How Do Tax Credits Affect R&D Expenditures by Small Firms? Evidence from Canada*

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Abstract

We exploit a change in eligibility rules for the Canadian Scientific Research and Experimental Development (SRED) tax credit to gain insight on how tax credits impact small-firm R&D expenditures. After a 2004 program change, privately owned firms that became eligible for a 35 percent tax credit (up from a 20 percent rate) on a greater amount of qualifying R&D expenditures increased their R&D spending by an average of 15 percent. Using policy-induced variation in tax rates and R&D tax credits, we estimate the after-tax cost elasticity of R&D to be roughly -1.5. We also show that the response to the after-tax cost of R&D is larger for contract R&D expenditures than for the R&D wage bill, and is larger for firms that (a) perform contract R&D services or (b) recently made R&D-related capital investments. We interpret this heterogeneity as evidence that small firms face fixed adjustment costs that lower their responsiveness to a change in the after-tax cost of R&D.

Keywords: Research and Development, Tax Credits, Adjustment Costs.

JEL Codes: O38, H25, D83.

1 Introduction

Economists have long suspected that private incentives for research and development (R&D) are too low, since knowledge spillovers cause research spending to resemble investment in a public good. Tax subsidies are a market-oriented approach to this problem. However, it is often unclear whether fiscal incentives for R&D produce a large private response, particularly among smaller firms that may lack sophisticated tax-planning capabilities and who may balk at the fixed costs of starting a new line of research. We use a change in eligibility rules for R&D tax credits under Canada's Scientific Research and Experimental Development (SRED) tax incentive program to gain insight on the impact of fiscal incentives on R&D spending by small private firms.

In 2004, Canadian Controlled Private Corporations (CCPCs) with prior-year taxable income between $200 and $500 thousand became eligible for a 35 percent R&D tax credit on a larger amount of qualifying R&D expenditures. We show that firms eligible to benefit from the more generous tax credit program spent more on R&D following the program change, compared to firms with the same taxable income before the change. Specifically, these firms increased their R&D spending by an average of 15 percent. Using the program-induced variation in the after-tax cost of R&D as an instrumental variable, we also estimate an R&D cost elasticity of approximately -1.5, which implies that our sample of small Canadian firms is quite sensitive to the after-tax price of R&D.

Our findings make two main contributions to the literature on R&D tax incentives. First, we focus on small private firms.[1] While large firms account for the bulk of private R&D spending, several authors have argued that small firms have a comparative advantage in product innovation or exploratory research (Cohen and Klepper, 1996; Akcigit and Kerr, 2010). Our estimates of the R&D cost elasticity suggest that small private firms may be more responsive to R&D tax incentives than the average firm, perhaps due to liquidity constraints that limit their access to external finance (Himmelberg and Petersen, 1994).

Our second contribution is to highlight the potential importance of fixed adjustment costs in small firms' response to R&D tax incentives. Based on our sub-sample of small firms, we provide several pieces of evidence on the role of adjustment costs. First, we show that contract R&D spending (a spending category with relatively low adjustment costs, we assume) has a greater after-tax cost elasticity than the R&D wage bill. Second, we show that firms with recent R&D-related capital expenditures (one source of adjustment costs) are more responsive to the more generous tax incentives. Finally, we show that much of the increase in the average R&D

[1] Though CCPCs, the type of firm in our sample, can be of any size, firms in our sample are generally small.

wage bill is concentrated in the professional, scientific and technical services sector (NAICS 541), where contract R&D is performed, and where firms are less likely to view scientists as a project-related fixed cost.

In the remainder of the paper we review prior research on R&D tax credits (Section 2), describe the Canadian SRED program change and our empirical strategy in greater detail (Section 3), present our empirical results (Section 4), and speculate on the possible broad implications of these findings (Section 5).

2 Related Literature

Hall and Van Reenen (2000) review the early literature on R&D tax incentives, and identify two broad empirical strategies. One approach is to estimate a reduced form R&D demand equation that includes a shift parameter to measure the impact of changes in the R&D tax credit, for example. This strategy is used in several papers, including Swenson (1992), Bailey and Lawrence (1992) and Czarnitzki et al. (2011). A second approach is to regress R&D spending on the after-tax cost of R&D to obtain a scale-free estimate of the cost elasticity of R&D spending.[2] This latter method is implemented by Hall (1993), Bloom et al. (2002), Lokshin and Mohnen (2012), Wilson (2009) and Rao (2012). Given the complexities of calculating the after-tax cost of R&D, and the potential simultaneity of R&D spending and the tax rate on the marginal dollar of a firm's taxable income, the reduced-form approach is often simpler. However, the second strategy is better grounded in economic theory and produces estimates that are easier to interpret. We implement both strategies.

While early research on the impact of R&D tax incentives focused on the United States, a number of recent studies have provided evidence from other countries, including Canada (Dagenais et al., 1997; Baghana and Mohnen, 2009; Czarnitzki et al., 2011), Japan (Yohei, 2011; Koga, 2003) and the Netherlands (Lokshin and Mohnen, 2012). The results of these studies are broadly consistent with the conclusion in Hall and Van Reenen (2000) that, "A tax price elasticity of around unity is still a good ballpark figure, although there is a good deal of variation around this from different studies as one would expect."

Our study is one of a small number papers on R&D tax credits to focus on relatively small firms. Lokshin and Mohnen (2012) split their sample into large and small firms (above or below 200 employees), and find that the small firms have a larger cost elasticity of R&D. Koga (2003) finds the opposite result — a larger cost elasticity for large firms — in a sample of Japanese manufacturing firms, though in that study size is based on capital rather than employees. In

[2]To our knowledge the only paper to examine innovation outcomes other than R&D spending is Czarnitzki et al. (2011).

a related line of work, Yohei (2011) uses matched cross-sectional data to show that tax credits have significantly larger impacts at firms that face liquidity constraints, where such constraints are identified based on a series of survey questions related to conditions imposed by bank lenders. Hao and Jaffe (1993) and Harhoff (1997) also find evidence that small firm R&D investments respond to changes in liquidity, whereas large firms do not. We do not provide an explicit comparison of the impact of tax credits on large and small firms, since our natural experiment only impacts those with taxable income between $200 and $500 thousand. Instead we focus on a sample of relatively small firms, find relatively large cost elasticities, and provide evidence that the response to a change in the cost of R&D is greater among firms that face low adjustment costs. Our findings complement those of Himmelberg and Petersen (1994), who show both R&D and other types of capital investment are sensitive to cash flow for small firms in high-tech industries. They suggest that this cash flow sensitivity reflects small firms' lack of access to external finance, and they attribute the larger elasticity of non-R&D investments to adjustment costs.

To our knowledge, there is no study that has sought direct evidence of adjustment costs on R&D investment. Many authors have noted that the within-firm variance in R&D expenditures is much lower than for capital goods, and that one way to rationalize this observation is to assume some type of adjustment cost. But there is some disagreement over what these costs might be. For example, Lach and Schankerman (1989) argue that the bulk of R&D spending are labor costs, which should not impose substantial fixed costs, at least for large firms. However, Hall (1993) suggests that the long-term nature of research and the fact that much of a firm's knowledge capital is tied up in its R&D workforce make it difficult for even large firms to quickly adjust their R&D spending. A number of papers seek evidence of adjustment costs in the lag structure of R&D investments (e.g. Bloom et al., 2002). However, this is a difficult empirical exercise, precisely because within each firm, R&D expenditures are typically quite smooth over time (e.g. Hall et al., 1986). Our approach is to identify firm and industry-level proxies for R&D adjustment costs and seek evidence of a larger response to a change in tax policy among firms with lower levels of these proxy variables. Unlike prior studies that identify adjustment costs by using a dynamic model (Hall, 1993; Bernstein and Nadiri, 1988), we compare different types of R&D spending – contracts versus wages – and utilize direct proxies for the firm-level cost of adding R&D resources.

3 Empirical Framework and Identification

3.1 Tax Credits, Adjustment Costs and R&D Investment

Our empirical specification is motivated by a simple framework, along the lines described in Hall (1993): the equilibrium level of R&D is determined by the intersection of a downward sloping schedule of potential projects (ranked in terms of net present value) and an upward sloping supply of R&D inputs (chiefly labor, but also specialized equipment and facilities). A change in the after-tax cost of R&D corresponds to a rightward shift of the supply curve, leading to a greater quantity of R&D and a lower (private) value for the marginal project. Note that this framework makes no assumptions about liquidity or financing constraints – firms simply do more R&D because it costs less. However, to the extent that small firms cannot easily tap external finance for R&D investments, tax credit programs that refund some portion of a firms R&D expenditures in cash should have a larger impact on small firm R&D expenditures.

Adjustment costs enter this simple framework as a discontinuous jump in a firm's marginal cost or supply curve due to the presence of fixed costs. One source of fixed costs is specialized machinery and equipment. We expect firms that have recently made investments in R&D related capital to have a larger supply of "bench ready" projects. To the extent that such firms have already incurred the sunk costs of capacity building, they should be more responsive to a change in R&D user costs; that is, they are unlikely to be "stuck" on the vertical part of the supply curve.

Small firms may also view hiring new scientists or engineers as a fixed cost. A standard economic model of R&D investment treats research expenditures as building capital within employees. Hiring is then only done if it is expected that these knowledge workers will be retained over the long-term. Tax credits mitigate the cost of hiring, but not by enough if potential future research projects are improbable and thus cause high expected rates of worker turnover. One alternative to hiring a new researcher is to outsource R&D projects to a contractor. Firms that face significant adjustment costs of hiring, but have a supply of "one off" R&D projects with an expected return near their hurdle rate, may respond to a decrease in the after-tax cost of R&D by increasing their contract R&D spending. We test this hypothesis by decomposing overall research and development spending into wages, contract research and other expenditures, and comparing the response within each type of spending to an equal sized change in after-tax marginal costs. We also examine the response in NAICS category 541 (Professional, Scientific and Technical Services) as a sort of placebo test. Because firms in this sector *perform* contract research, we expect them to treat R&D labor as a fungible input, and to increase wages more than contract spending.

3.2 The SRED Tax Incentive Program

To qualify for SRED support, a firm's R&D expenditures must broadly satisfy two conditions. First, the work must be a "systematic investigation or search that is carried out in a field of science or technology by means of experiment or analysis." And second, this work must be undertaken to achieve a technological advancement or further scientific knowledge.[3]

There are two main components to SRED. First, all companies operating and carrying out R&D in Canada may deduct 100 percent of qualifying R&D expenditures from their taxable income, including capital. And second, the same firms are eligible to receive tax credits on qualifying expenditures at the rate of 20 percent. Beyond these two components, the SRED program provides CCPCs with additional tax credits at the rate of 15 percent, for a total tax credit rate of 35 percent, on R&D expenditures up to a threshold called the *expenditure limit*. Our empirical strategy exploits a change in the formula used to calculate this expenditure limit.

The expenditure limit varies across firms, and is a function of prior-year taxable income and capital. To simplify exposition, we focus only on how taxable income affects the expenditure limit because taxable capital is only relevant for a handful of sample firms. Formally, the expenditure limit (EL_t) can be written as

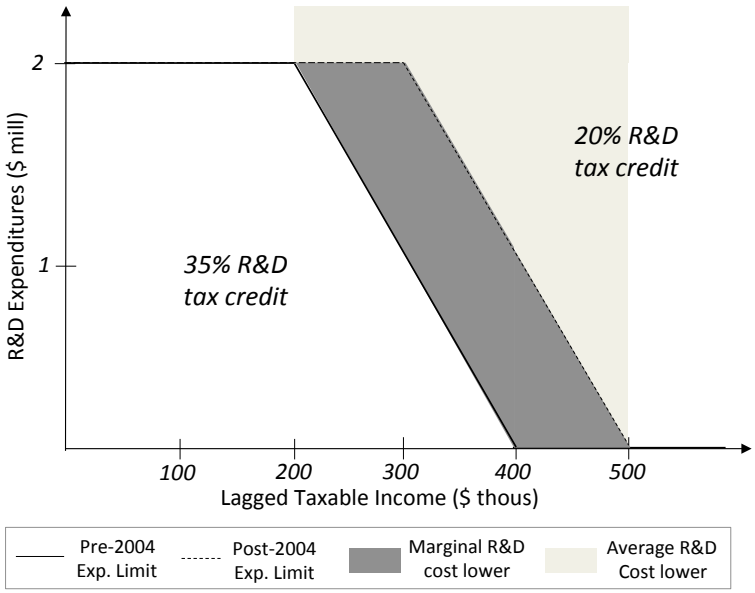
$$EL_t = min\{\$2 \text{ million}, max\{0, Z_t - 10\ TY_{t-1}\}\} \tag{1}$$

where TY_{t-1} is prior-year taxable income, and the intercept Z_t determines where the expenditure limit begins to be phased out. Figure 1 illustrates the change in expenditure limits.

Prior to 2004, when Z_t was set to \$4 million, firms with prior-year taxable income below \$200 thousand were eligible for a 35 percent tax credit rate on their first \$2 million in R&D expenditures, and a 20 percent rate on any additional R&D. Firms with prior-year taxable income between \$200 and \$400 thousand had a lower expenditure limit, and those earning more than \$400 thousand only benefitted from the 20 percent R&D tax credit rate. In 2004, as part of a broad package of tax reforms, Z_t was increased from \$4 million to \$5 million. This lowered the after-tax cost of R&D for all CCPCs with \$200 to \$500 thousand in prior-year taxable income whose R&D spending exceeded their pre-2004 expenditure limit. In Figure 1, this change corresponds to a rightward shift of the region where the 35 percent credit is phased out, leading to a decline in the marginal after-tax cost of R&D for any firm in the darkly shaded parallelogram, and a decline in the average after-tax cost of R&D for any firm in the lightly shaded area above that parallelogram.

[3]See http://www.cra-arc.gc.ca/txcrdt/sred-rsde/clmng/lgbltywrkfrsrdnvstmnttxcrdts-eng.html#N101D1 for more detail.

Figure 1: SRED Expenditure Limits Before and After Policy Change



While our empirical strategy exploits changes in the expenditure limit formula, the after-tax cost of R&D also depends on several other factors, including corporate tax rates, provincial tax laws, and a firm's specific tax position (e.g. other credits, deductions and carry-forwards). Conceptually, the marginal after-tax cost of R&D (U_t) is determined by the deductions (τ_t) and tax credits (ρ_t) applied to an additional dollar of R&D, and is given by:

$$U_t = 1 - \tau_t(TY_t, R_t) - \rho_t(R_t, EL_t, TaxesOwed_t) \tag{2}$$

Deductions are typically equal to a firm's marginal tax rate, which is determined by both taxable income (TY_t) and contemporaneous R&D expenditures (R_t), due to the progressive nature of the tax system.[4] These deductions reduce the after-tax cost of R&D as long as taxable income net of other deductions is positive.

SRED tax credits work as a subsidy to reduce the after-tax cost of R&D. The value of these credits depends on the firm's R&D expenditure level, expenditure limit and the total taxes it owes after all other credits and deductions are accounted for. As described above, an additional dollar invested in R&D earns the firm 35 cents in tax credits if its R&D expenditure is below the expenditure limit, and 20 cents otherwise. However, the value of these credits in lowering

[4]Table A-1 in the Appendix shows how marginal tax rates varied by year and taxable income level during our sample period.

R&D costs depends on whether the credits are refundable or on the taxes the firm must pay. Credits earned at the 35 percent rate are entirely refunded.[5] Consequently, the credits earned on the marginal dollar invested in R&D reduces this cost by 35 cents. Credits earned at the 20 percent rate reduce the cost of the marginal R&D dollar by 20 cents as long as the firm has a remaining tax liability, since these credits can be used to fully offset taxes payable. Finally, even without any taxes owing, a firm may value a portion of the credits earned at the 20 percent rate. If a firm is small enough that its expenditure limit is at the maximum level (i.e. $2 million during our sample period), 40 percent of the credits earned at the 20 percent rate are refunded.[6] Consequently, these credits reduce the after-tax cost of an additional dollar in R&D by 8 cents. Thus, we have

$$\rho_t(R_t, EL_t, TY_t) = \begin{cases} 0.35, & \text{if } R_t \leq EL_t \\ 0.20, & \text{if } EL_t < R_t \text{ and } 0 < TaxesOwed_t \\ 0.08, & \text{if } EL_t < R_t,\ TaxesOwed_t \leq 0 \text{ and } EL_t = \$2,000,000 \end{cases}$$

It is important to note that our measure of the after-tax cost of R&D is only an approximation. Specifically, we do not account for provincial tax incentives or the fact that unused Federal R&D tax credits and deductions can be carried-over to other years. These omissions may cause us to overstate the true after-tax cost of R&D. On the other hand, our approximation may understate the true after-tax cost of R&D because we do not account for the income tax on credits received.

3.3 Data and Measures

Our data come from the tax records of the Canada Revenue Agency (CRA) for all firms claiming SRED credits during the 2000 to 2007 sample period. Our estimation sample includes all firms that operated as CCPCs throughout the sample period, and claimed R&D tax credits at least once between 2000 and 2003. We also limit the sample to firms that operated in only one province throughout the sample period to ensure that our analysis is not complicated by having to consider how firms active in multiple jurisdictions might geographically re-allocate

[5] Here we assume that the marginal SRED dollar represents a current (as opposed to a capital) expenditure. This is an important and sensible assumption. It is important because current expenditures earning the 35 percent credit rate are fully refundable while only 40 percent of credits earned from capital expenditures are refundable. It is sensible to assume the additional dollar invested is a current expenditure because the majority of CCPC SRED expenditures are current expenditures.

[6] We note that credit and deductions are more valuable than what we suggest here and thus we likely overstate the after-tax cost of R&D. This is because, as noted above, we assume these tax benefits can only be used in the year they are earned. Consequently, we do not account for the value of these benefits that is derived from the ability of firms to use them in other years.

their R&D activity in response to differences in provincial R&D support.[7] This yields an unbalanced panel of 4,514 firms and 35,222 firm-year observations. Forty-four percent of these firms are in service industries, 31 percent in manufacturing industries, and the remaining 25 percent are primarily involved in agriculture.

Table 1 provides summary statistics for our estimation sample. Total annual SRED-eligible R&D expenditures averaged $72,780 per year, which implies that aggregate annual R&D spending for the firms in our estimation sample was roughly $330 million. Seventy percent of a representative firm's annual expenditures (or $50,203) reflect wages paid to R&D personnel. Fifteen percent of R&D expenditures (or $10,679) were spent on contract research.[8] Expenditures on R&D capital were the smallest component, accounting for only $2,368, or about three per cent of overall expenditures. However, conditional on claiming R&D capital, the average expenditure was about $27,000. The remaining 16 percent of total R&D spending is highly correlated with R&D Wages, and we interpret this residual spending as overhead.[9]

Our main explanatory variables are a pair of dummies for eligibility before and after the policy change, and a pair of measures of the marginal after-tax cost of R&D. The dummy variable *Eligible* (E_t) equals one in any year when a firm's prior-year taxable income falls between $200 and $500 thousand: the range of taxable income over which the expenditure limit increased as a result of the change in SRED (see Figure 1). We also create a variable $PostPolicy_t$ that equals one in any year after the SRED eligibility limits were changed. Table 1 shows that 8.4 percent of all observations were eligible, and of those, 5.4 percent were treated (i.e. eligible after 2004). By far, the main reason why firms were not eligible is that their taxable income was less than $200 thousand

We calculate each firm's marginal after-tax cost of R&D (U_t) by accounting for deductions and tax credits as described above. For firms in our estimation sample, the average after-tax cost of an additional dollar of R&D was 58 cents.[10]

Equation (2) shows that U_t is a function of contemporaneous R&D spending. We might expect this simultaneity produces a positive bias in estimates of the cost elasticity. This arises as increased R&D spending tends to raise the marginal cost of R&D once the tax credit rate decreases from 35 to 20 percent when expenditures come to exceed the expenditure limit. To

[7] We also exclude any firm that is associated at any time during our sample period with any other firm. Under the SRED program, associated firms must share a common expenditure limit and must divide room under this limit. To simplify analysis, firms in such sets are not included in the sample.

[8] Contract research expenditures reflect expenditures on the same type of activities that would qualify for SRED benefits if undertaken in-house.

[9] A two-way fixed effects regression of R&D Wages on "other" R&D expenditures produced a coefficient of 0.16 with t=10.71.

[10] Table A-2 in the Appendix provides additional detail on the distribution of U_t and the within-firm variation in marginal after-tax costs.

Table 1: Summary Statistics

Variable	Mean	SE
Total R&D	72,780	199,149
R&D Indicator		
R&D Wages	50,203	137,690
R&D Contracts	10,679	54,724
R&D Capital	2,368	26,279
Tax Policy Variables		
Eligible	0.084	0.278
Eligible X Post-policy	0.054	0.227
R&D User Cost	0.580	0.080
Synthetic User Cost	0.550	0.080
Control Variables		
Pre-policy R&D Capital	0.160	0.367
NAICS 541	0.252	0.434
Total revenues†	1.315	4.261
Total assets†	1.314	3.134
Total liabilities†	0.808	1.709
Interest rate (per cent)	9.05	888.9

† Millions of nominal Canadian dollars.

address this endogeneity problem, we create a "synthetic" after-tax cost that is used as an instrument for U_t. Intuitively, the synthetic cost is just the after-tax cost of R&D calculated under the assumption that a firm's prior-year R&D expenditures and taxable income remain unchanged from the preceding year. Thus, the synthetic cost reflects changes in the tax code, but not a firm's current income or R&D spending. This type of instrument was first proposed by Auten and Caroll (1999) and Gruber and Saez (2002), and subsequently used by Rao (2012) to estimate R&D cost elasticities. In our sample, the average synthetic user cost is 55 cents. An OLS regression in first differences of marginal on synthetic user costs yields a coefficient of 0.58 [t= 58].

The bottom panel in Table 1 provides summary statistics for several additional controls, including our two proxies for adjustment costs – an indicator for firms in *NAICS 541* (roughly 25 percent of the estimation sample), and an indicator for firms that made *R&D Capital* expenditures prior to the policy change (about 16 percent of the sample).

3.4 Estimation

We begin our empirical analysis by estimating the average change in R&D expenditures for firms that were eligible for a larger tax credit after the 2004 revision of the SRED expenditure limit. Specifically, we estimate the following reduced-form regression

$$E[Y_{it}|E_{it}, X_{it}] = \exp\{E_{it}PostPolicy_t\beta_1 + E_{it}\beta_2 + \gamma_i + \lambda_t + X_{it}\theta\} \tag{3}$$

where E_{it} is the *Eligible* dummy variable; $PostPolicy_t$ equals one for all years after 2003; γ_i are firm fixed effects; λ_t are year effects; and X_{it} are time-varying firm-level controls. For outcome variables (Y_{it}), we use *Total R&D* expenditures, *R&D Wages* and *R&D Contracts*.

In this model, β_2 measures the average difference in Y_{it} between eligible and ineligible firms before 2004. Since the model includes firm-effects, β_2 is identified by firms that experience a change in eligibility status during the pre-policy time period. Similarly, the average change in R&D expenditures for firms that change eligibility status in the post-policy period is $(\beta_1 + \beta_2)$. The parameter β_1 measures the pre- versus post-policy difference in the association between eligibility and expenditures. We interpret β_1 as the mean impact of the change in the SRED expenditure limit.[11]

We estimate equation (3) using a Poisson quasi-maximum likelihood (QML) model. This approach handles the large number of cases where $Y_{it} = 0$ in our data more naturally than a log-log model, and yields coefficient estimates that may be interpreted as elasticities. The quasi-maximum likelihood approach uses robust standard errors to correct for over-dispersion, leading to asymptotically correct confidence intervals.

The key assumption behind our causal interpretation of β_1 is that β_2 is a valid estimate of the counter-factual relationship between eligibility (i.e. prior-year taxable income) and R&D expenditures in the absence of a policy change. Since we include year-effects to control for aggregate time-trends, the main threat to causal inference is an omitted variable that leads to an upward shift in β_2 around the same time as the policy change. We cannot test the assumption that β_2 remains constant following the expenditure limit reformulation. However, we do construct a set of "placebo" policy-changes during the pre-intervention period and find no evidence that β_2 is trending upwards prior to 2004.

Although estimates of (3) are relatively easy to understand, they do not show how firms respond to changes in the marginal user cost of R&D, for which eligibility is only a coarse

[11] Because eligibility is a function of prior-year taxable income, (3) is not a standard difference-in-differences estimator. In particular, we never observe the average difference in outcomes for two firms with the same prior-year income but different SRED eligibility limits in a given year. Rather, our model compares the association between R&D and having prior-year taxable income in the relevant range before and after a change in SRED policy.

proxy. Figure 1 shows that depending on their level of R&D expenditure, firms with $E_{it} = 1$ may experience no change in user costs, a decline in the average cost of R&D, or a decline in marginal user costs. We therefore supplement our reduced from estimates with results from a second set of regressions based on the following specification:

$$E[Y_{it}|U_{it}, X_{it}] = \exp\{log(U_{it})\delta \ + \gamma_i + \lambda_t + X_{it}\theta\} \tag{4}$$

In equation (4), the parameter δ estimates the user-cost elasticity of R&D expenditures. To address the simultaneity of Y_{it} and *R&D User Cost* (i.e. the marginal after-tax cost of R&D), we instrument for $\log(U_{it})$ with the log of *Synthetic User Cost* (i.e. the synthetic, after-tax cost of R&D). In these regressions, the user cost elasticity of R&D (δ) is identified by the changes in the SRED expenditure limit, and also by variation in corporate tax rates (see Appendix Table A-1), which influence both actual and synthetic costs through the deductibility of R&D expenditures. We estimate (4) using the moment conditions for nonlinear panel data models with endogenous explanatory variables described in Blundell et al. (2002).

4 Results

4.1 The Impact of R&D Tax Credits

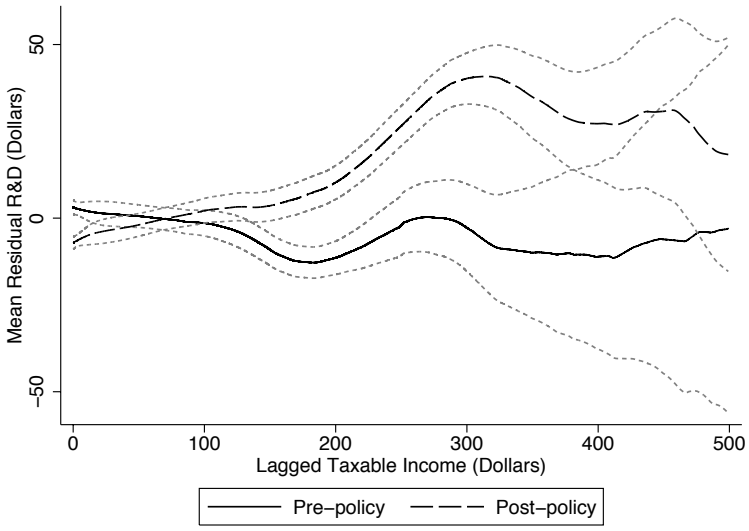
Figure 2 provides graphical intuition for our estimates and identification. To create the figure, we estimate a two way fixed-model (i.e. a linear regression of Total R&D on a full set of firm and year effects) and then use a local polynomial regression to plot the mean of the residuals from that regression against a firm's prior-year taxable income. Recall that the change in SRED tax credits potentially lowers the after-tax cost of R&D for firms with prior-year taxable income between \$200 and \$500 thousand. So we expect to see an increase in the residual part of R&D expenditures for firms making more than \$200 thousand in the post-policy period. This is exactly what we observe in Figure 2.[12]

We now turn to a regression that decomposes the residuals graphed in Figure 2. Table 2 presents estimates of the impact of expenditure limit reformulation on Total R&D from Poisson-QML estimation of equation (3). Estimates of β_1, the impact of the change in the expenditure limit, appear in the first row of the table.

Column 1 contains estimates from a parsimonious specification with only firm effects, dummies for *Eligible*, *PostPolicy*, and an interaction that identifies whether firms' R&D spending

[12]While it would be reassuring to observe a return to the same mean-zero baseline for firms above \$500 thousand, we do not have enough data to reliably estimate the mean residual on that portion of the support of the prior-year taxable income distribution.

Figure 2: Smoothed R&D Residuals Pre vs. Post Policy



became more sensitive to the eligibility threshold after the change in policy. The coefficient of 0.15 in the first row can be interpreted as an elasticity: crossing the eligibility threshold produces a 15 percent greater increase in R&D expenditures after the policy is in place than before. This effect is statistically significant at the 1 percent level. The coefficient on *Eligible* shows that firms above the threshold had greater R&D expenditures than firms below the threshold, even before the policy change. The coefficient on *PostPolicy* shows that there was a secular trend toward more R&D expenditures over this period, even among firms that did not change eligibility status. However, the *Eligible* x *PostPolicy* interaction shows that the proportional difference in Total R&D expenditures between eligible and ineligible firms doubles after the policy change.

In Column 2 we add year effects, which absorb the main effect of *PostPolicy*. This causes our estimates of the policy impact to increase somewhat – to 18 percent – and to become a bit more precise. In column 3 we add a host of time-varying firm-level controls, including the log of Assets and Revenues. Adding these size controls removes any statistically significant correlation between eligibility and R&D expenditures during the pre-policy period. However, we continue to find a highly significant ($p < 0.001$) increase in R&D expenditures at the eligibility threshold once the new SRED expenditure limits are in place.[13]

[13]Estimates from OLS regressions using *log(Total R&D)* as the outcome variable yield similar results, but are sensitive to the treatment of observations with zero reported R&D expenditure. For example, in a log-linear OLS model analogous to the specification reported in column 3, the coefficient on *Eligible x PostPolicy* is 0.74 (SE=0.19) when we treat a reported zero as $1 of R&D. The same coefficient is estimated at 0.18 (SE=0.04)

Table 2: Baseline Panel Regressions

Specification: Poisson Quasi-ML Regression Unit of Analysis: Firm-Year					
Outcome Variable	Total R&D (1)	Total R&D (2)	Total R&D (3)	R&D Wages (4)	R&D Contracts (5)
Eligible X Post policy	0.15***	0.18***	0.14***	0.12***	0.23**
	(0.06)	(0.05)	(0.05)	(0.05)	(0.10)
Eligible	0.11***	0.07*	0.03	0.01	0.09
	(0.04)	(0.04)	(0.04)	(0.04)	(0.09)
Post policy	0.15***				
	(0.03)				
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes	Yes
Controls	No	No	Yes	Yes	Yes
Psuedo-R2	0.75	0.75	0.80	0.84	0.68
Observations	35,222	35,222	35,222	35,222	35,222
Number of firms	4,514	4,514	4,514	4,514	4,514
Mean of outcome variable	72,780	72,780	72,780	50,203	10,679

Notes: Robust standard errors in parentheses. Significance levels: ***$p = 0.001$; **$p = 0.01$; *$p = 0.1$.

Columns 4 and 5 in Table 2 examine alternative outcomes. *R&D Wages* account for 70 percent of total R&D spending, and the results for that outcome are (not surprisingly) similar to those for *Total R&D*. However, column (5) shows that the percentage increase in *Contract R&D* is roughly twice the size of the wage effect. These results are in line with our expectation that R&D Wages are subject to greater adjustment costs than contract R&D.[14]

Unfortunately, our data on the R&D wage bill does not distinguish between hiring additional employees (real effects) and paying higher R&D wages (crowding out). However, to the extent that starting a new project requires bringing in a new R&D employee, we expect substantial fixed adjustment costs to reduce the impact of a more favorable tax credit policy. Intuitively,

if we treat the zeroes as $10,000 of R&D, and 0.03 (SE=0.05) if we drop observations with no reported R&D expenditures. J. M. C.Santos-Silva and Tenreyro (2006) explain how log-linear models can produce biased estimates, particularly in applications with many zeroes, and suggest using Poisson-QML as an alternative.

[14]We also estimate the impacts for R&D Capital and Other R&D spending. Neither effect is statistically different from zero.

these small firms face an integer constraint – new employees must be hired one at a time – and an incremental unit of R&D labor is not a negligible expenditure for firms whose average R&D wage bill is $50,203 (roughly 80% of the starting salary for a single engineer).[15] Firms that specialize in contract R&D should have fewer adjustment costs, primarily because a contractor's scale allows them to keep R&D employees with specialized skills utilized.

Our discussions with several managers and tax consultants suggest several different ways that adjustment costs might influence the decision to outsource R&D . First, if managers view both their research budget *and* the quantity of permanent R&D labor as fixed factors, contracting provides a way to exhaust the budget when tax incentives reduce the cost of internal R&D. Second, contract R&D may provide a relatively transparent (i.e. easy to document) form of R&D expenditure. Thus, even if a firm could allocate its current employees to a new research project, managers may favor contract R&D because they believe the *existence* of a contract raises the probability that the expenditures will qualify for tax credits.[16] Finally, contractors can pass any SRED-related tax savings to clients in at least two different ways: by allowing a client to claim the credits directly, or by claiming the credit themselves and passing the savings to clients in the form of lower prices.

4.1.1 Placebo Policies

For the specification used in Table 2, it is not possible to test the hypothesis that pre-policy outcome trends were identical for treated and untreated firms, in part, because the same firm could belong to both groups depending on the time-path of prior-year taxable income, which determines treatment eligibility. As an alternative test of our identifying assumptions, we look for a sharp change in firms' responsiveness to the eligibility limit thresholds around the year when the policy actually changed, relative to a set of "placebo" policy years.

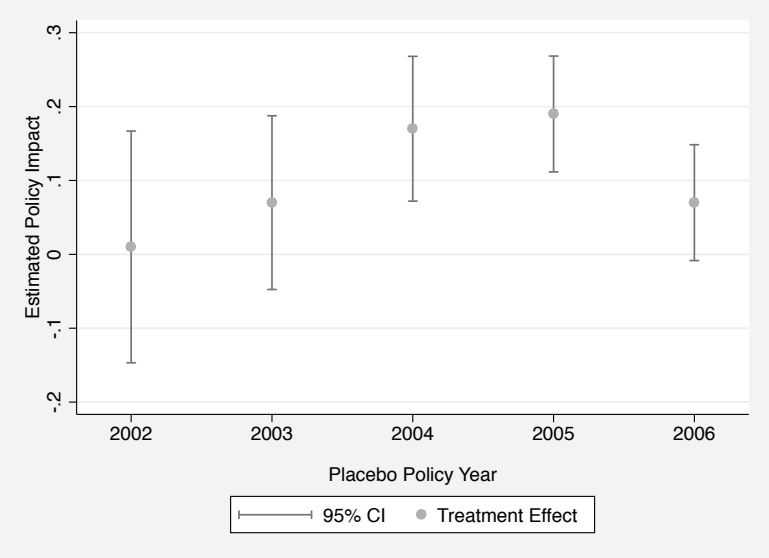
To implement this test, we took all eight years of data and created five overlapping 4 year panels (2000-2003, 2001-2004, etc.). We then estimate equation (3) under the (usually false) assumption that the new SRED expenditure limits went into effect in the third year of each panel. Thus, in the first placebo panel (2000-2003) the "placebo policy" occurs in 2002, and there is no real post-policy data used in estimation. Similarly, for the last placebo panel (2004-2007) the fake policy occurs in 2006 and there is no real pre-policy data used in estimation. We expect to see the largest estimated effects for the 2002-2005 panel, where the placebo policy coincides with the timing of the actual expenditure limit reformulation.

[15] The web site talentegg.ca reports starting salaries for Canadian engineers between $57,000 and $84,000, with a median of roughly $65,000 in 2013, or about $60,000 in 2008 dollars.

[16] We find supporting evidence for this story by analyzing related party (i.e. non-arms length) contract R&D expenditures, and finding that they are a significant piece of the overall contract R&D effect.

In Figure 4 we plot the "placebo policy" coefficients (β_1) from this exercise, along with their 95 percent confidence intervals, using *Total R&D* as the outcome variable. The estimated impact of the first placebo policy is zero. There is a sharp increase in the estimated policy impact when the placebo year moves from 2003 to 2004, when the change actually occurred. While the largest estimates occur for a placebo year of 2005, the key coefficient declines significantly when we move to the last placebo-panel, which contains no pre-intervention data.

Figure 3: Placebo Treatment Effects



Overall, Figure 4 illustrates that our baseline results are driven by a sharp change in firms' responsiveness to the eligibility threshold centered on the year when the thresholds actually changed. This lends credibility to a causal interpretation of our baseline results, since the main threat to our identification strategy is an upward trend in the slope of the earnings-R&D relationship over the entire sample period.

4.2 Firm-Level Heterogeneity

This sub-section further explores the idea of adjustment costs by estimating triple-difference models that allow the estimated impact of the SRED policy change to vary across different groups of firms. We focus on firms that made R&D capital investments in the pre-policy period and/or belong to the Professional, Scientific and Technical Services sector (NAICS 541).[17] The

[17]Example of firms in this industry are engineering and internet consulting companies as well as specialized software developing companies.

triple difference specification extends equation (3) by adding main effects and interactions for these particular firms. In particular, we estimate the following regression:

$$E[Y_{it}|E_{it}, X_{it}] = \exp\{D_i E_{it} PostPolicy_t \beta_1 + D_i PostPolicy_t \beta_2 + D_i E_{it} \beta_3 + E_{it} PostPolicy_t \beta_4 + E_{it} \beta_5 + \gamma_i + \lambda_t + X_{it}\theta\} \quad (5)$$

where D_i is a NAICS 541 (R&D Capital) dummy, and the other variables are defined above. Note that this model contains a full set of two-way interactions, and that the main effects of D_i and $PostPolicy_t$ are subsumed in the firm and year fixed-effects respectively.

The first three columns in Table 3 show the differential policy impact for firms in the Professional, Scientific and Technical Services sector (NAICS 541) in terms of *Total R&D*, *R&D Wages* and *R&D Contracts*. For *Total R&D* and *R&D Wages* we estimate that the post-policy increase in R&D spending at a NAICS 541 firm is roughly 20 percent larger than for the average firm.

We interpret the differential treatment effect for these firms in terms of adjustment costs. In particular, contract R&D providers may not view an additional scientific or technical employee as a fixed cost that would be difficult to keep fully utilized. Compared to other firms, these specialized R&D providers can more easily shift human and physical assets between *internal* R&D projects (for which they can claim a tax credit) and revenue generating work.[18] Because the adjustment costs of hiring or making capital acquisitions are smaller, we observe a larger treatment effect for firms in NAICS 541.

Columns 4 through 6 in Table 3 show the differential response to the change in SRED policy for firms outside NAICS 541 that purchased R&D capital before 2004. If capital expenditures are an important component of adjustment costs, then these firms should have a larger response to the policy change since those costs have already been sunk. This is exactly what we see in columns 4 and 5, where firms that made *ex ante* R&D capital expenditures increase Total R&D spending by 28 percent more, and R&D Wages by 22 percent more, than otherwise eligible firms in the post-policy period. Contract R&D spending also increases more for these firms, though our estimates for that outcome are imprecise.

[18] Firms that perform R&D services can expense their work for foreign clients, or for Canadian firms that do not claim the R&D tax credit. The latter option raises an interesting tax arbitrage possibility that we have not yet explored.

Table 3: Capital Adjustment Costs and the Impact of R&D Tax Credits

Specification: Poisson Quasi-ML Regression Unit of Analysis: Firm-Year						
Sample	All Firm-Years			Non-NAICS 541 Firm-Years		
R&D Outcome Variable	Total	Wages	Contracts	Total	Wages	Contracts
Eligible X Policy X NAICS 541	0.21**	0.22**	0.18			
	(0.09)	(0.09)	(0.19)			
Eligible X NAICS 541	-0.04	-0.06	-0.19*			
	(0.05)	(0.04)	(0.10)			
Policy X NAICS 541	-0.07	-0.12	0.09			
	(0.08)	(0.08)	(0.18)			
Eligible X Policy X Capital				0.28**	0.22**	0.38
				(0.12)	(0.10)	(0.26)
Policy X Capital				-0.27***	-0.16***	-0.34**
				(0.07)	(0.05)	(0.13)
Eligible X Capital				-0.16*	-0.16*	-0.09
				(0.09)	(0.09)	(0.20)
Eligible X Policy	0.07	0.04	0.15	-0.04	-0.04	0.03
	(0.06)	(0.05)	(0.13)	(0.05)	(0.06)	(0.17)
Eligible	0.05	0.05	0.06	0.11**	0.11**	0.09
	(0.04)	(0.04)	(0.10)	(0.04)	(0.05)	(0.13)
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Psuedo-R2	0.80	0.84	0.68	0.81	0.84	0.67
Observations	35,101	27,424	26,020	26,251	19,273	19,945
Total Firms	4,495	3,515	3,326	3,350	2,463	2,542
NAICS 541 / Capital Firms	1,146	1,052	785	539	510	425
Mean of outcome	73,030	64,479	14,455	61,833	56,359	10,600

Notes: Robust standard errors in parentheses. Significance levels: ***$p = 0.001$; **$p = 0.01$; *$p = 0.1$. All models are estimated using an unbalanced panel of all available firm-years; changes in sample size are due to omission of any firm with all-zero outcomes.

4.3 User Cost Elasticities

While the estimates reported in Tables 2 and 3 are closely linked to the change in SRED expenditure limits, and useful for exploring the role of adjustment costs in determining small firm R&D expenditures, they do not measure the effect of a change in the marginal after-tax cost of R&D. In particular, Figure 1 shows how firms that we define as *Eligible* for increased SRED credits based on their prior-year taxable income may or may not experience a decline in marginal user costs. Our final set of results focuses on the marginal cost elasticity of R&D, in order to provide a clear link to both theory and the prior empirical literature.

Table 4 presents a series of estimates of the relationship between R&D expenditures and the marginal after-tax cost of R&D. To address the simultaneity of R&D expenditures and the tax rate paid on the marginal dollar of a firm's taxable income, we instrument the marginal after-tax cost with the synthetic cost described above (i.e. the marginal after-tax cost faced a by a firm that did not change its R&D expenditures or taxable income from the prior year). We continue to use an exponential conditional mean (Poisson) specification, and estimate the model via GMM using the moment conditions described in Blundell et al. (2002).[19,20] Recall that the implicit "first stage" relationship between synthetic and actual marginal user costs of R&D is quite strong – unreported OLS regressions show a partial correlation of 0.7 between actual and synthetic R&D costs, with T-statics of roughly 50.

The first column in Table 4 shows a user cost elasticity of -1.5. This number is broadly in line with previous studies, though at the high end of the range. It lends support to earlier work that finds larger tax elasticities of R&D for small firms that may face financial constraints that limit access to external funds. An elasticity greater than one also implies that the SRED tax credit stimulates additional private R&D expenditures.[21]

The second and third columns in Table 4 estimate alternative specifications of our baseline model. In column 2, we add the lagged dependent variable (in logs) to allow for some dynamics in firms' response to changes in the cost of R&D. While there is a statistically strong time-series correlation in R&D expenditures, this produces very little change in the estimated marginal cost elasticity. In column 3, we use the moment conditions proposed in Windmeijer (2000) to

[19] The moment conditions used to produce the estimates in Table 4 are $E_{it}\left[\left(y_{it} - exp(x_{it}\beta)\frac{\overline{y_i}}{\overline{\mu_i}}\right)x_{it}\right] = 0$, where $\overline{y_i}$ and $\overline{\mu_i}$ are within-firm averages of the outcome and predicted outcome ($\exp(x_{it}\beta)$) respectively.

[20] We obtain very similar estimates from linear instrumental variables specifications that use *log(Total R&D)* as the outcome and treat observations with no reported R&D as missing at random. Using *log(Total R&D +$1)* as the outcome produces very large estimated user-cost elasticities, suggesting that many firms censor their reported R&D at values considerably greater than zero.

[21] As with the reduced form models in Table 2, we obtain much larger estimates in log-linear IV models that treat zero reported R&D as a nominal expenditure (e.g. setting the reported zeroes equal to $1,000 yields an estimated marginal cost elasticity of -5.78 (SE=0.13) in a specification akin to column 1). Dropping all of the observations with no reported R&D yields estimates very similar to those presented in Table 4.

Table 4: User Cost Elasticity of R&D

Specification: IV Poisson (GMM) Unit of Analysis: Firm-Year Instruments: Synthetic R&D User Cost					
Outcome Variable	Total R&D (1)	Total R&D (2)	Total R&D (3)	R&D Wages (4)	R&D Contracts (5)
log R&D User Cost	-1.54***	-1.57***	-1.22***	-1.16***	-2.71***
	(0.21)	(0.21)	(0.19)	(0.19)	(0.55)
log Total R&D$_{t-1}$		0.07***			
		(0.00)			
log Assets	0.34***	0.28***	-0.83*	0.30***	0.37***
	(0.07)	(0.06)	(0.44)	(0.06)	(0.10)
log Revenues	0.04*	0.03*	0.05**	0.06***	0.00
	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)
Year FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Observations	35,222	35,222	35,222	35,222	35,222
Number of firms	4,514	4,514	4,514	4,514	4,514
Mean of outcome variable	72,780	72,780	72,780	50,203	10,679

Notes: Robust standard errors in parentheses. Significance levels: ***$p = 0.001$; **$p = 0.01$; *$p = 0.1$.

address the concern that our regressors are not strictly exogenous (e.g. residuals in the current-period R&D equation might be correlated with future levels of assets or revenues).[22] This leads to a slightly smaller estimated elasticity, though we cannot reject the null hypothesis that the cost elasticity is equal to the estimate in column 1, where we assume strictly exogenous regressors.

Columns 4 and 5 in Table 4 return to the moment conditions used in models 1 and 2, and focus on alternative outcomes. Similar to the reduced form results, we find that estimates of the cost elasticity for *R&D Wages* are quite close to the estimates for *Total R&D* expenditures, while *R&D Contracts* exhibits a significantly larger response.

[22] This is analogous to using first differences rather than conditional fixed effects in a linear panel data model. The moments used to estimate the model are $E_{it}\left[\left(\frac{y_{it}}{\mu_{it}} - \frac{y_{it-1}}{\mu_{it-1}}\right) x_{it-s}\right] = 0$ for $s \geq 1$ and $\mu_{it} = \exp(x_{it}\beta)$.

5 Conclusions

We exploit a change in eligibility rules for R&D investment tax credits under the Canadian SRED policy to estimate the impact of this program on small-firm R&D expenditures. We find that privately owned firms that became eligible to benefit from a 35 percent R&D tax credit rate on a greater amount of qualified R&D expenditures increased their R&D spending by an average of 15 percent, compared to before the program. This corresponds to a cost elasticity of R&D of -1.5. This relatively large estimated elasticity contributes to a growing body of evidence suggesting that tax incentives can induce private R&D expenditures, even among small firms. While small firms account for a modest share of aggregate R&D, they may have a comparative advantage in specific types of innovation, and linking our findings to innovation outcomes is an important open topic for future research.

This study also provides several pieces of evidence that fixed adjustment costs play an important role in how small firms respond to a change in the after-tax cost of R&D. First, we decompose R&D spending into wages and contracts, and show that estimated elasticities are much larger for the second category, which poses fewer adjustment costs for a small firm that may not be able to fully utilize a new scientist or engineer. Second, we show that the response to a reduced after-tax R&D cost was larger among firms that (a) perform contract R&D services or (b) recently made R&D-related capital investments.

Beyond providing new evidence on adjustment costs and response of small firms to the R&D tax credit, our findings raise the intriguing question of why Canada's SRED program seemingly succeeds at stimulating small-firm R&D where U.S. policies appear weak or, at best, appear to yield inconclusive evidence of their effectiveness? One possibility is that firms pay more attention to SRED as the largest form of public R&D subsidy in Canada. Indeed, an industry of consultants exists that helps firms attain their credits. Another possibility is that outcomes reflect significant differences in the design of the policies, such as the fact that U.S. R&D tax credits are only applied to a firm's *marginal* expenditures (relative to a moving average baseline) during the period when many U.S. studies were done. The importance of this and other policy-design decisions in mediating the impact of R&D tax credits is another important topic for additional research.

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Appendix

Table A-1: Canadian Controlled Provate Corporation Marginal Tax Rates

	2000	2001	2002	2003	2004	2005	2006	2007
Maximum small business limit ($thous.)	$200	$200	$200	$225	$250	$300	$300	$400
Tax rate up to reduced business limit[†]	13.12	13.12	13.12	13.12	13.12	13.12	13.12	13.12
Tax rate from reduced business limit to $300K	29.12	22.12	22.12	22.12	22.12	22.12	22.12	22.12
Tax rate above $300K or small-business deduction threshold	29.12	28.12	26.15	24.12	22.12	22.12	22.12	22.12

[†]The reduced business limit varies between $0 and the maximum small business deduction threshold depending on the firm's size as determined by taxable capital employed in Canada.

Table A-2: Distribution of Incremental R&D User Cost

	User Cost (U_{it}): Cents per $R&D	Within Firm Changes (Max U_t - Min U_t)
90th Percentile	65	22
75th Percentile	65	13
50th Percentile	60	13
25th Percentile	52	0
10th Percentile	52	0
Observations	35,222	4,514