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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 changes in 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.

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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 meaningful private response, particularly among smaller firms that may lack sophisticated tax-planning capabilities, have little or no tax liability, and that 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 into the impact of fiscal incentives on R&D spending by small private firms.[1]

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 (i.e., user 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 three contributions to the literature on R&D tax incentives. First, we

[1] While the program is commonly referred to as SR&ED in Canada, we have decided to conserve an ampersand by adopting the acronym SRED throughout this paper.

focus on small private firms.[2] 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).

Second, because SRED credits are fully refundable for most of the firms in our sample, our findings are relevant to debates over the design of the R&D tax credit. In particular, observers such as Tyson and Linden (2012) have called for the U.S. to adopt a similar policy, given that small firms are often tax-exhausted and do not receive cash equivalent benefits from non-refundable tax credits.

Our third 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 we assume to have relatively low adjustment costs) 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 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.

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

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 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. 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 (i.e., user cost) of R&D to obtain a scale-free estimate of the cost elasticity of R&D spending.[3] 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, some recent studies provide evidence from other countries, including Canada (Dagenais et al.,

[3] To our knowledge, the only paper to examine innovation-related outcome variables other than R&D spending is Czarnitzki et al. (2011).

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 of 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 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 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.

To our knowledge, no study 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. However, 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.

Finally, as noted in the introduction, the refundable nature of SRED credits makes our results relevant to U.S. tax policy debates. Since most firms in our sample earn fully refundable credits, we cannot test whether the elasticity of R&D differs for credits earned as non-cash carry-forwards versus cash equivalents. Nevertheless, our findings complement the results in Zwick and Mahon (2014), which show that small financially constrained firms exhibit a greater response to accelerated depreciation benefits in their capital expenditures, and those of Himmelberg and Petersen (1994), which show that R&D investments are sensitive to cash flow for small firms in high-tech industries.

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 firm's R&D expenditures in cash should have a larger impact on small-firm R&D expenditures than for large firms.

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. Therefore, 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 also may 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

The SRED program is a tax incentive provided by the federal government to encourage businesses of all sizes and sectors to conduct research and development in Canada. 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.[4]

There are two main components to the SRED program. First, all companies operating and carrying out R&D in Canada may deduct 100 percent of qualifying R&D expenditures from their taxable income.[5] And second, the same firms are eligible to receive a non-refundable investment tax credit on qualifying expenditures at the general rate of 20 percent.[6] Furthermore, the SRED program provides small and medium-sized CCPCs with an additional 15 percent tax credit, for a total tax credit rate of 35 percent, on R&D expenditures up to a threshold called the *expenditure limit*. Credits earned at this higher rate are fully refundable. 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 prior-year taxable capital employed in Canada. To simplify exposition, we focus only on how taxable income affects the expenditure limit, because taxable capital is only relevant for a handful of the firms in our estimation sample. Formally, the expenditure limit for firm i in year t (EL_{it}) can be written as:

$$EL_{it} = min\{\$2 \text{ million}, max\{0, Z_t - 10\ TY_{i(t-1)}\}\}, \tag{1}$$

where $TY_{i(t-1)}$ 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.

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

[5]Until 2014, qualifying expenditures included both current and capital expenditures used in the conduct of qualifying SRED activities. Since January 1, 2014, capital expenditures no longer qualify.

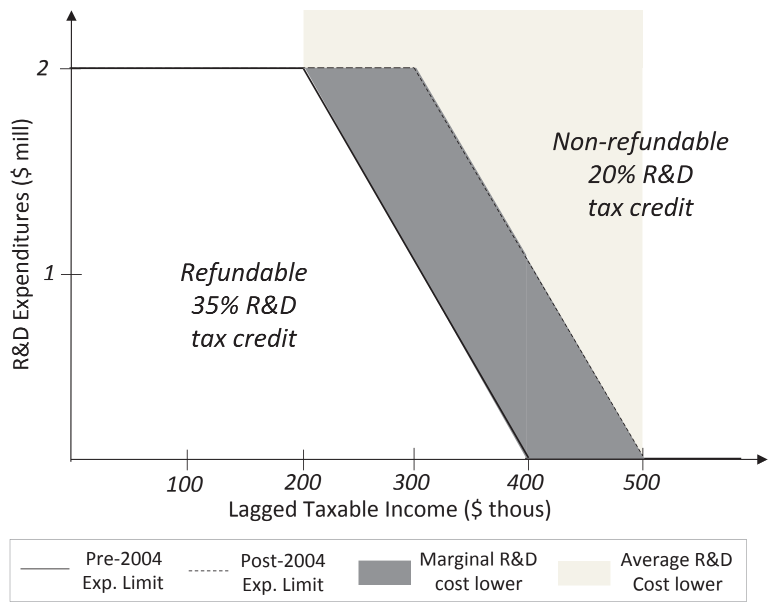
[6]As of January 1, 2014, the general credit rate is now 15 percent.

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, which increased the upper bound of the expenditure limit phase-out range to $500 thousand in prior-year taxable income, while the lower bound was increased to $300 thousand. 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.

Figure 1 illustrates how the expenditure limit works and how the change in 2004 had its effect. The solid line reflects how the expenditure limit before 2004 depended on a firm's prior-year taxable income. R&D expenditures below this line earned tax credits at the rate of 35 percent, while additional expenditures above this threshold earned credits at 20 per cent. The 2004 change extended rightward the expenditure limit. In Figure 1, this extension is depicted by the dashed line. Given prior-year taxable income levels of between $200 and $500 thousand, the change lowered the *marginal* after-tax cost of R&D for any firm whose last dollar spent on R&D reached the darkly shaded parallelogram. It also lowered the *average* after-tax cost of R&D for any firm whose last dollar spent reached either the darkly shaded parallelogram or the lightly shaded area above the parallelogram.

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

Figure 1: SRED Expenditure Limits Before and After Program Change



tax laws, and a firm's specific tax position (e.g., other credits, deductions, carry-forwards). Conceptually, the marginal after-tax cost of R&D (C_{it}) is determined by the deductions (τ) and tax credits (ρ) applied to an additional dollar of R&D and is given by:

$$C_{it} = 1 - \tau_t(TY_{it}, R_{it}) - \rho_t(R_{it}, EL_{it}, TaxesOwed_{it}). \tag{2}$$

Deductions are typically equal to a firm's marginal tax rate, which is determined by both taxable income (TY_{it}), due to the application of a lower tax rate on an initial tranche of income earned by small businesses, and contemporaneous R&D expenditures (R_{it}), which as a result of the deduction influences taxable income.[7] These deductions reduce the after-tax cost of R&D as long as taxable income net of other deductions is positive.

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

SRED tax credits work as a subsidy to reduce the after-tax cost of R&D. The value of the marginal SRED credit depends on a 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 a $0.35 tax credit if its R&D expenditure is below the expenditure limit and a $0.20 tax credit otherwise. However, the value of these credits in lowering R&D costs depends on whether the credits are refundable and on the taxes the firm must pay. Credits earned at the 35 percent rate are entirely refunded.[8] Credits earned at the 20 percent rate reduce the marginal cost of R&D by 20 cents as long as the firm has a remaining tax liability, since these credits can be used to fully offset taxes payable. If a firm does not owe any taxes but does have the maximum expenditure limit (i.e., $2 million during our sample period), it earns a fully refundable tax credit of 8 percent.[9] Thus, we have:

$$\rho_t(R_{it}, EL_{it}, TaxesOwed_{it}) = \begin{cases} 0.35, & \text{if } R \leq EL \\ 0.20, & \text{if } EL < R \text{ and } 0 < TaxesOwed \\ 0.08, & \text{if } EL < R,\ TaxesOwed \leq 0 \text{ and } EL = \$2,000,000 \end{cases}.$$

Table 1 illustrates the joint distribution of the credit rate (ρ) and marginal tax rate – or equivalently, the approximate value of a $1 deduction ($\tau$) – for all firm-years in our estimation sample. In these data, the vast majority of firms receive the fully refundable 35 percent

[8]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 vast majority of CCPC SRED expenditures are current expenditures.

[9]In reality, credits and deductions are somewhat more valuable than we suggest here, since we do not account for the fact that firms may use them in other years. This implies that we overstate the after-tax cost of R&D.

SRED tax credit. Roughly half the observations also have no taxable income. These tax-exhausted firms receive no deduction for R&D expenditures, and under U.S. tax policy would only benefit through carry-forwards to future years. Of course tax-exhaustion depends upon R&D expenditures, since R&D spending directly reduces taxable income (i.e., $TaxesOwed_{it}$ is a function of R_{it}). Thus, once firms leave the 35 percent credit category, the after-tax cost of R&D will tend to rise rapidly because SRED credits have a lower rate and are (mostly) non-refundable. In addition, because R&D expenditures lower taxable income, SRED credits are more likely to generate carry-forwards instead of cash.

Table 1: Distribution of Deductions & Credits

	Marginal tax rate (τ)			
Credit Rate (ρ)	0%	13.1%	22.1%	Total
35%	55.5	39.5	3.2	98.3
20%	0.0	0.1	0.4	0.5
8%	0.6	0.0	0.0	0.6
0%	0.6	0.0	0.0	0.6
Total	56.8	39.6	3.7	100

Each cell in this table shows the percentage of firm-year observations with a given deduction level and R&D tax credit rate in our unbalanced sample ($N = 48,638$).

Before moving on, it is important to note that our measure of the after-tax marginal cost of R&D $(1-\rho-\tau)$ 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 reduce tax-payable in 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 liability that is payable on the 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 their R&D activity in response to differences in provincial R&D support.[10] This yields an unbalanced panel of 7,239 firms and 48,638 firm-year observations. Fifty percent of these firms are in service industries, 29 percent in manufacturing industries, and the remaining 21 percent are in other sectors (primarily agriculture).

Table 2 provides summary statistics for our estimation sample. Total annual SRED-eligible R&D expenditures averaged \$82,887 per year, which implies that aggregate annual R&D spending for the firms in our estimation sample was roughly \$600 million.[11] Sixty-six percent of a representative firm's annual expenditures (or \$55,217) reflect wages paid to R&D personnel. Seventeen percent of R&D expenditures (or \$14,077) were spent on contract research.[12] Ex-

[10]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.

[11]Thus, if SRED produced a 10-15 percent increase in aggregate R&D for firms in our sample, it would amount to incremental spending of \$60 to \$90 million. We do not view this amount as likely to merit investigation of general equilibrium effects or crowding out in the market for R&D labor.

[12]Contract research expenditures reflect expenditures on the same type of activities that would qualify for

penditures on R&D capital were the smallest component, accounting for only $3,022, or about 3.6 percent of overall expenditures. However, conditional on claiming R&D capital, the average expenditure was about $27,000. The remaining 13 percent of total R&D spending is highly correlated with R&D Wages, and we interpret this residual spending as overhead.[13]

Table 2: Summary Statistics

Variable	Mean	SE	Min	Max
R&D Indicator	0.590	0.492	0.0	1.0
Total R&D	82,887	216,352	0.0	>6.5M
R&D Wages	55,217	147,591	0.0	>3.5M
R&D Contracts	14,077	63,350	0.0	>2.5M
R&D Capital	3,022	27,868	0.0	>2.0M
Non-R&D Investment	78,420	368,447	0.0	>35M
Tax Policy Variables				
Eligible	0.073	0.260	0.0	1.0
Eligible X Post-policy	0.048	0.214	0.0	1.0
R&D User Cost	0.591	0.084	0.359	1.0
Synthetic User Cost	0.566	0.085	0.359	1.0
Control Variables				
Pre-policy R&D Capital	0.238	0.426	0.0	1.0
NAICS 541	0.289	0.453	0.0	1.0
Total revenues†	1.166	3.822	<0.0	>200M
Total assets†	1.155	2.805	<0.0	>150M
Total liabilities†	0.769	1.630	0.0	>50M

† Millions of nominal Canadian dollars. All statistics based on an unbalanced panel of N=48,638 firm-year observations. Disclosure rules prevent reporting max and min for all variables.

SRED benefits if undertaken in-house.

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

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 2 shows that 7.3 percent of all observations are eligible, and of those, 4.8 percent are treated (eligible after 2004). By far, the main reason why firms are not eligible is that their taxable income was less than \$200 thousand.

To create the variable *R&D User Cost*, we calculate each firm's marginal after-tax cost of R&D (C_{it}) by accounting for deductions and tax credits as described above. The average after-tax cost of an additional dollar of R&D for firms in our estimation sample was 59 cents. The variable *Synthetic User Cost* is used as an instrument for C_{it}. Intuitively, this variable measures the after-tax cost of R&D calculated under the assumption that a firm's R&D expenditures and taxable income remain unchanged from the preceding year. Formally, *Synthetic User Cost* $= 1 - \tau_t(TY_{i(t-1)}, R_{i(t-1)}) - \rho_t(R_{i(t-1)}, EL_{it})$. Changes in *Synthetic User Cost* reflect 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 was subsequently used by Rao (2012) to estimate R&D cost elasticities. In our sample, the average synthetic cost of R&D is 57 cents, and we show below that this variable is strongly correlated with *R&D User Cost*.

The bottom panel in Table 2 provides summary statistics for several additional controls, including our two proxies for adjustment costs: (a) an indicator for firms in *NAICS 541* (roughly 29 percent of the estimation sample) and (b) an indicator for firms that made *R&D Capital* expenditures prior to the policy change (about 24 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:

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

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. The outcome variable R_{it} is either *Total R&D* expenditures, *R&D Wages*, or *R&D Contracts*.

In this model, β_2 measures the average difference in R_{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.[14]

[14] 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

We estimate equation (3) using a Poisson quasi-maximum likelihood (QML) model. This approach handles the large number of cases where $R_{it} = 0$ in our data more naturally than a log-log specification and yields coefficient estimates that may be interpreted as elasticities. The QML 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 from (3) are relatively easy to understand, they do not show how firms respond to changes in the marginal after-tax cost of R&D, for which eligibility is only a coarse proxy. Figure 1 shows that depending on their level of R&D expenditure, firms with $E_{it} = 1$ may experience no change in after-tax costs, a decline in the average cost of R&D, or a decline in marginal costs. We therefore supplement our reduced form estimates with results from a more structured analysis, based on the following specification:

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

between R&D and having prior-year taxable income in the relevant range before and after a change in SRED policy.

In equation (4), the parameter δ corresponds to the cost elasticity of R&D. The key challenge for identification is that C_{it} is a function of contemporaneous R&D spending (see Equation 2). We expect this mechanical relationship to produce a positive bias in estimates of δ, since greater R&D expenditures lead to an automatic increase in the after-tax cost of R&D when firms either exceed the expenditure limit or run out of taxable income. To address this simultaneity problem, we use *log(Synthetic User Cost)* as an instrumental variable. Thus, our estimates of δ are identified by policy-induced variation in $log(C_{it})$ produced by changes in the SRED expenditure limit formula and also by variation in corporate tax rates (see Appendix Table A-1). We estimate (4) via Generalized Method of Moments (GMM), using the moment conditions for nonlinear panel data models with endogenous explanatory variables described in Blundell et al. (2002).[15]

4 Results

4.1 Graphical Evidence

Figures 2 and 3 provide some graphical intuition for our identification strategy and results. First, Figure 2 shows that a discontinuous jump in the distribution of firm-year observations at exactly the point where *Total R&D* crosses the expenditure limit. We know from Table 1 that only 1.7 percent of our sample actually does cross this threshold. Figure 2 suggests that for those firms the change in their after-tax marginal cost of R&D exerts a strong influence

[15] Code for estimating these models in Stata is available on the authors' website.

on overall R&D expenditures.[16] Appendix B provides details on the creation of Figure 2 and develops a simple model to rationalize the spike in observations just above the expenditure limit.

Figure 3 illustrates how the 2004 change in the expenditure limit formula influenced R&D expenditures. To create the figure, we estimate a two-way fixed-effects 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 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 3.[17]

Figure 2: R&D at the Expenditure Limit

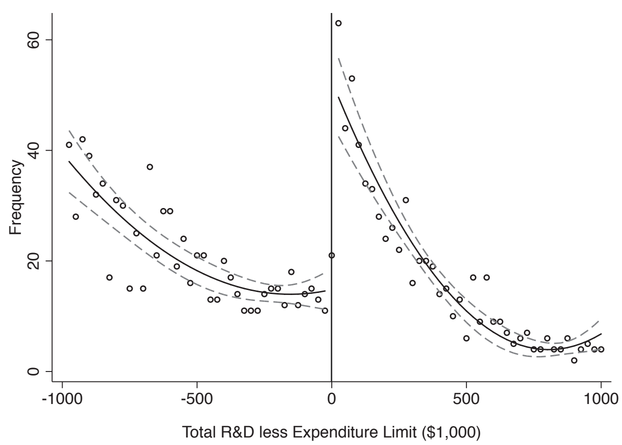
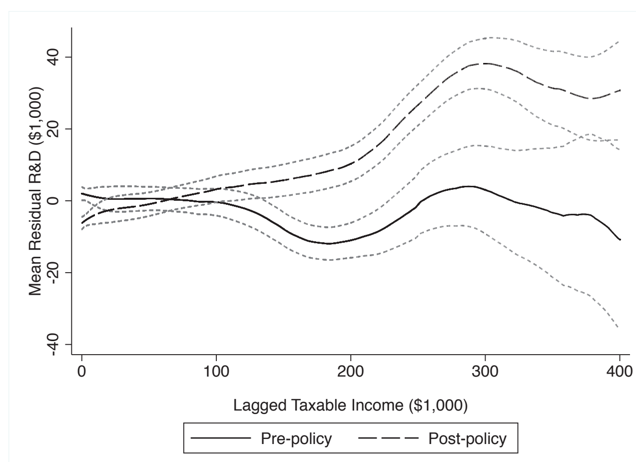


Figure 3: Pre- & Post-Policy R&D



[16]This figure also shows that we *cannot* utilize regression discontinuity methods to estimate the impact of the SRED policy, since firms can manipulate their location relative to the expenditure limit through their choice of R&D expenditures, and clearly do so.

[17]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.

4.2 The Impact of R&D Tax Credits

We now turn to a regression that decomposes the residuals graphed in Figure 3. Table 3 presents estimates of the impact of expenditure limit reformulation on Total R&D from the 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 became more sensitive to the eligibility threshold after the change in policy. The coefficient of 0.17 in the first row can be interpreted as an elasticity: crossing the eligibility threshold produces a 17 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 in the post-policy time period, the average difference in Total R&D expenditures between eligible and ineligible firms is almost twice the average difference from the baseline period.

In Column 2, we add year effects, which absorb the main effect of *PostPolicy*. This causes our estimates of the policy impact to increase very slightly, to 18 percent. 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

Table 3: Reduced Form Estimates for Change in SRED Eligibility Limits

Specification: Poisson QML 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)	Non-R&D Investment (6)
Eligible X Post policy	0.17***	0.18***	0.18***	0.12***	0.36**	0.16*
	(0.05)	(0.05)	(0.04)	(0.04)	(0.09)	(0.10)
Eligible	0.09**	0.07*	-0.00	0.00	0.02	0.06
	(0.04)	(0.04)	(0.03)	(0.03)	(0.08)	(0.07)
Post-policy	0.11***					
	(0.02)					
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes	Yes	Yes
Controls	No	No	Yes	Yes	Yes	Yes
Psuedo-R2	0.75	0.75	0.81	0.83	0.67	0.61
Observations	48,638	48,638	48,638	38,748	36,235	46,809
Number of firms	7,239	7,239	7,239	5,806	5,378	6,895
Mean of outcome variable	82,887	82,887	82,887	69,310	18,895	81,732

Notes: Significance levels: $***p = 0.001$; $**p = 0.01$; $*p = 0.1$. Robust standard errors (clustered by firm) in parentheses. All models are estimated using an unbalanced panel of all available firm-years; changes in sample-size occur when firms with all-zero outcomes are dropped from the conditional fixed-effects specification. The mean value of the outcome variable is calculated for all firm-years used in the estimation.

($p < 0.001$) increase in R&D expenditures at the eligibility threshold once the new SRED expenditure limits are in place.[18]

Columns 4 through 6 in Table 3 examine alternative outcomes.[19] Column (4) shows that

[18]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 (see Table A-5). 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.

[19]Sample sizes change for different outcomes because our models contain a multiplicative fixed effect and therefore all observations with all-zero outcomes are dropped. As a robustness check, we re-run all regressions with the outcome set to $\max\{1, R_{it}\}$ and obtain identical results.

R&D Wages exhibit a 12 percent increase. Column (5) shows that *Contract R&D* increases by 36 percent. Because wages account for two-thirds of R&D spending, the wage effect is larger in real terms. However, the scale-free coefficient on *Contract R&D* is twice that of *Total R&D* and three times the size of the *R&D Wages* effect. These results are in line with our expectation that R&D Wages are subject to greater adjustment costs than contract R&D.[20]

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, 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 $55,217 (roughly the starting salary for a single engineer).[21] 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 practitioners 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

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

[21] 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.

research project, managers may favor contract R&D because they believe use of contracted R&D services facilitates the assessment of these expenditures for purposes of the tax credit.[22] 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.

Finally, the last column in Table 3 examines changes in *Non-R&D Investment*. If the observed increase in *Total R&D* reflects re-labeling of expenditures that firms would have made even in the absence of a SRED program change, we would expect a reduction in other types of investment. Instead, we find an imprecisely estimated 16 percent increase in non-R&D capital expenditure for eligible firms in the post-policy period.[23]

4.2.1 Placebo Policies

For the specification used in Table 3, 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 take all eight years of data and created five overlapping four-year panels (2000-2003, 2001-2004, etc.). We then estimate equation (3) under the (usually false)

[22] We find supporting evidence for this story by examining 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.

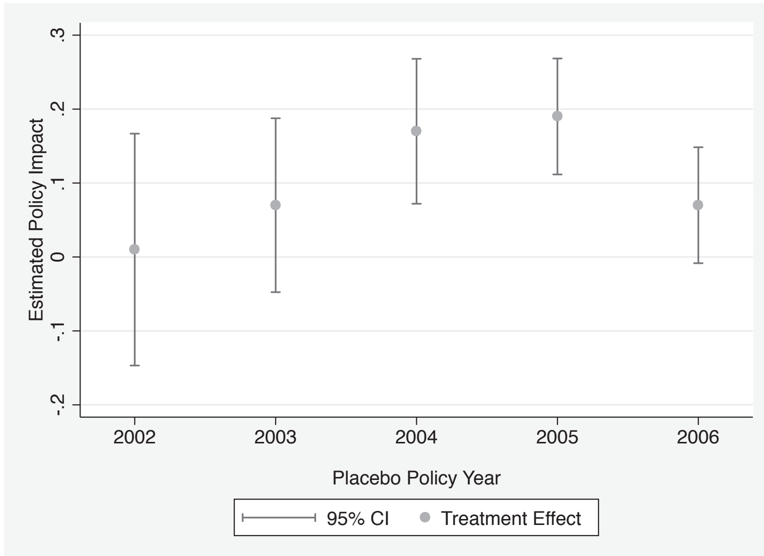
[23] Table A-2 replicates the results in Table 3 using a balanced panel of 4,495 firms that appear in our data for all eight years of the sample period. In that sample, the *Non-R&D Investment* result is not statistically significant.

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 the 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 the 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. For this exercise, we use a balanced panel of firms that appear in our data for all eight years of the sample period, so the estimation sample is held constant across each of the shorter panels.

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.

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 the reduced-form results in Table 3, since the main threat to our identification strategy is an upward trend in the slope of the lagged-earnings-to-R&D relationship over the entire sample period.

Figure 4: Placebo Treatment Effects



4.3 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).[24] The triple difference specification extends equation (3) by adding main effects and interactions for these particular firms. In particular, we estimate the following regression:

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

[24]Examples of firm types in this industry are engineering and internet consulting companies as well as specialized software development companies.

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 4 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.[25] Because the anticipated adjustment costs of hiring or making capital acquisitions are smaller, we observe a larger treatment effect for firms in NAICS 541. Moreover, the absence of any statistically significant difference in *Contract R&D* expenditures for firms in NAICS 541 provides a type of placebo test, since our theory of adjustment costs does not apply to contract expenditures for the firms that provide such services.

Columns 4 through 6 in Table 4 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

[25] 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 4: Capital Adjustment Costs and the Impact of R&D Tax Credits

Specification: Poisson QML Regression
Unit of Analysis: Firm-Year

Sample	All Firm-Years			Non-NAICS 541 Firm-Years		
R&D Outcome Variable	Total (1)	Wages (2)	Contracts (3)	Total (4)	Wages (5)	Contracts (6)
Eligible X Policy X NAICS 541	0.18**	0.22***	-0.11			
	(0.09)	(0.09)	(0.19)			
Eligible X NAICS 541	-0.03	-0.06*	-0.05			
	(0.04)	(0.04)	(0.08)			
Policy X NAICS 541	-0.08	-0.14*	0.17			
	(0.07)	(0.07)	(0.17)			
Eligible X Policy X Capital				0.25**	0.24**	0.11
				(0.11)	(0.10)	(0.24)
Policy X Capital				-0.26***	-0.19***	-0.22*
				(0.06)	(0.05)	(0.12)
Eligible X Capital				-0.15*	-0.16**	-0.05
				(0.08)	(0.08)	(0.17)
Eligible X Policy	0.12**	0.04	0.40***	0.02	-0.05	0.34**
	(0.05)	(0.05)	(0.13)	(0.05)	(0.05)	(0.16)
Eligible	0.02	0.05	-0.04	0.08**	0.11**	-0.02
	(0.04)	(0.04)	(0.09)	(0.04)	(0.04)	(0.12)
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	0.81	0.83	0.67	0.81	0.83	0.66
Observations	48,638	38,748	36,235	34,595	25,964	26,133
Total Firms	7,239	5,806	5,378	5,051	3,837	3,793
NAICS 541 / Capital Firms	2,188	1,969	1,585	879	820	690
Mean of outcome	82,887	69,310	18,895	66,176	57,108	13,393

Notes: Significance levels: ***$p = 0.001$; **$p = 0.01$; *$p = 0.1$. Robust standard errors (clustered by firm) in parentheses. All models are estimated using an unbalanced panel of all available firm-years; changes in sample size occur when firms with all-zero outcomes are dropped from the conditional fixed-effects specification. The mean value of the outcome variable is calculated for all firm-years used in the estimation.

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 25 percent more and *R&D Wages* by 24 percent more than otherwise eligible firms in the post-policy period.[26]

4.4 Tax Cost Elasticity of R&D

While the estimates reported in Tables 3 and 4 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 5 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 marginal tax rates, we instrument for the actual marginal after-tax cost of R&D with the synthetic marginal after-tax cost described above (i.e., the marginal after-tax cost of R&D for a firm that did not change its R&D expenditures or taxable income from the prior year). Because this instrument is constructed from prior-year financial data, we lose one year of data from the panel. We continue to use an exponential conditional mean (Poisson) specification,

[26]Table A-3 shows that we obtain very similar results using a balanced panel.

and estimate the model via GMM using the moment conditions described in Blundell et al. (2002).[27] The implicit "first-stage" relationship between synthetic and actual marginal user costs of R&D is quite strong – OLS regressions show a partial correlation of 0.6 with T-statistics of roughly fifty.[28]

The first column in Table 5 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.[29] An elasticity greater than one also implies that the SRED tax credit stimulates additional private R&D expenditures.

The second and third columns in Table 5 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 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).[30]

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[27]The moment conditions used to produce the estimates in Table 5 are $E\left[\left(y_{it} - \mu_{it}\frac{\overline{y_i}}{\overline{\mu_i}}\right) z_{it}\right] = 0$, where $\mu_{it} = exp(x_{it}\beta)$ and $(\overline{y_i}, \overline{\mu_i})$ are the within-firm averages of the outcome and predicted outcome (μ_{it}), respectively.

[28]Table A-6 reports both the first-stage and IV estimates for a log-linear model. Treating observations with no reported R&D as missing at random (i.e., dropping them) leads to very similar estimates. However, the log-linear IV results are generally sensitive to decisions about how to treat cases where $R_{it} = 0$. In particular, using *log(Total R&D +$1)* as the outcome produces implausibly large estimates, reinforcing our view that an exponential specification is more appropriate.

[29]Regressing *Total R&D* on *log(R&D User Cost)* without any instruments produces a positive and statistically significant coefficient, indicating that it is important to account for the simultaneity of taxes and R&D expenditures in these data.

[30]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 $\mu_{it} = \exp(x_{it}\beta)$. We lose a few additional observations with this specification due to the presence of lagged variables in the moment

Table 5: GMM Estimates of the 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	-1.49***	-1.43***	-1.13***	-1.05***	-3.00***
	(0.20)	(0.18)	(0.12)	(0.18)	(0.50)
log Total R&D$_{t-1}$		0.06***			
		(0.00)			
log Revenues	0.03***	0.03**	0.08***	0.04***	0.00
	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)
log Assets	0.33***	0.29***		0.31***	0.29***
	(0.05)	(0.04)		(0.05)	(0.07)
Year FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Observations	44,314	42,521	38.845	44,314	44,314
Number of firms	7,353	7,353	7,186	7,353	7,353
Mean of outcome variable	84,028	84,028	84,028	56,652	13,923

Notes: Significance levels: ***p = 0.001; **p = 0.01; *p = 0.1. Robust standard errors (clustered by firm) in parentheses. All models are estimated using an unbalanced panel of all available firm-years; changes in sample-size occur when firms with all-zero outcomes are dropped. †See text and footnote 30 for a discussion of the alternative moments used to estimate model (3).

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.[31]

Columns 4 and 5 in Table 5 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 about two-thirds the size of the estimates for *Total R&D* expenditures, while *R&D Contracts* exhibits a response that is twice as large as the effect for *Total R&D*.[32]

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

equations.

[31] One caveat that applies to all of the results in Table 5 is that we can only approximate the true after-tax cost of R&D. In particular, if provincial R&D tax incentives and other unobserved tax-policy changes are positively correlated with changes in the SRED program, our estimates may exaggerate the magnitude of the reported elasticities. However, other simplifications, such as not incorporating the taxable nature of SRED tax credits into our approximation of the after-tax cost of R&D, should have a countervailing effect. Moreover, any mis-measurement of the after-tax cost of R&D should not affect the relative magnitudes of the elasticity estimates for different expenditure categories.

[32] Table A-4 shows that we obtain similar results if we restrict the sample to a balanced panel.

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 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 an additional 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 the response of small firms to the R&D tax credit, our findings highlight significant differences between U.S and Canadian tax policy in this area. We show that Canada's SRED program succeeds at stimulating small-firm R&D. Studies of the U.S. R&D tax credit typically focus on larger firms and tend to find weak effects or inconclusive evidence. One explanation for this discrepancy may be that firms pay more attention to SRED as the largest form of public R&D subsidy in Canada. Another possibility is that outcomes reflect significant differences in the design of the policies, such as the fact that SRED credits are often fully refundable. In our sample, over half of the firm-year observations were tax-exhausted and would therefore only receive carry-forwards under U.S. policy, as opposed to cash under SRED. Moreover, during the time period examined in many studies, the U.S. R&D tax credit applied to incremental expenditures relative to a moving average baseline, as opposed to all qualifying R&D expenditures as under SRED. The importance of these and other policy-design decisions in mediating the impact of R&D tax credits is a promising topic for future research.

References

Akcigit, U. and W. Kerr (2010). Growth Through Heterogeneous Innovations. *NBER Working Paper*, #16443.

Altshuler, R. (1988). A dynamic analysis of the research and experimentation credit. *National Tax Journal 41*, 453–466.

Auten, G. and R. Caroll (1999). The Effect of Income Taxes on Household Income. *Review of Economics and Statistics 81*(4), 681–693.

Baghana, R. and P. Mohnen (2009). Effectiveness of R&D tax incentives in small and large enterprises in Quebec. *Small Business Economics 33*, 91–107.

Bailey, M. N. and R. Lawrence (1992). Tax Incentives for R&D: What Do the Data Tell Us? Technical report, Council on Research and Technology, Washington, DC.

Bernstein, J. I. and M. I. Nadiri (1988). Rates of Return on Physical and R&D Capital and Structure of the Production Process: Cross Section and Time Series Evidence. *NBER Working Paper #2570*.

Bloom, N., R. Griffith, and J. Van Reenen (2002). Do R&D Tax Credits Work? Evidence from a Panel of Countries, 1979-1997. *Journal of Public Economics 85*, 1–31.

Blundell, R., R. Grifith, and F. Windmeijer (2002). Individual effects and dynamics in count data models. *Journal of Econometrics 108*, 113–121.

Cohen, W. and S. Klepper (1996). Firm Size and the Nature of Innovation within Industries: The Case of Process and Product R&D. *The Review of Economics and Statistics 78*(2), 232–243.

Congressional Budget Office (2007). Federal support for research and development. *Publication #2927*.

Czarnitzki, D., P. Hanel, and J. M. Rosa (2011). *Research Policy 40*, 217–229.

Dagenais, M., P. Mohnen, and P. Therrien (1997). Do Canadian Firms Respond to Fiscal Incentives to Research and Development? Technical report, CIRANO, Discussion Paper 97s-34.

Gruber, J. and E. Saez (2002). The Elasticity of Taxable Income: Evidence and Implications. *Journal of Public Economics 84*, 1–32.

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

Hall, B. H., Z. Griliches, and J. A. Hausman (1986). Patents and R&D: Is There a Lag? *International Economic Review 27*(2), 265–283.

Hall, B. H. and J. Van Reenen (2000). How Effective Are Fiscal Incentives for R&D? A Review of the Evidence. *Research Policy 29*, 449–469.

Hao, K. Y. and A. Jaffe (1993). Effect of Liquidity on Firm's R&D Spending. *Economics of Innovation and New Technology 2*, 275–282.

Harhoff, D. (1997). Are there Financing Constraints for R&D and Investment in German Manufacturing Firms? *ENSAE Annales d'Economie et de Statistique 49-50*, 421–456.

Himmelberg, C. P. and B. C. Petersen (1994). R&D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries. *The Review of Economics and Statistics 76*(1), 38–51.

J. M. C. Santos-Silva and S. Tenreyro (2006). The Log of Gravity. *Review of Economics and Statistics 88*, 641–658.

Koga, T. (2003). Firm size and R&D tax incentives. *Technovation 23*(7), 643–648.

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

Lokshin, B. and P. Mohnen (2012). How effective are level-based R&D tax credits? Evidence from the Netherlands. *Applied Economics 44*(12), 1527–1538.

Mansfield, E. (1986). The R&D Tax Credit and Other Technology Policy Issues. *American Economic Review 76*, 190–194.

Rao, N. (2012). Do Tax Credits Stimulate R&D Spending? Revisiting the Effect of the R&D Tax Credit in its First Decade. *New York University Working Paper*.

Swenson, C. (1992). Some tests of the incentive effects of the research and experimentation tax credit. *Journal of Public Economics 49*, 203–218.

Tyson, L. and G. Linden (2012). The Corporate R&D Tax Credit and U.S. Innovation and Competitiveness. Technical report.

Wilson, D. J. (2009). Beggar Thy Neighbor? The In-State, Out-of-State, and Aggregate Effects of R&D Tax Credits. *Review of Economics and Statistics 91*(2), 431–426.

Windmeijer, F. (2000). Moment Conditions for Fixed Effects Count Data Models with Endogenous Regressors. *Economics Letters 68*, 21–24.

Yohei, K. (2011). Effect of R&D Tax Credits for Small and Medium-sized Enterprises in Japan: Evidence from Firm-Level Data. *RIETI Discussion Paper Series 11-E-066*.

Zwick, E. and J. Mahon (2014). Do Financial Frictions Amplify Fiscal Policy? Evidence from Business Investment Stimulus. *Working Paper Harvard University.*

Appendix A

Table A-1: Canadian-Controlled Private 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: Reduced Form Policy Effects for Balanced Panel

Specification: Poisson QML 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)	Non-R&D Investment (6)
Eligible X Post policy	0.15***	0.18***	0.14***	0.12***	0.23**	0.11
	(0.06)	(0.05)	(0.05)	(0.05)	(0.10)	(0.10)
Eligible	0.11***	0.07*	0.03	0.01	0.09	0.12
	(0.04)	(0.04)	(0.04)	(0.04)	(0.09)	(0.08)
Post policy	0.15***					
	(0.03)					
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes	Yes	Yes
Controls	No	No	Yes	Yes	Yes	Yes
Psuedo-R2	0.75	0.75	0.80	0.84	0.68	0.58
Observations	35,101	35,101	35,101	27,424	26,020	34,129
Number of firms	4,495	4,495	4,495	3,515	3,326	4,364
Mean of outcome variable	73,018	73,018	73,018	64,468	14,448	87,152

Notes: Robust standard errors (clustered by firm) in parentheses. Significance levels: $***p = 0.001$; $**p = 0.01$; $*p = 0.1$. All models are estimated using a balanced panel of N=35,101 firm-years; changes in sample size are due to omission of any firm with all-zero outcomes. The mean value of the outcome variable is calculated for all firm-years used in these estimations.

Table A-3: Adjustment Cost Estimates for Balanced Panel

Specification: Poisson QML 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	1,145	1,052	784	538	509	425
Mean of outcome	73,018	64,468	14,448	61,821	56,343	10,600

Notes: Robust standard errors (clustered by firm) in parentheses. Significance levels: ***$p = 0.001$; **$p = 0.01$; *$p = 0.1$. All models are estimated using a balanced panel of N=35,101 firm-years; changes in sample size are due to omission of any firm with all-zero outcomes. The mean value of the outcome variable is calculated for all firm-years used in these estimations.

Table A-4: GMM Estimates for Balanced Panel

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	-1.45***	-1.48***	-1.24***	-1.09***	-2.61***
	(0.21)	(0.21)	(0.46)	(0.19)	(0.54)
log Total R&D$_{t-1}$		0.07***			
		(0.00)			
log Revenues	0.04*	0.03*	0.05**	0.06***	0.00
	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)
log Assets	0.34***	0.28***	-0.90***	0.30***	0.38***
	(0.07)	(0.06)	(0.42)	(0.06)	(0.10)
Year FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Observations	31,160	31,160	29,926	31,160	31,160
Number of firms	4,514	4,514	4,511	4,514	4,514
Mean of outcome variable	75,241	75,241	75,241	52,636	10,631

Notes: Robust standard errors (clustered by firm) in parentheses. Significance levels: ***p = 0.001; **p = 0.01; *p = 0.1. All models are estimated using a balanced panel of N=35,101 firm-years; changes in sample size are due to omission of any firm with all-zero outcomes. †See text and footnote 30 for a discussion of the moments used to estimate model (3). The mean value of the outcome variable is calculated for all firm-years used in these estimations.

Table A-5: OLS Estimates of Reduced Form Policy Impact

Specification: Ordinary Least Squares Outcome: log(max{Total R&D, X})				
Outcome: X =	Missing (1)	\$10,000 (2)	\$25,000 (3)	\$50,000 (4)
Eligible X Post policy	0.11***	0.18***	0.12***	0.09***
	(0.03)	(0.03)	(0.02)	(0.02)
Eligible	0.03	0.06*	0.06***	0.05***
	(0.03)	(0.03)	(0.02)	(0.02)
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.93	0.72	0.75	0.77
Observations	28,713	48,638	48,638	48,638
Number of firms	7,239	7,239	7,239	7,239

Notes: Robust standard errors (clustered by firm) 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. Model (1) drops observations with no reported R&D expenditures.

Table A-6: Linear Instrumental Variable Estimates of the User Cost Elasticity of R&D

Outcome: log(max{Total R&D, X})				
Instruments: log(Synthetic R&D User Cost)				
X =	Missing	\$10,000	\$25,000	\$50,000
	(1)	(2)	(3)	(4)
log(R&D User Cost)	-1.45***	-2.85***	-1.69***	-0.99***
	(0.08)	(0.06)	(0.04)	(0.03)
log Revenues	0.02***	0.02***	0.01***	0.01***
	(0.00)	(0.00)	(0.00)	(0.00)
log Assets	0.16***	0.12***	0.08***	0.05***
	(0.01)	(0.00)	(0.00)	(0.00)
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
First-Stage Coefficient on Excluded Variable				
log(Synthetic Cost)	0.51***	0.59***	0.59***	0.59***
	(0.01)	(0.00)	(0.00)	(0.00)
Observations	26,286	44,314	44,314	44,314
Number of firms	6,897	7,353	7,353	7,353

Notes: Robust standard errors (clustered by firm) 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. Model (1) drops observations with no reported R&D expenditures.

Appendix B

This appendix describes how we created Figure 2 (which is reproduced below as Figure B-1 for convenience) and provides a simple model of R&D investment to rationalize the distribution of *Total R&D* in the vicinity of the expenditure limit.

To produce Figure B-1, we first created a variable X_{it}, equal to firm i's *Total R&D* in year t minus its expenditure limit EL_{it} in the same year. Next, using the 1,501 observations where $|X_{it}| < \$1$ million, we counted the number of firm-years where X_{it} fell into each of a series of 80 "bins" with a bandwidth of \$25,000. Formally, letting $k = -39 \ldots 40$ index the bins, we created variables $Y_k = \sum_{i,t} 1[25,000 * (k-1) < X_{it} \leq 25,000 * k)]$ and $X_k = 25k$. Figure B-1 is a scatter plot of the 80 values of (Y, X), along with the fitted values and 95% confidence intervals from the regression:

$$Y = \alpha + \beta_1 X + \beta_2 X^2 + 1[X > 0]\{\alpha_2 + \gamma_1 X + \gamma_2 X^2\} + \varepsilon_k$$

.

We initially found the large spike in the distribution of Total R&D just above the expenditure limit (i.e., where marginal costs *increase*) counterintuitive. However, this feature of the data can be rationalized by a simple model of investment with three assumptions: (1) firms differ in their marginal productivity of R&D, (2) the marginal cost of R&D is discontinuous at the expenditure limit, and (3) R&D requires requires "lumpy" or discrete expenditures.

To illustrate, suppose that a firm investing x in R&D receives gross benefits $B(x;\eta) = \eta x^{\theta}$, where $\theta < 1$ and η is a random parameter with distribution F (Assumption 1). Further, suppose that the marginal cost of R&D is c^L up to some expenditure limit EL, and c^H thereafter (Assumption 2), so total costs are $C(x) = c^L \min\{x, EL\} + c^H \max\{0, x - EL\}$. The first-order condition for R&D investment then implies that:

$$x^*(\eta) = \begin{cases} \left[\frac{\theta\eta}{c}\right]^{1/(1-\theta)} & \text{if } \eta \leq \underline{\eta} \text{ or } \eta \geq \overline{\eta} \\ \\ EL & \text{if } \underline{\eta} < \eta < \overline{\eta}, \end{cases} \tag{B-1}$$

where c is marginal cost, $\underline{\eta} = c^L \frac{EL^{(1-\theta)}}{\theta}$, and $\overline{\eta} = c^H \frac{EL^{(1-\theta)}}{\theta}$. Thus, Assumptions 1 and 2 suffice to generate a spike in the distribution of *Total R&D* at the expenditure limit, since there is an atom of types $F(\overline{\eta}) - F(\underline{\eta})$ that spend exactly $x^* = EL$.

In Figure B-1, there is a discrete jump in the distribution of R&D spending at the expenditure limit but also an increased probability of exceeding the limit by amounts up to about \$500,000. While this could reflect the distribution of R&D productivity (i.e., $F(\eta)$ in our toy model), we find it more natural to assume that research typically requires discrete or "lumpy" expenditures that cause firms that would otherwise invest exactly EL to exceed the limit (Assumption 3).

To illustrate that Assumptions 1-3 can generate the pattern observed in Figure B-1, we use simulated data to produce the Figure B-2. For this simulation, we assume that $c^L = 0.65$ and $c^H = 0.80$ (as they typically do for the SRED program) and set $\theta = 0.75$. We then draw 30,000 random values of $TY_{i(t-1)}$ and η_i and use them to calculate the pre-policy expenditure limit EL_i and optimal level of R&D expenditures $x^*(\eta_i)$, using equations (1) and (B-1).[33] Adding lumpy

[33]We assume that $TY_{i(t-1)}$ has a beta(2,5) distribution and η has a Poisson(7) distribution. To capture the strong relationship between earnings and R&D, we generate these two variables using the same underlying random draws, so they have a raw correlation of 0.95.

R&D expenditures to this model necessarily involves some ad-hoc assumptions, since there is no *a priori* reason to assume a particular size or location for the marginal investment. Our approach is to assume that the size (S_i) of all R&D "projects" for a particular firm is drawn from a uniform distribution with support [$75,000,$300,000] and then set the firms' simulated R&D expenditures equal to $S_i \left\lceil \frac{x^*(\eta_i)}{S_i} \right\rceil$. As seen in Figure B-2, the result is a distribution of R&D that closely mimics Figure B-1. Stata code for producing the simulated data along with Figure B-2 is available on the authors' website.

Figure B-1: R&D at the Expenditure Limit

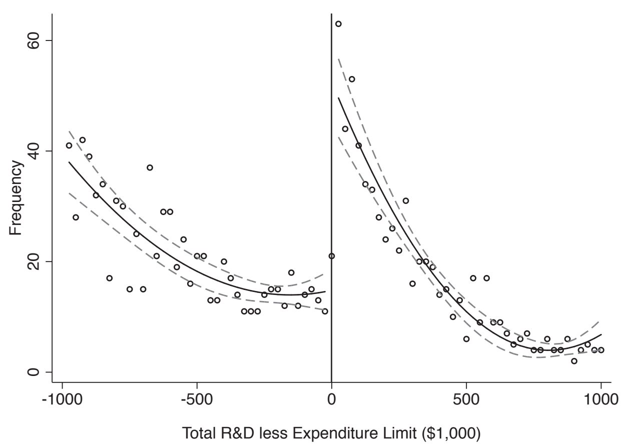

Figure B-2: Simulated Expenditure Limit