has the lowest level of R & D effort of the G-7 because of its high proportion of foreign controlled companies, which are presumed to perform most of their research in the home country. Hines (1993, 1994) has shown that multi-national firms are not indifferent to tax incentives when locating their R & D around the world. Bloom, Griffith and Van Reenen (1997) confirm these results.

7. Physical capital — This may be a complement or a substitute for research. Most empirical studies conclude that the relationship is complementary.

We also estimated a model of random individual effects, in which a random term $\alpha_{j,i},\ j = 1, 2$ is added to the error term $u_{j,it}$. In that case, we assume that the α-s are distributed independently of the u-s and follow a normal-bivariate distribution $N(0, \Omega)$, where the elements of Ω are parameters to be estimated. This version of the model was estimated by the simulated maximum-likelihood method. In the unconditional likelihood function, the double integral with respect to the $\alpha_{j,i}$'s is replaced by a mean of n random draws from $(\alpha_{1i}, \alpha_{2i})$[26]. These estimates may not be consistent if the stochastic individual effects are correlated with some of the explanatory variables. To correct for this eventuality, we also estimated the random-effects model including among the independent variables their respective means for each firm.

To ensure that the covariance matrix of the error terms Σ is positive definite, we reparametrized its elements : $\Sigma = \left(1, \rho\sigma_1^2, \sigma_2^2\right)$, where $\sigma_1 = 1$, ρ is the coefficient of correlation between $u_{1,it}$ and $u_{2,it}$, and σ_2 is the standard deviation of $u_{2,it}$, as $w = \ln(\sigma_2)$ and $z = 0.5 \ln \left[\frac{(1+\rho)}{(1-\rho)}\right]$. We also reparameterized the elements of Ω.

If the error term is heteroscedastic, and if this is not accounted for in the formulation of the maximum-likelihood function, the estimators are no longer consistent. To avoid problems of heteroscedasticity we used ordinary least squares to perform a preliminary estimation (for each specification we explored) of the quantitative part of the model, and

[26]To perform random draws from the distribution of $(\alpha_{1i}, \alpha_{2i})$ with covariance Ω, we can proceed as follows: draw from two independent standard normal distributions $N(0, 1)$, b_i and g_i, then setting $\omega_1 = \sqrt{\omega_{11}}$, $\omega_2 = \sqrt{\omega_{22}}$ and $\xi = \frac{\omega_{12}}{(\omega_1 \omega_2)}$ generate $\alpha_{1i} = b_i \omega_1$ and $\alpha_{2i} = \left(\xi b_i + \sqrt{1 - \xi^2} g_i\right) \omega_2$. We performed 10 draws for each observation. Lemieux and McLeod (1996) report that simulation based on ten or twenty draws yielded very similar results.

performed a Breusch-Pagan test. As heteroscedasticity prevailed, we regressed the log of the square of the error terms on a set of variables which yielded significant coefficients. We then used the estimated standard errors to weight the observations so as to preserve homoscedasticity. In the presence of uncorrected serial correlation in the likelihood function, the estimators remain consistent but are not efficient, while the estimated standard deviations of the parameters are no longer consistent. Testing for first-order serial correlation in the quantitative part of the model under the assumption of a constant coefficient of serial correlation for all firms, we obtained a coefficient of 0.25. With a coefficient of this size, we chose not to correct for autocorrelation (Fomby-Guilky (1978) and Dagenais (1994)).

6 Analysis of the Results

We estimated the fixed-effects model for different values of ρ. In table 2 we present the results for $\rho = 0.9$[27]. In both parts of the model, we eliminated the variable nationality of the firm, FC, since its coefficient were not significant and had little impact on the other results. For the same reason we dropped the variable retained earnings, $RETEARN$, in the probit part of the model[28]. There is no dichotomous variable identifying the industry in the probit part of the model, since when all the firms in an industry do, or do not, perform R & D, this variable alone explains the entire qualitative aspect for this industry, and hence its coefficient is indeterminate. Also note that we lagged the variables $SALES$ and stock of physical capital, $CAPITAL$, and measured for each firm the industry R & D stock net of the firm's own stock of R & D.

The coefficients for the effective user cost of research have the expected sign: if the effective cost of R & D declines, the probability that firms which weren't performing R & D will begin to do so, and the

[27]Because the calculations were very time consuming, we only considered a few values for ρ. For these values, the maximum of the likelihood function increased with ρ. Because of concerns about the precision of the calculations, we were not able to explore values higher than $\rho = 0.97$. However, for values of ρ higher than 0.7, the changes in the estimated coefficients were negligible relatively to their standard errors. For similar reasons of precision, calculations performed in which ρ was treated as an additional parameter to be estimated did not converge. Note that fixing ρ may have as a consequence to underestimate the asymptotic variances of the estimators of the other parameters.

[28]For some observations the retained earnings were negative. We replaced these values with values slightly above zero. Modifying these values did not materially affect our results.

amount of R & D conducted by those already involved, both increase. This coefficient is small and is not significant in the probit part. In the regression part, the elasticity of research with respect to its own user cost is -0.07 in the short term and -1.09 in the long term, given the estimated speed of adjustment of R & D of six percent per year[29]. These estimates are compatible with those found in the literature. Consequently, if changes in fiscal policy were to reduce the effective price of research by ten percent, the stock of R & D would increase by 0.7% in the first year and by 10.9% in the long term.

The stock of R & D, $STKRD$, increases with the size of the firm. There appears to be a complementary relationship between research capital and physical capital, but a substitutability between own R & D and industry-wide R & D. As expected, the availability of internal funding increases research efforts, but this coefficient is not significant. Sectoral effects (not reported in table 2) may be interpreted as indictors of technological opportunity. It is not surprising that sectors which are research intensive, such as telecommunications equipment, office equipment, pharmaceuticals, scientific equipment, computer services, etc., have positive coefficients. In the qualitative part, sales and the physical capital have a negative sign. It appears that, in our sample, there are fewer large firms than small firms performing research, as it is unlikely that any one firm will stop conducting research as it grows. Firms which were performing R & D continue to do so (positive coefficient on the lagged R & D stock variable). Time dummy variables (not reported in table 2) have a positive sign, indicating an increased propensity to perform R & D relative to 1975.

We performed sensitivity analysis on the fixed-effects model.

1. If we use firm dummies instead of industry dummies, the price effect becomes insignificant and drops to zero for the short and for the long term. The model is, in a sense, over-parametrized. When individual fixed effects are included, nearly all the explanatory power of the model seems to be captured by these effects. This type of result is common in longitudinal studies. It is more difficult to extract information from the variation of the other variables over time, in the presence of these individual fixed effects.

2. Replacing the time dummies with a trend variable (with or without a squared term in order to capture the acceleration or deceleration of technical progress) yields less satisfactory results.

[29]The speed of adjustment α of the capital stock toward its long-term equilibrium is obtained from the coefficient $(1-\alpha)$ of the lagged stock of R & D..

3. Since the number of firms may vary between industries, it is perhaps less the total capital stock of the industry than the average capital stock per firm in the industry that one should look at. We divided the industry stock by the number of firms performing research or by the total number of firms in that industry. Our results were only marginally affected. As neither the data on the number of firms conducting R & D, nor those on the total number of firms in each industry were very reliable because of changes in the R & D surveys and in industrial classifications, we chose not to retain these results.

4. The effective price of research is itself endogenous insofar as ceilings on tax credits for R & D may depend on the amount of R & D performed. If we regress the effective price of research on its price without ceilings and on other exogenous variables, and use the resulting fitted variable as an instrument, the problem of endogeneity is avoided. The short-term price elasticity is then increased very slightly.

5. We performed a regression with the annual means of the variables for each firm (only in the quantitative part of the model), omitting the lagged dependent variable. This is equivalent to performing an inter-firm estimation and suppressing variations over time, and yields another estimate of the long-term price elasticity of R & D. The coefficient of the effective price is -1.3, and the t-statistic is 1.7. This estimate appears quite similar to that yielded by our dynamic model.

6. The lagged R & D stock variable in the qualitative part of the model captures a large share of the explanatory power of the model, but does not reveal why a firm performs research. However, if we omit this variable, we risk increasing the serial correlation of the error term and inducing an estimation bias since we no longer account for the individual firm's propensity to perform R & D. The absolute value of the coefficient of the effective price then increases and becomes significant in the probit part of the model. In the regression part, the coefficients of the lagged R & D stock variable and of the effective price are modified so as to make the long-term price elasticity become unreasonable. Because of this lack of robustness and the increased risk of serial correlation, we dropped this specification[30].

[30] In the qualitative part of the model, the log of the stock of lagged R & D was set to -12 for firms not performing R & D.

7. To compare with other studies, we also estimated a flow model, which is consistent with our model if we set the depreciation rate for research equal to one. Our estimate of the short-term elasticity of R & D expenditures with respect to the effective price of research is at least four times smaller than those reported by Hall (1993), Hines (1993) and Baily and Lawrence (1992) using the flow model on American data. Our results are close to those reported by Bloom, Griffith and Van Reenen (1997). However, we believe that the assumption of immediate depreciation is not realistic.

8. Instead of a double-log specification, we tested a linear specification of the model. Neither the signs nor the orders of magnitude of the estimated coefficients made any sense.

9. We estimated a dynamic specification with finite lags and various lag structures. These results were even less satisfying.

As noted above, we also considered models with random effects. In addition, we estimated a simple Tobit model, with fixed effects and with random effects. The maximum values we obtained for the likelihood functions suggested that these models are less appropriate, judging by the criteria suggested by Pollack and Wales (1991).[31]

[31] As can be seen in table 2, in the retained solution, the log-likelihood function is equal to -2136.88. The total number of estimated parameters is equal to 77. For the random effects model, the value of the log-likelihood function was -3602.28 with 87 estimated parameters. The number of parameters in the random effects model was larger because, as mentioned before, we included the means of the explanatory variables as separate regressors. For the simple Tobit model with fixed effects, the log-likelihood was -2412.08 with 53 parameters and for the simple Tobit model with random effects, the log-likelihood was -2386.90 with 56 parameters.Here we only included the means of the explanatory variables which yielded significant coefficients, namely three.

Table: 2 Results of the Generalized Tobit Model

Fixed Effects Model with $\rho = 0.9$					
Probit Part			Regression Part		
Variables	Estimator	t-stat.	Variables	Estimator	t-stat.
Intercept	−0.6776	−1.708	Intercept	−0.3574	−0.606
$\ln(CEFF)$	−0.0169	−0.105	$\ln(CEFF)$	−0.0686	−1.632
$\ln(SALES_1)$	−0.1307	−2.505	$\ln(SALES_1)$	0.0279	1.373
$\ln(STKRDT)$	0.0499	1.291	$\ln(STKRDT)$	−0.0163	−1.419
$\ln(CAPITAL_1)$	−0.1283	−2.736	$\ln(CAPITAL_1)$	0.0161	0.927
$\ln(STKRD_1)$	0.4214	14.701	$\ln(RETEARN)$	0.0312	0.472
			$\ln(STKRD_1)$	0.9369	115.143
time dummy		yes	time dummy		yes
sector dummy		no	sector dummy		yes
Number of observations:		4859	log of the likelihood:		-2136.88

7 Effectiveness of Tax Incentives to R & D

Did increases in R & D spending induced by changes in tax policy exceed the forgone tax revenues?

If we calculate the amount of R & D induced by a dollar of tax expenditure using Bernstein's (1986) method, we obtain \$0.40 in R & D for each dollar of tax expenditure, which is half of what he obtained[32]. We propose a new measure. It compares in present value terms the difference in R & D expenditures on the old and on the new path of adjustment toward the respective steady state to the difference in the cost incurred by the government to support the R & D by fiscal policy in the two scenarios.

Assume that before the change in the fiscal parameter, γ, R & D expenditures (I_t) tended toward a long-term equilibrium R & D stock, R_t^*. After the change, R & D spending adjusts so that the stock slowly moves to its new long-term equilibrium. Let I_t', $t = 0, \ldots, \infty$, be the adjusted expenditure on R & D and $R_t^{*\prime}$ the new long-term equilibrium stock. Previously, the government supported some proportion, β_1, of the level of R & D expenditures, and a further proportion, β_2, of the growth in these expenditures with respect to a certain base. Subsequent to the change, these values are β_1' and β_2' respectively. If support to research has increased, $\beta_1' \geq \beta_1$ and $\beta_2' \geq \beta_2$. The government collects taxes at

[32]Bernstein (1986) takes the ratio of the change in the value of the stock of research and the change in the cost of production subsequent to a change in tax policy. The numerator is interpreted as new investment in R & D while the denominator represents a direct government subsidy. It can be shown to be equivalent to the ratio of the elasticity of the stock of R & D (multiplied by the research deflator) to the user cost of R & D.

the rate $(u_f + u_p)$[33] on the return (ζ) to the increased stock of R & D. The formula we propose to calculate the induced R & D per dollar of tax expenditure is:

$$\frac{\Delta RD}{\Delta TaxExp} = \frac{\sum_{t=1}^{\infty} \frac{\left(I_t' - I_t\right)}{(1+r)^{t-1}}}{\sum_{t=1}^{\infty} \frac{\left\{\beta_1'\left(I_t' - I_t\right) + \left(\beta_1' - \beta_1\right) I_t + \left[\beta_2'\left(I_t' - \bar{I}_t'\right) - \beta_2\left(I_t - \bar{I}_t\right)\right] - \Omega_t\right\}}{(1+r)^{t-1}}} \tag{7.2}$$

where r is the interest rate, $\bar{I}_t = \frac{(I_{t-1} + I_{t-2} + I_{t-3})}{3}$, and $\Omega_t = (u_f + u_p)\,\zeta\,(R_t' - R_t)$. Gross investment is $I_t = R_t - (1-\delta)\,R_{t-1}$, where $R_t = (R_t^*)^{\alpha}\,(R_{t-1})^{1-\alpha}$ and $R_t^{*\prime} = R_t^* + \frac{\partial R_t^*}{\partial \gamma}$.

To better understand this measure it is useful to decompose the denominator. The first term represents the cost to the government of a change in the level of R & D. The increase in R & D may be due to a change in a fiscal parameter via β_1 and/or β_2. The second term represents a simple transfer payment. Notice that if the incentives only affect β_2, the fiscal transfer disappears. This is a subsidy to R & D expenditures which would be performed in any case. The third term relates to the differential in support associated with incremental R & D. The fourth term represents the additional taxes collected on returns to the new research.

Let us apply this measure to one percent variations in the different fiscal parameters which determine the effective cost of research — distinguishing between effects on those firms which are, and those which are not, constrained by ceilings. A one percent increase in the federal tax credit to R & D yields an average of $0.98 additional R & D expenditure per dollar of tax expenditure. This result applies to all the firms in our sample which perform R & D and which are subject to a ceiling in their use of federal tax credits. Using this same measure on firms which are not subject to a ceiling, we obtain $1.04. The possibility of carry forward and carry back and of immediate reimbursements seems to remove the effects of ceilings. Furthermore, increases in the provincial R & D tax credit, which correspond essentially to a subsidy, yield $1.09 in additional R & D per dollar of tax expenditure[34]. These orders of magnitude are significantly lower than most of those reported recently in the literature. They are, however, close to those calculated by Bernstein (1986).

[33]Additional attention should be paid to the impact tax incentives have on the probability of performing research. Since,in our case, this is negligible, we ignore it.

[34]These results are for values of β_1, β_1', β_2, β_2' particular to each firm. We assume that R & D yields an internal after-tax return of 20%.

Tax transfers account for over 80% of government support for R & D. The inefficiency of tax credits has been illustrated in the case of Australia, where a study by the Bureau of Industry Economics (1993) reported that 83% of R & D eligible for tax incentives would have been performed in any case. Since these transfers are sizable, it seems appropriate to analyze the behavior of our measure relative to a variation in the incremental research tax credit. If the only support to research consisted of tax credits to incremental research, the tax transfer would disappear, as the government would only be paying a fraction of the new research and not subsidizing recurring R & D. A one percent increase in this parameter stimulates \$4.00 in extra R & D per dollar of government expenditure! However,this extremely large amount is misleading; it is due to the fact that the denominator in equation (7.2) becomes then very small. It should, in fact, be noted that the growth in research effort in response to an incremental incentive is minimal, since the elasticity of the effective price of research with respect to a change in the rate of credit to incremental research is only -0.01.

The final fiscal parameter appearing in the effective price of research is the corporate income tax rate. On the one hand, a lower rate has the effect of diminishing government support for R & D ($\beta_1' < \beta_1$ and $\beta_2' < \beta_2$), since firms can deduct less for R & D expenditures. On the other hand, a lower rate increases after-tax income and therefore decreases the effective price of R & D. In general, the second effect dominates[35]. A decline in the corporate tax rate allows the government to reduce tax expenditures on recurring R & D. Since the effective price is lower, firms invest more in R & D. Thus, we may even find a growth in the level of R & D together with a decline in government outlays. One could not conclude, however, that such a policy would be fully efficient, given the numerous other effects it would have on the economy. The research tax credit seems to us a more targeted and appropriate method of stimulating R & D.

Before concluding, we wish to underline some of the limits to our study and suggest future areas of research:

1. We do not know whether support for R & D in Canada may have prompted some companies to locate in Canada instead of going elsewhere. This in and of itself, would be worth a study. Hines (1994b) finds that R & D locates in response to tax considerations,

[35]There are exceptions where the effective price for R & D increases with a lower tax rate. This is the case for Quebec firms which are not taxed at the provincial level for research tax credits. This is also true for some firms which face ceilings in their use of research tax credits, but which may use the incremental research credit.

such as the possibility of tax-free repatriation of royalties generated by research or the receipt of tax credits prorated to foreign sales.

2. It is likely that the inefficiency aspects of tax credits would be even greater if more of the large Canadian firms had been present in our sample. Conversely, the incentives provided by tax credits may be underestimated to the extent that small firms are under-represented in our study.

3. It is possible that the elimination of firms with fewer than four observations may have lead us to drop starting firms and hence to ignore the effect of tax policy on the creation of new firms.

4. We did not account for the possibility that tax credits for investment in plant and equipment may stimulate research. This may work two ways. First, tax credits provide companies with internal liquidity which may serve to fund research projects, while investments in physical capital can more easily be financed on capital markets. Second, inasmuch as the two types of investment are complementary, support for investment in physical capital stimulates investment in R & D capital. But, two counterarguments can be raised. First, the two types of investments may prove to be substitutes. Second, it is not obvious that investments in plant and equipment Granger-cause investments in R & D. Lach and Schankerman (1989) actually found the opposite to be true.

5. Our results are biased upward to the extent that some R & D expenditure claims may be inflated in order to benefit from tax credits. However, the complaints voiced by firms concerning the tight verification process accompanying applications for R & D tax credits lead us to believe that this bias is probably small. Our results may be biased downward to the extent that tax incentives induce firms to conduct informal research not accounted for in our data (cf. Lipsett and Lipsey (1995) for an evaluation of the latter in British Columbia).

6. Of the R & D induced by tax incentives, some would not otherwise have been performed, and this research is probably characterized by a low rate of return. In other words, we do not know whether these incentives promoted good or bad projects. To evaluate this, it would be necessary to have access to data measuring the output of the research, such as innovations, publications or patents.

7. We did not account for the administrative costs of tax incentives (auditing, project verification by experts, separate accounting).

Gunz et al. (1996) suggest that the procedures for claiming R & D related tax credits generally do not cost firms more that 0.7% of the amounts claimed. These weigh much more heavily on small firms, however, where the corresponding figure is about 15%. The cost to governments of administering these projects must also be included.

8. Since we adopted a partial-equilibrium analysis we did not consider the indirect incidence of fiscal stimulants, as emphasized by Berger (1993). Firms benefiting from tax credits may find themselves forced by competition to share some of their tax benefits with other agents (buyers facing lower prices, suppliers receiving higher prices, and research staff benefiting from salary increases).

9. While ceilings on tax incentives were considered, we do not know whether all potentially available tax credits were in fact claimed. About 20% of the firms in our sample attained tax-credit ceilings, while a study by the Department of Finance (1983) reported that for companies with $50 million and more in equity, 60% of research-related tax credits went unused in 1981. Clearly, the carry forward, the carry back, and the immediate reimbursement provisions introduced in 1983 eliminated most of the ceilings which had existed earlier.

10. In addition to stimulating R & D, tax incentives may encourage firms to change the pace and composition of their research.

8 Policy Relevance

The reasons given to justify government support for private R & D derive from its public good characteristics. Nonappropriability of benefits, high risk, and enormous financing requirements all prevent firms from performing the socially desirable level of R & D, given the externalities it generates. Tax incentives are superior to contractually targeted research subsidies, because they leave R & D decisions under the control of the individual entrepreneur, who is more knowledgable about his market and the required innovations than a political decision-maker can be. Furthermore, the prospect of losing money or making profits provides an incentive to make the right choices. The moral hazard of policy makers joining hands with recipients of research funds to pursue their own interests at the expense of social welfare is lower with tax inducements than with subsidies. Although contracts and direct subsidies allow funds to be channelled to promising projects which would not otherwise be undertaken, it cannot be assumed that public authorities know the external benefits of the research, the direction in which scientific progress is moving, and the value of new projects[36].

Our study finds that one dollar of fiscal support to R & D yields $0.98 in additional research. It has also pointed out a possible flaw in the current system of supporting private research through tax incentives. A proportion of this money (which we estimate at over 80%) finances research which would be performed even without assistance and thus resembles a disguised policy of subsidies to research. Even if the magnitude of this phenomenon needs to be verified with other data (aggregate data comprising all research, data on small and medium-sized businesses and, ideally, data on tax credits actually paid out to firms), the question needs to be asked whether better instruments cannot be found to stimulate research. And, pursuing this line of reasoning further, would it not be preferable to attack directly the market failures associated with research and put into place incentive measures which account for asymmetric information, moral hazard and the nonappropriability of benefits which arise at the different stages in the research activities, rather than give money to anyone claiming to do research?

[36]For a discussion of the relative merits of tax credits and direct subsidies to R & D, see Bozeman and Link (1984). For a general discussion of the effectiveness of fiscal support to R & D, cf. Palda (1995), Office of Technology Assessment (1995) and Griffith et al. (1995).

9 References

Asmussen, E. and C.Berriot (1993), "Le crédit d'impôt recherche, coût et effet incitatif", Direction de la Prévision, Paris (version provisoire).

Baily, M.N. and R.Z.Lawrence (1992), Tax Incentives for R & D: What Do the Data Tell Us. Washington, D.C., Study commissioned by the Council on Research and Technology.

Berger, P.G. (1993), "Explicit and Implicit Tax Effects of the R & D Tax Credit", *Journal of Accounting Research*, 31(2), 131-171.

Bernstein, J.I. (1986), "The Effect of Direct and Indirect Tax Incentives on Canadian Industrial R & D Expenditures", *Canadian Public Policy*, 12(3), 438-448.

Bernstein, J.I. and M.I.Nadiri (1990), "Rates of Return on Physical and R & D Capital and Structure of the Production Process: Cross Section and Time Series Evidence", in B. Raj (ed.), *Advances in Econometrics and Modeling*. London: Kluwer Academic Publishers.

Bloom, N., R. Griffith and J. Van Reenen (1997), "Do R & D Tax Credits Work? Evidence from an International Panel of Countries 1979-94", Paper presented at the TSER Conference "Innovation, Competition and Employment", Chania, August 1997.

Bound, J., C. Cummins, Z. Griliches, B. Hall and A. Jaffe (1984), "Who does R & D and who patents?", in Z. Griliches (ed.),*R & D, Patents and Productivity*. Chicago: University of Chicago Press.

Bozeman, B. and A.Link (1984), "Tax Incentives for R & D: A Critical Evaluation", *Research Policy*, 13, 21-31.

Bureau of Industry Economics (1993), *R & D, Innovation and Competitiveness: An Evaluation of the Research and Development Tax ConcessionResearch Report 50,* Australian Government Publishing Service, Canberra.

Bureau of Labor Statistics (1981), *The Impact of Research and Development on Productivity Growth.* U.S. Department of Labor, Bulletin 2331

Cardani, A. and P. Mohnen (1984), "Labor Productivity Slowdown in a Dynamic Model with Energy, Capital, and R & D for Italian and French Manufacturing", *Giornale degli Economisti e Annali di Economia*, 43(7-8), 471-490.

Clark, W.S., G. Goodchild, B. Hamilton and B. Toms (1993), "Canada's R & D Tax Incentives: Recent Developments", *Canadian Tax Journal*, 32:1-32:39.

Conseil de la science et de la technologie, Government of Quebec (1988), *Les avantages fiscaux associés aux activités de recherche et de développement.* Document no. 88.02, March 1988.

Cordes, J.J. (1989), "Tax Incentives and R-D Spending: A Review of the Evidence", *Research Policy*, 18, 119-133.

Dagenais, M.G. (1994), "Parameter Estimation in Regression Models with Errors in the Variables and Autocorrelated Disturbances", *Journal of Econometrics*, 64, 145-163.

Deloitte & Touche (1995), *A Comparison of Tax Incentives for Performing Research and Development in Canada and the United States*, October 1995.

Department of Finance and Revenue Canada (1994), *Income Tax Incentives for Research and Development, 1994 Report of the Auditor General of Canada*, 32-1 to 32-22.

Disclosure Inc. (1995), *Cancorp plus.* Bethesda, MD.

Doern, G. B. (1995), *Aspects institutionnels des stimulants fiscaux à la R-D: le crédit d'impôt à la RS&DE.* Industrie Canada, Document Hors Série no. 6.

Eisner, R., S.H.Albert and M.Sullivan (1984), "The New Incremental Tax Credit for R-D: Incentive or Disincentive", *National Tax Journal*, 37, 171-183.

Fomby, T.B. and D.K. Guilky (1978), "On choosing the Optimal Level of Significance for the Durbin-Watson Test and the Bayesian Alternative", *Journal of Econometrics*, 8, 203-214.

General Accounting Office, U.S. Congress (1989), The Research Tax Credit Has Stimulated Some Additional Research Spending. Vol. GAO/GGD-89-114. Washington D.C.: U.S. General Accounting Office

Goldberg, L. (1979), "The Influence of Federal R and D Funding on the Demand for and Returns to Industrial R and D", The Public Research Institute, CRC 388.

Gourieroux, C. (1989), *Econométrie des variables qualitatives.* Paris: Economica.

Grégoire, P.E. (1995), "Au-delà du mystère ou des préjugés: Jalons pour une évaluation des mesures fiscales à la R-D industrielle", Ministère de l'industrie, du commerce, de la science et de la technologie, mimeo.

Griffith, R., D. Sandler and J. Van Reenen (1995), "Tax Incentives for R & D", *Fiscal Studies*, 16(2), 21-44.

Gunz, S., A. Macnaughton and K. Wensley (1996), "Measuring the Compliance Cost of Tax Expenditures: the Case of Reserach and Development Incentives", *Canadian Tax Journal*, 43(6), 2008-34

Hall, B. H. (1993), "R & D Tax Policy During the Eighties: Success or Failure", *Tax Policy and the Economy*, 7, 1-36.

Himmelberg, C.P. and B.C.Petersen (1994), "R & D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries", *Review of Economics and Statistics*, 38-51.

Hines, J.R. (1993), "On the Sensitivity of R & D to Delicate Tax Changes: The Behavior of U.S. Multinationals in the 1980s", in *Studies in International Taxation*, A. Giovannini, R.G. Hubbard and J. Slemrod (eds.). Chicago: University of Chicago Press.

Hines, J.R. (1994), "Taxes, Technology Transfer, and the R & D Activities of Multinational Firms", NBER Working Paper no. 4932.

Lach, S. and M. Schankerman (1989), "Dynamics of R & D and Investment in the Scientific Sector", *Journal of Political Economy*, 97(4), 880-904.

Lebeau, D. (1996), Mesures fiscales d'aide à la R-D, version préliminaire, Conseil de la science et de la technologie, Gouvernement du Québec, février 1996.

Lemieux, T. and B.MacLeod (1996), "Supply Side Hysteresis: The Case of the Canadian Unemployment Insurance System", mimeo.

Lipsett, M. and R.Lipsey (1995), "R & D and Innovation at the Firm Level: Improving the S&T Policy Information Base", CPROST Report CP 95-9.

Lord, G. and P.Gagné (1989), "Les avantages fiscaux à la recherche scientifique et au développement expérimental au Québec", *Revue fiscale canadienne*, 37(4), 969-1017.

Lucas, R.E. Jr. (1967), "Adjustment Costs and the Theory of Supply", *Journal of Political Economy*, 75, 321-334.

Maddala, G.S. (1983), *Limited Dependent and Qualitative Variables in Econometrics*. New York: Cambridge University Press.

Mamuneas, T. and M.I.Nadiri (1995), "Public R & D Policies and Cost Behavior of the U.S. Manufacturing Industries, NBER Working Paper no. 5059.

Mansfield, E. and L.Switzer (1985), "The Effects of R & D Tax Credits and Allowances in Canada", *Research Policy*, 14, 97-107.

Matyas, L. and P. Sevestre (1996), *The Econometrics of Panel Data*. 2nd Revised Edition, Kluwer Academic Publishers.

McFetridge, D.G. and J.P. Warda (1983), *Canadian R & D Incentives: Their Adequacy and Impact.* Canadian Tax Paper no. 70, Toronto: Canadian Tax Foundation.

McGraw-Hill (1994), *Standard and Poor's Compustat. Canadian file.* Englewood Cliffs, Colorado.

Ministère des Finances (1983), La politique fiscale en matière de recherche et de développement. Document de consultation de l'Honorable Marc Lalonde, avril 1983.

Mohnen, P. (1996), "R&D Externalities and Productivity Growth", *STI Review*, 18, 39-66.

Mohnen, P., M.I. Nadiri and I. Prucha (1986), "R&D, Production Structure, and Rate of Return in the U.S., Japanese and German Manufacturing Sectors: A Nonseparable Dynamic Factor Demand Model", *European Economic Review*, 30, 749-771.

Nadiri, M.I. (1980), "Contributions and Determinants of Research and Development Expenditures in the U.S. Manufacturing Industries", in George von Furstenberg, ed., *Capital, Efficiency and Growth.* Cambridge: Ballinger.

Nadiri, M.I. and I. Prucha (1990), "Dynamic Factor Demand Models, Productivity Measurement, and Rates of Return: Theory and an Empirical Application to the U.S. Bell System", *Structural Change and Economic Dynamics*, 1, 263-89.

Office of Technology Assessment, Congress of the United States (1995), *The Effectiveness of Research and Experimentation Tax Credits.* OTA-BP-ITC-174. Washington D.C.: U.S. Government Printing Office.

Pagé, L. (1995), L'incidence des subventions sur les dépenses privées en recherche et développement: une approche microéconomique. Mémoire de maîtrise, Université de Sherbrooke.

Palda, K. (1993), *Innovation Policy and Canada's Competitiveness.* Vancouver: The Fraser Institute.

Pollack, R.A.and T.J.Wales (1991), "The likelihood Dominance Criterion: A New Approach To Model Selection". *Journal of Econometrics,* 47 (2/3), 227-242

Research Money (various June issues), "Canada's Top 100 Corporate R & D Spenders", Evert Communications Ltd.

Revenu Canada (1993), *Bulletin d'interprétation IT-151R4*, Loi de l'impôt sur le revenu, Dépenses de recherche scientifique et de développement expérimental, 16 août 1993.

Scherer F.M. (1980), *Industrial Market Structure and Economic Performance.* Boston: Houghton Mifflin Company.

Shah, A. (1994), The Economics of Research and Development, How Research and Development Capital Affects Production and Markets and Is Affected by Tax Incentives, World Bank, Policy Research Department, Working Paper 1325.

Sweeney, T. and C.Robertson (1989), "Income Tax Incentives for Canadian Research and Development", *Canadian Tax Journal*, 37(2), 310-340.

Warda, J. (1990), *International Competitiveness of Canadian R&D Tax Incentives: An Update.* The Conference Board of Canada, Report 55-90.

Warda, J. (1994), *Canadian R&D Tax Treatment. An International Comparison.* The Conference Board of Canada, Report 125-94.

Warda, J. and J.Zieminski (1995), *R&D Outlook 1996.* The Conference Board of Canada.

Williamson, W.G. et A.C. Lahmer (1982, 1986, 1992), *Preparing Your Corporate Tax Returns. Canada and Provinces.* CCH Canadian Limited.

APPENDIX

A List of Industries

Table: A1.1 Description of the Industry Variables

Industry	Definition	SIC 80
agric	agriculture, fishing and trapping, forestry	010, 030, 040
minem	metal mining	061
mines	other mines	062
petro	oil and gas extraction	070
food	food and beverages	100
tobac	tobacco products	110
rubb	rubber products	151
plast	plastics	161
texti	textiles	181
wood	lumber and wood products, except furniture	250
furn	furniture	260
paper	paper and allied products	270
print	printing, publishing and allied products	280
metxp	partially transformed metals (ferrous)	291
metnf	partially transformed metals (non ferrous)	295
metal	fabricated metal products	300
machi	machinery	310
aeron	aircraft and parts	321
autom	automobiles & parts and accessories	323
eqtrp	other transportation	329
eqcom	telecommunications equipment	330
tronq	electronic parts and components	331
othel	other electronic equipment	335
offic	office equipment	336
eltrc	other electrical equipment	339
nmetl	non metallic minerals	350
rpetr	refined fossil fuels	360
pharm	pharmaceuticals	374
chem	other chemical products	379
scien	scientific and professional equipment	391
othm	other manufacturing industries	399
const	construction	400
energ	electricity	410
utils	other utilities	420
trans	transportation and storage	450
commu	communications	480
comp	computer and related services	772
engin	engineering and scientific services	775
servi	retail, wholesale, financial, insurance, real estate services, management consultants, other service industries	500, 600, 700, 777,960

B Definitions and Statistical Sources of the Variables

Table A2.1 Variables with Data obtained from Compustat

Variable	Description	Compustat
RD	R&D expenditures	data046
SALES	Firm's sales	data012
RDI	Research Intensity	data046/data012
STKRD	R&D stock of the firm	
REVENUE	Revenue before extraordinary items & depreciation	data018 & data014
CAPITAL	Physical capital & inventories	data08 & data03
ASSETS	Total assets	data006
RETEARN	Retained earnings	data036

Table A2.2 Variables with Data not obtained from Compustat

Variable	Description	Source or Construction
PRD	R&D deflator	Prepared by Stat Can
PQ	Production deflator	Stat Can Cat 15-201 and 15-202
F1	Tax incentives index or B-index	Appendix C
EFFRD	Effective price of R&D	(PRD/PQ)*F
RDT	R&D expenditures of the industry	Stat Can Cat 88-202
STKRDT	R&D stock of the industry (net of STKRD)	
IR	Interest rate	
DEPR	Depreciation rate of the stock of R&D	
EFFC	Effective user cost of R&D	EFFRD*(IR+DEPR)
FC	Foreign control	Stat Can Cat 61-517

C R & D Tax Incentives Index

Notation:

d	=	percent of R & D expenditures admissible for tax credits (physical plant excluded)
d^*	=	$d + (1-d) \cdot 0.314$, where 0.314 is the depreciation rate for buildings suggested by Warda (1994)
i_O	=	dummy variable for Ontario
i_Q	=	dummy variable for Quebec
c_f	=	rate of the federal tax credit
c_p	=	rate of the provincial tax credit
γ	=	reimbursable share of the tax credit
ω	=	rate of tax credit on incremental R & D
ψ	=	utilisation capacity of the tax credit for incremental research
n	=	reference period for the tax credit for incremental R & D
T	=	admissible carry forward period
T^*	=	admissible carry back period
r	=	interest rate
u_f	=	federal tax rate on corporate profits
u_p	=	provincial tax rate on corporate profits
d_L	=	percent of labor costs in R & D expenditures
β_0	=	fraction of potentially usable tax credits out of current and past tax payments
β_j	=	fraction of potentially usable tax credits from payments in the year $t+j$
δ_0	=	fraction of R & D expenditure in year t deductible in year t
δ_j	=	fraction of R & D expenditure in year t deductible in year $t+j$
G	=	average present value of carry forward and carry back per dollar of potential tax credits
H	=	average present value of a dollar of potential tax credits

Therefore, we have:

- $\psi = \max\left\{0, \frac{R\&D_t}{(\sum_{j=1}^{n} R\&D_{t-j}/n)} - 1\right\}$
- $\beta_0 = \min\left\{1, \frac{\sum_{j=0}^{T*} tax_{t-j}}{c_{ft}.R\&D_t}\right\}$ where $tax = (u_f + u_p) revenue$
- $\beta_i = \min\left\{1, \frac{tax_{t+i}}{\Pi_{j=0}^{i-1}(1-\beta_j)c_{ft}.R\&D_t}\right\}$ for $i = 1, ..., T$

- $\delta_0 = \min\left\{1, \max\left\{\frac{revenue_t}{d_t^* R\&D_t}, 0\right\}\right\}$

- $\delta_i = \frac{1}{(1+r_t)^i}\Pi_{j=0}^{i-1}(1-\delta_j)\min\left\{1, \max\left\{\frac{(revenue_{t+i} - R\&D_{t+i})}{\Pi_{j=0}^{i-1}(1-\delta_j)d_t^* R\&D_t}, 0\right\}\right\}$ for $i = 1, ..., \infty$

- $G = \varepsilon_3 + (1-\varepsilon_3)[\beta_0 + \frac{(1-\beta_0)\beta_1}{(1+r)} + \cdots + \Pi_{t=0}^{T-1}\frac{(1-\beta_t)\beta_T}{(1+r)^T}]$

- $H = 1 \times \varepsilon_1 + \gamma(1-\varepsilon_1)\varepsilon_2 + (1-\varepsilon_1)(1-\varepsilon_2)G$

- $\varepsilon_1 = \begin{cases} 1 & \text{if } c_{ft} * R\&D_t \leq tax_t \text{ (tax credits can be used directly)} \\ 0 & \text{otherwise.} \end{cases}$

- $\varepsilon_2 = \begin{cases} 1 & \text{if } \gamma \geq G \text{ (reimbursement is preferred to carry forward or back)} \\ 0 & \text{otherwise.} \end{cases}$

- $\varepsilon_3 = \begin{cases} 1 & \text{if } \sum_{j=0}^{T*} tax_{t-j} \geq c_{ft}.R\&D_t \text{ (tax credits may be entirely carried back)} \\ 0 & \text{otherwise.} \end{cases}$

The tax incentives index (F), or B-index, in other words the effective cost of a dollar of R & D relative to the net income from a dollar of sales is thus:

$$\begin{aligned} F \; = \; & (1-u_f-u_p)^{-1}\{1-(u_f+u_p)d^*\textstyle\sum_{j=0}^{\infty}\delta_j \\ - \; & \{1-u_f i_Q-(u_f+u_p)(1-i_Q)\} \\ & \{i_Q[d_L c_p+(1-d_L c_p)dc_f H]+(1-i_Q)[dc_p+(1-dc_p)dc_f H]\} \\ - \; & d\omega\psi(u_f+u_p)[1-\tfrac{1}{n}\textstyle\sum_{t=1}^{n}\frac{1}{(1+r)^t}]\} \end{aligned}$$

The denominator of this expression represents income after taxes from one dollar of revenue. This is the factor by which the output deflator is multiplied in the expression for the effective price of research. The numerator of F indicates the net price of a dollar of expenditure on R & D. As to the subtracted terms, the first represents the reduction in payable tax resulting from the almost complete deduction (except part of physical plant) of R & D expenditures. The second term represents tax benefits resulting from federal and provincial research tax credits, and the last term captures incremental research tax credits[37] [38] [39].

Assumptions:

1. Past taxable income has not already been used for earlier applications for tax credits when calculating the possibilities of carry back for unused tax credits.

2. Labor costs account for 50% of total R & D expenditures.

3. Expenditures on physical plant for R & D represent 5% of total R & D.

4. Forecasts of future income used to calculate the possibilities for carry forward are perfect.

5. Tax credits to incremental research are 100% usable[40].

6. The nominal interest rate is fixed at 10%.

D Analysis of the Data

As indicated in table A4.2, only seven percent of firms did not survive until 1992, and a third of those disappeared in 1991. We observe a substantial increase in the number of firms in 1982. These companies are not new, but rather newly admitted to the database (for example Air Canada and Bell Canada). We eliminated those appearing after 1989, since they had fewer than four observations. Table A4.3 reveals that only 108 firms from our sample of 434 (after eliminations) perform, or declare performing, R & D. For about 70 of these we have long series, comprising at least ten consecutive years. As table A4.4 reveals, in every year except the first three, between sixteen and twenty percent of our firms perform R & D, while the corresponding amount for the entire Canadian economy was 0.3% in 1980 (Department of Finance (1983)).

[37] In Quebec, research tax credits only apply to the wages of research staff, and are only taxed at the federal level.

[38] This is a general formulation. The rates take different values depending on the year, the province, and the size of the firm. For example, the incremental rate of tax credits was 50% on incremental research expenditures (current and capital, including physical plant) with respect to the average of the three preceding years from 1978 to 1982 (thus $d = 1, w = 0.5, n = 3$). It disappeared in 1983 (so $d = 0$), and reappeared, only in Ontario, in 1988 ($d = 0.95$, since buildings are excluded, $w = 37.5\%$ or 50% depending on the size, and $n = 3$).

[39] Provincial tax credits are 100% reimbursable.

[40] In any case, tax credits for incremental R & D represent small amounts (cf. Bernstein (1986), McFetridge and Warda (1983)).

Companies performing R & D are thus relatively overrepresented in our sample.

With few exceptions, we cover all industries in the Canadian economy (table A4.5). In 1989 we have no more than ten firms in any one industry performing R & D in our sample, while some industries have none. Comparison with Statistics Canada data reveals that these are not research intensive industries. In three industries, our industry totals are greater than those of Statistics Canada. Since we used Canadian data published in the United States, we may be inclined to attribute these incompatibilities to differences in industrial classification or R & D definitions, but that is not the case (cf. Deloitte and Touche (1995)). The following four reasons may explain the divergences:

1. Declared expenditures are revised by Statistics Canada and sometimes excluded if they do not correspond to the official definition of R & D.

2. Amounts declared in annual reports do not correspond with those declared to Statistics Canada or to Revenue Canada.

3. A firm's R & D is assigned to the industry of its primary area of activity. This classification may change over time, but Compustat does not revise a firm's industrial assignment.

4. For the listed companies, the R & D reported by Compustat includes that performed in other countries. Frequently the extra R & D originates from a large company with foreign branches (Alcan for metnf, Moore Corp. for print, Northern Telecom for eqcom, and Bell Canada for commu).

We have a higher proportion of Canadian than of foreign-controlled firms in our sample. A larger share of the latter performed research (table A4.6). Among firms doing R & D, Ontario firms are overrepresented vis-à-vis Quebec firms (in comparison with data from Statistics Canada, cat. 88-202). Conversely, the average Quebec firm in our sample performs more R & D than the average Ontario firm (table A4.7), which also contradicts Statistics Canada's data.

In table A4.8, we group firms by size, using their total average assets (the average size corresponds to the total average assets of between $25m and $250m). Whether we use assets, production or employment for size, two facts stand out: research intensity declines with size, and firms that do R & D are smaller. This can be explained by the simple omission of large R & D performing firms in our sample. Small firms are also underrepresented. Among those which declare employment (for many companies this information is missing), only 25% have fewer than 200 workers. Thus our sample is truncated at both ends.

We have a reasonable amount of variation in R & D, and of its determinants, between industries (table A4.9). In 1989, the tax incentives index (F) ranges from 0.60 to 1.17 for different industries, while for individual firms it ranges from 0.50 to 1.80. A good deal of this variability is due to ceilings in the use of tax incentives which are unique to each firm. In 1989, the relative price of R & D was higher for firms in oil and gas, refining, and office automation than for those in other sectors, because price increases in these three industries were smaller. Missing data for research intensity indicate sectors or firms with no R & D in 1989. A value of zero represents values less than 0.5%.

The graph in figure 1 shows the evolution of the annual average of the R & D deflator relative to the production deflator (RELPRD) for all firms conducting R & D. Overall, the price of R & D has increased faster than the production price over our sample period. However, the relative price adjusted for the index of tax incentives (RELEFFRD), has increased at a slower rate than the relative price, and even declined in some years (figure 2). 1983 was marked by dramatic changes in tax incentives to research. Annual averages reported in figure 2 conceal the differences between firms. A typical firm, not affected by ceilings (figure 3), generally saw its effective price (RELNC) decline over the sample period, while for a firm with ceilings in 1982, 1985, 1989 and 1991 this effective price (RELWC) shows a very different pattern (figure 4).

Table A4.1 Data cleaning process

Sample	remaining	
	obs.	firms
Entire sample	5642	573
Entire sample minus firms with less than four observations	5397	487
Entire sample minus subsidized firms (indicated in Compustat)	5360	483
Entire sample minus subsidized firms (elim. of firms running deficits)	5266	472
Entire sample minus firms with inflated R&D claims	5388	486
Entire sample minus holding firms	5095	456
Entire sample minus firms with R&D intensity greater than one	5381	483
Remaining sample (after all eliminations)	4859	434

Table A4.2 Persistence of firms in the sample													
Start /End	79	81	82	83	84	85	86	87	88	89	90	91	92	Tot.
75	1	2	1	0	0	1	1	0	0	1	1	2	127	137
76	0	0	0	0	0	0	0	0	0	0	0	0	2	2
77	0	0	0	0	0	0	0	0	0	0	0	0	2	2
78	0	0	0	0	0	0	0	0	0	0	0	0	2	2
79	0	0	0	0	0	0	0	0	0	0	0	0	2	2
80	0	0	0	0	0	0	0	0	0	1	0	0	0	1
81	0	0	0	0	0	0	0	0	0	2	0	0	4	6
82	0	0	0	0	0	0	1	0	2	1	1	1	103	109
83	0	0	0	0	0	0	2	0	0	0	0	1	16	19
84	0	0	0	0	0	0	0	0	0	0	0	0	20	20
85	0	0	0	0	0	0	0	0	1	0	0	0	16	17
86	0	0	0	0	0	0	0	0	0	0	0	2	17	23
87	0	0	0	0	0	0	0	0	0	0	1	2	48	51
88	0	0	0	0	0	0	0	0	0	0	0	2	22	24
89	0	0	0	0	0	0	0	0	0	0	0	0	19	19
90	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91	0	0	0	0	0	0	0	0	0	0	0	0	0	0
92	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	1	2	1	0	0	1	4	0	3	5	3	10	404	434

Table A4.3 Persistence of firms performing R&D in the sample													
Start /End	79	81	82	83	84	85	86	87	88	89	90	91	92	Tot.
75	0	1	0	0	0	0	0	0	0	0	0	0	46	47
76	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77	0	0	0	0	0	0	0	0	0	0	0	0	0	0
78	0	0	0	0	0	0	0	0	0	0	0	0	2	2
79	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0	1	0	0	0	1
81	0	0	0	0	0	0	0	0	0	0	0	0	1	1
82	0	0	0	0	0	0	0	0	1	0	0	0	19	20
83	0	0	0	0	0	0	0	0	0	0	0	0	1	1
84	0	0	0	0	0	0	0	0	0	0	0	0	3	3
85	0	0	0	0	0	0	0	0	0	0	0	0	5	5
86	0	0	0	0	0	0	0	0	0	0	0	1	2	3
87	0	0	0	0	0	0	0	0	0	0	0	1	9	10
88	0	0	0	0	0	0	0	0	0	0	0	0	9	9
89	0	0	0	0	0	0	0	0	0	0	0	0	6	6
90	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91	0	0	0	0	0	0	0	0	0	0	0	0	0	0
92	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	1	0	0	0	0	0	0	1	1	0	2	103	108

Table A4.4 Breakdown of Firms Performing R & D, by Year			
Year	% firms with R&D	no. of firms with R&D	total no. of firms
75	0.09	12.00	137.00
76	0.09	12.00	139.00
77	0.10	14.00	141.00
78	0.17	24.00	142.00
79	0.18	26.00	145.00
80	0.19	27.00	144.00
81	0.20	30.00	149.00
82	0.18	45.00	253.00
83	0.17	46.00	269.00
84	0.16	48.00	291.00
85	0.17	51.00	306.00
86	0.17	57.00	330.00
87	0.16	61.00	377.00
88	0.16	64.00	400.00
89	0.19	78.00	416.00
90	0.18	75.00	412.00
91	0.18	73.00	411.00
92	0.18	74.00	404.00

Table A4.5 Breakdown of Firms Performing R&D, by Industry for 1989					
Industry	No. firms perf. R&D	Total R&D in sample ($M)	Total R&D Stat Can ($M)	Represen-tativity	Total no. of firms
minem	1.00	3.07	35.23	0.09	41.00
mines	1.00	1.90	10.13	0.19	3.00
petro	3.00	17.20	50.81	0.34	65.00
food	3.00	16.70	60.83	0.27	18.00
tobac	0.00	0.00	8.57	0.00	1.00
plast	2.00	1.44	14.45	0.10	7.00
texti	0.00	0.00	43.66	0.00	2.00
wood	1.00	12.50	17.69	0.71	10.00
paper	4.00	24.22	151.40	0.16	12.00
print	1.00	32.21	8.39	3.84	11.00
metxp	1.00	8.21	23.67	0.35	10.00
metnf	6.00	220.92	138.07	1.60	10.00
metal	2.00	1.70	41.20	0.04	5.00
machi	3.00	12.37	97.54	0.13	5.00
aeron	1.00	0.92	501.72	0.00	3.00
autom	2.00	17.60	68.87	0.26	7.00
eqcom	7.00	913.11	742.08	1.23	8.00
tronq	2.00	0.57	38.50	0.01	2.00
offic	3.00	17.99	293.68	0.06	3.00
eltrc	2.00	2.45	64.69	0.04	5.00
nmetl	2.00	6.14	20.08	0.31	4.00
rpetr	3.00	123.00	149.71	0.82	7.00
pharm	2.00	3.59	176.71	0.02	2.00
chem	4.00	75.65	193.16	0.39	7.00
scien	3.00	31.11	62.02	0.50	4.00
othm	1.00	0.04	25.63	0.00	5.00
const	0.00	0.00	8.24	0.00	6.00
energ	0.00	0.00	222.83	0.00	10.00
utils	1.00	0.16	4.52	0.03	3.00
trans	0.00	0.00	20.09	0.00	11.00
commu	4.00	184.68	118.06	1.56	21.00
comp	8.00	31.64	213.57	0.15	11.00
engin	0.00	0.00	474.03	0.00	2.00
servi	5.00	39.30	474.03	0.08	95.00
All	78.00	1800.37	4621.99	0.39	416.00

R&D deflator/output deflator
(annual firm averages)

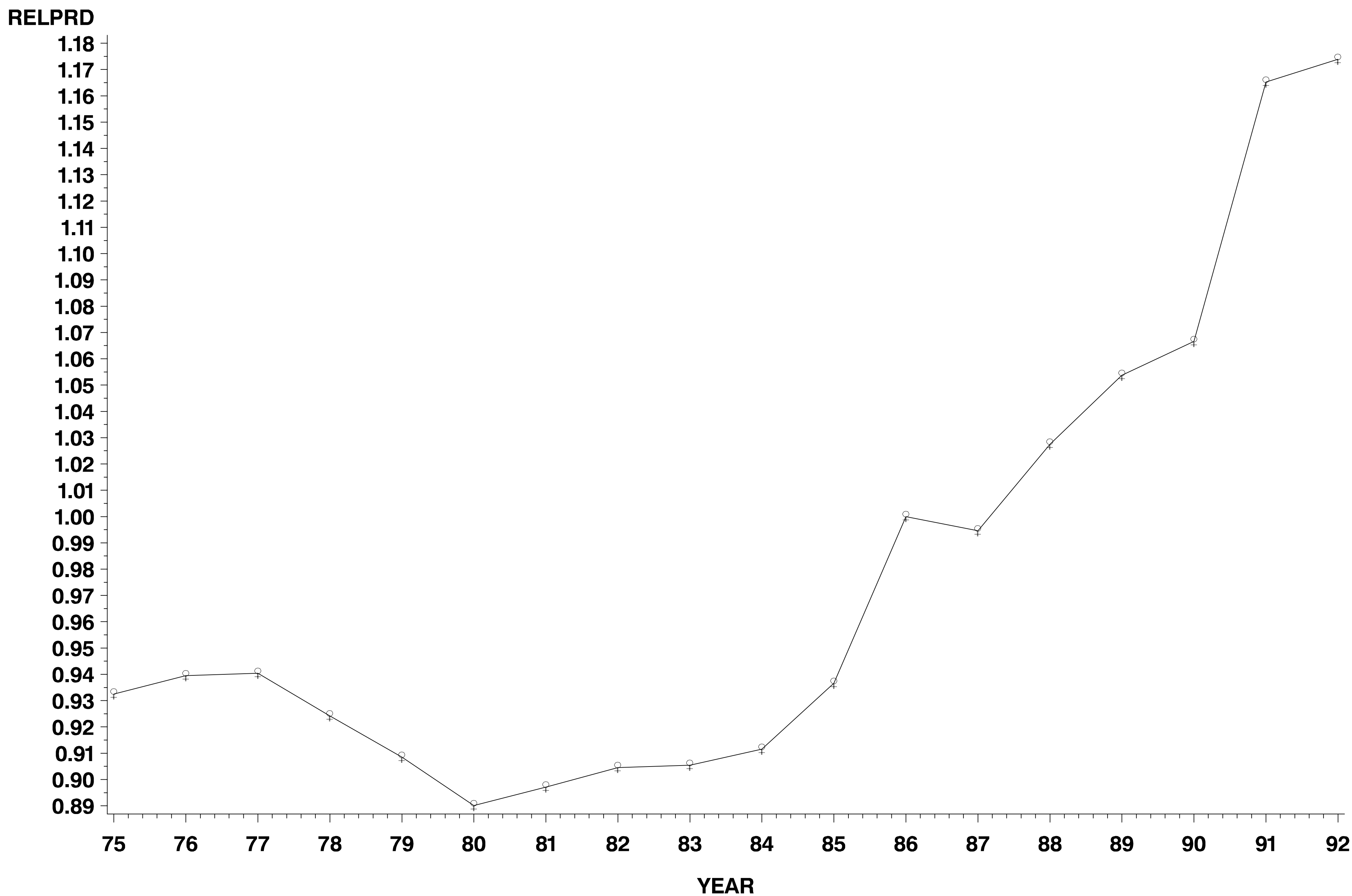

FIGURE 1

Effective price of R&D/output deflator
(annual firm averages)

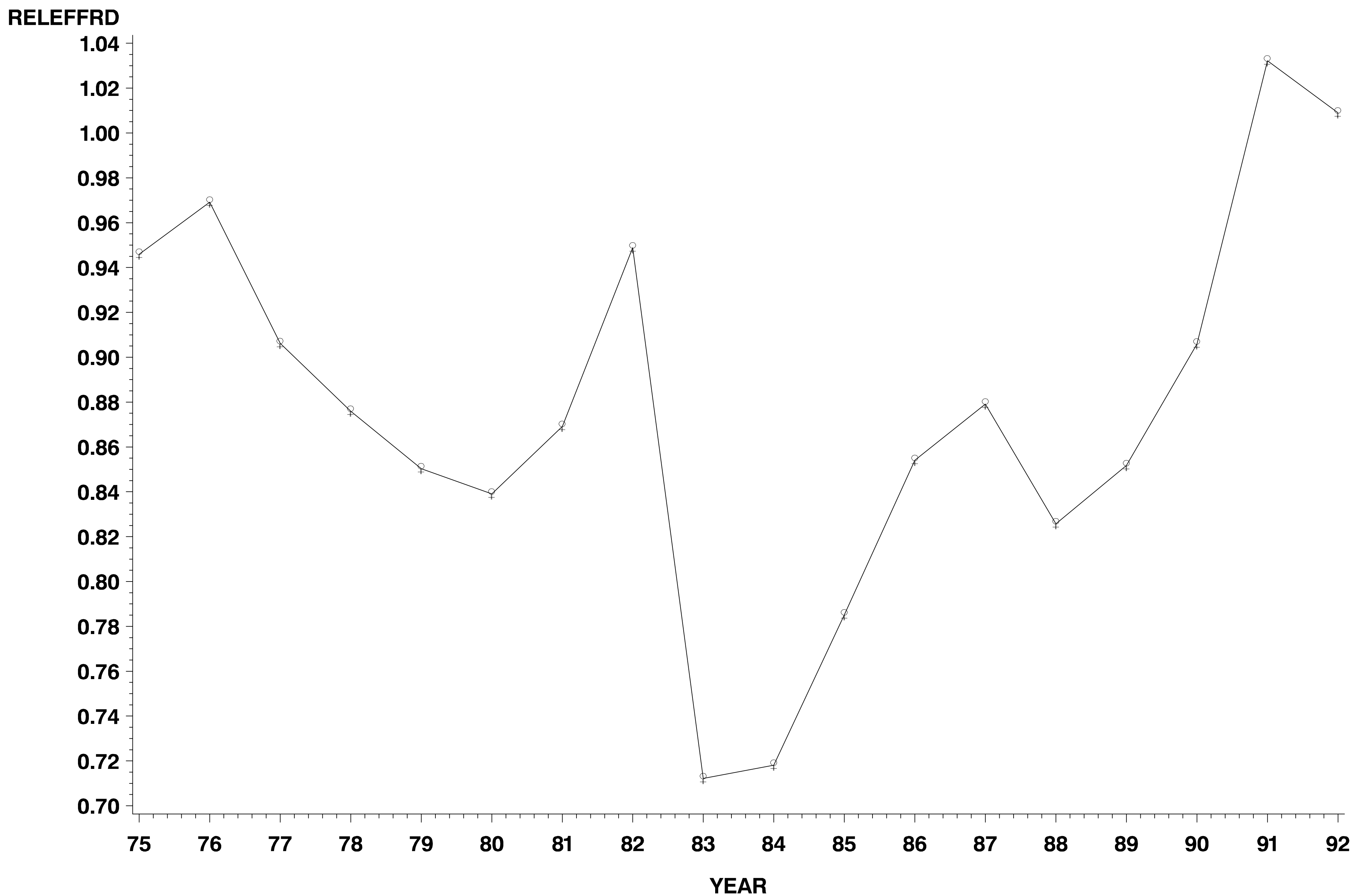

FIGURE 2

Effective price of R&D/output deflator

(firm without ceilings)

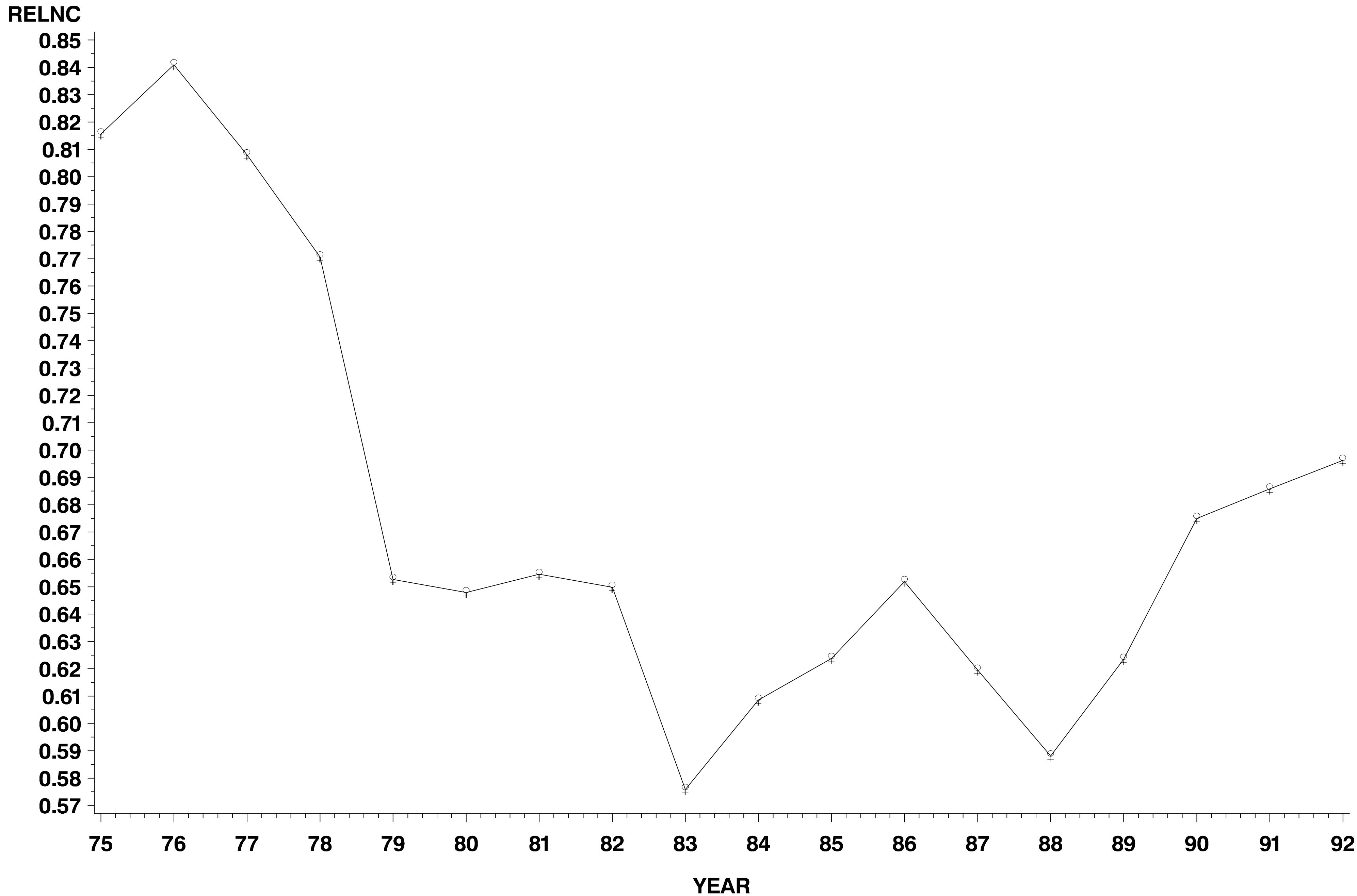

FIGURE 3

Effective price of R&D/output deflator

(typical firm with ceilings)

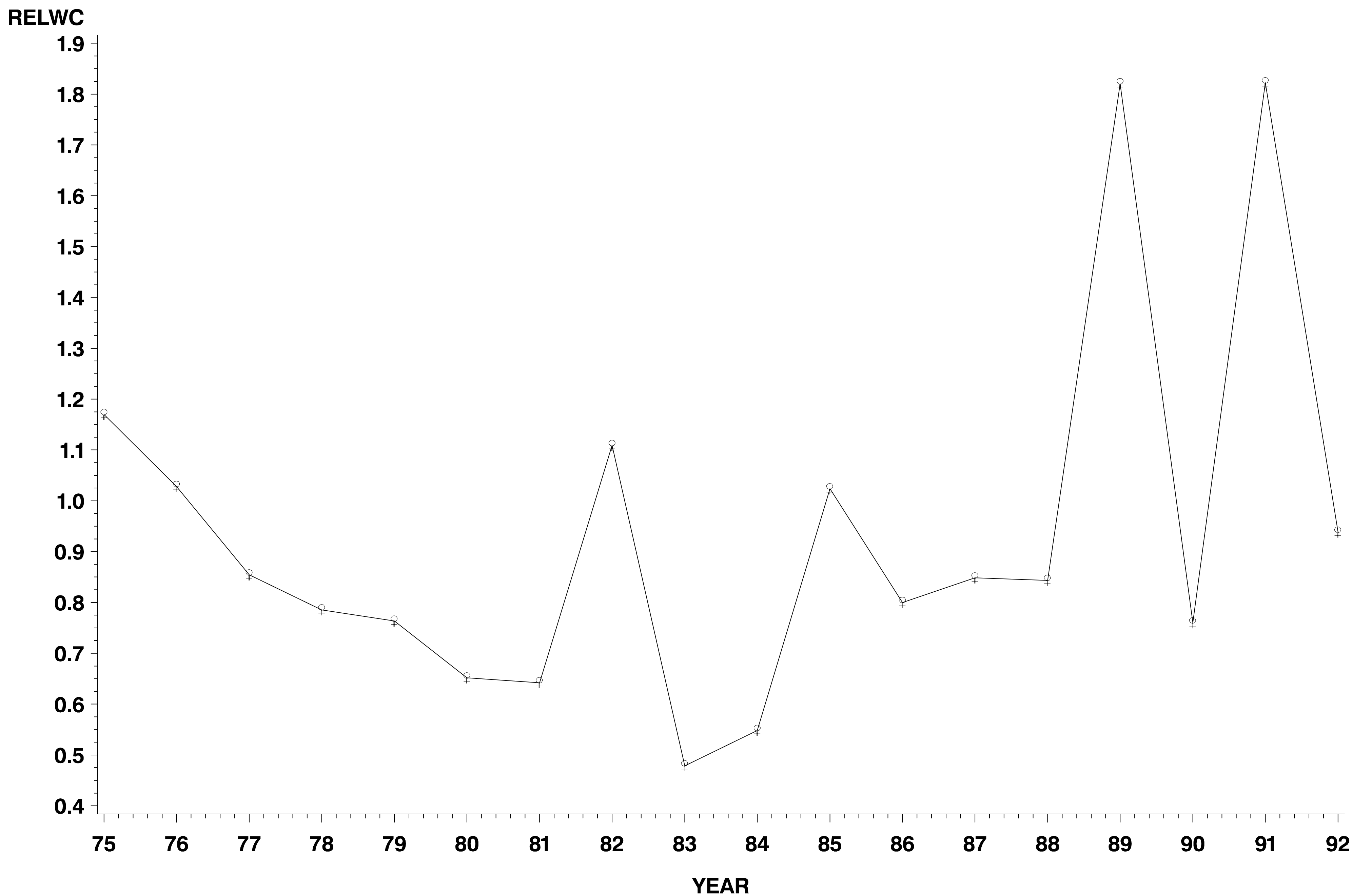

FIGURE 4

ADDENDUM

To CIRANO'S Scientific Series Working Paper no 97s-34,

"Do Canadian Firms Respond to Fiscal Incentives to Research and Development"

Table A4.6 Breakdown of Firms Performing R & D, by Nationality of the Firm's Head Office

CONTROLLED	% firms with R&D	no. of firms with R&D	Total no. of firms
canadien	0.22	79.00	358.00
foreign	0.38	29.00	76.00
ALL	0.25	108.00	434.00

Table A4.7 Breakdown of Firms Performing R & D, by Region

REGION	% firms with R&D	no. of firms with R&D	Total no. of firms
ONT	0.28	55.00	195.00
BC	0.19	14.00	72.00
QUE	0.32	21.00	66.00
MAN	0.13	1.00	8.00
ALB	0.17	13.00	76.00
NS	0.00	0.00	3.00
NB	0.33	1.00	3.00
SAK	0.75	3.00	4.00
NFLD	0.00	0.00	5.00
PEI	0.00	0.00	2.00
ALL	0.25	108.00	434.00

Table A4.8 Breakdown of Firms Performing R & D, by Size (by Total Average Assets)

SIZE	% firms with R&D	no. of firms with R&D	sales (means) of firms without R&D ($M)	sales (means) of firms with R&D ($M)	RDI means	Total no. of firms
small	0.21	15.00	556.34	185.71	0.07	70.00
medium	0.23	42.00	24475.42	5109.72	0.05	182.00
large	0.28	51.00	319498.6	92480.76	0.01	182.00
ALL	0.25	108.00	344530.4	97776.19	0.04	434.00

Table A4.9 Descriptive Statistics on Variables, by Sector for Year 1989 (see appendix B for the variables' definitions)

SECTOR	R&D means ($M)	SALES means ($M)	EFFRD means	F1 means	RETEARN means ($M)	CAPITAL means ($M)	RDI means	FIRMS no.
MINEM	0.06	83.66	0.81	0.90	41.05	209.64	0.01	41.00
MINES	0.54	96.53	0.74	0.82	30.24	421.50	0.01	3.00
PETRO	0.23	102.47	1.25	0.93	56.64	272.98	0.16	65.00
FOOD	0.80	866.67	0.86	0.81	384.72	415.56	0.00	18.00
TOBAC	0.00	323.15	0.64	0.64	124.41	294.48	.	1.00
PLAST	0.18	114.15	0.69	0.68	31.53	76.05	0.01	7.00
TEXTI	0.00	865.63	0.73	0.69	75.49	556.73	.	2.00
WOOD	1.09	650.63	0.84	0.80	190.70	596.98	0.00	10.00
PAPER	1.73	1233.96	0.66	0.69	326.63	1448.17	0.00	12.00
PRINT	2.58	1167.01	0.64	0.67	418.37	501.75	0.01	11.00
METXP	0.72	1011.38	0.66	0.73	245.76	1094.74	0.00	10.00
METNF	18.08	2323.10	0.75	0.77	504.00	2654.87	0.01	10.00
METAL	0.30	487.58	0.67	0.66	-0.04	175.58	0.01	5.00
MACHI	2.25	262.86	0.64	0.65	61.44	145.84	0.01	5.00
AERON	0.27	773.08	0.94	0.85	69.79	353.04	0.01	3.00
AUTOM	2.33	2615.76	0.79	0.74	289.38	595.94	0.01	7.00
EQCOM	96.32	982.08	0.79	0.68	253.26	387.73	0.08	8.00
TRONQ	0.24	9.63	1.04	0.87	-7.74	2.71	0.02	2.00
OFFIC	5.28	62.46	0.79	0.70	12.44	22.89	0.10	3.00
ELTRC	0.47	204.40	0.63	0.61	47.72	63.27	0.00	5.00
NMETL	1.19	611.95	0.79	0.66	195.35	411.48	0.00	4.00
RPETR	15.92	3181.98	0.87	0.75	1121.81	3035.45	0.01	7.00
PHARM	1.58	2.52	0.58	0.60	-0.83	2.69	0.47	2.00
CHEM	10.02	913.86	0.87	0.94	154.55	1059.09	0.01	7.00
SCIEN	7.06	339.82	0.81	0.86	140.07	110.25	0.08	4.00
OTHM	0.01	133.36	1.20	1.17	15.30	63.11	0.01	5.00
CONST	0.00	206.93	0.74	0.79	32.71	195.00	.	6.00
TRANS	0.00	2032.45	0.93	0.84	613.86	2685.18	.	11.00
COMMU	7.98	621.09	0.85	0.76	210.74	1061.60	0.02	21.00
ENERG	0.00	925.64	0.76	0.80	226.09	1798.40	.	10.00
UTILS	0.04	553.89	1.16	0.93	200.58	650.16	0.75	3.00
SERVI	0.37	1515.00	0.74	0.76	182.40	713.85	0.02	95.00
COMP	2.57	85.05	0.68	0.71	2.36	23.54	0.09	11.00
ENGIN	0.00	257.55	0.74	0.76	61.91	113.34	.	2.00
ALL	3.73	855.48	0.85	0.80	186.77	687.55	0.06	416.00

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