Do Tax Credits Stimulate R&D Spending? Revisiting the Effect of the R&D Tax Credit in its First Decade *

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Abstract

This paper examines the impact of the R&D tax credit during the 1981-1991 period using both publicly available data from financial filings and confidential IRS data from federal corporate tax returns. The key advance on previous work is the use of an instrumental variables strategy based on tax law changes that addresses the potential simultaneity between R&D spending and its user cost. The results yield a range of estimates for the effect of tax incentives on R&D investment. The tax change-based instrumental variables strategy yields elasticities half the size of elasticities from previous studies using US financial filing data. Estimates from IRS SOI data, which only reports qualified research expenditures, suggest that a ten percent reduction in the user cost would lead the average firm to increase qualified spending by $2.0 (0.39) million. Analysis of the components of qualified research spending shows that wages and supplies, which comprise the bulk of qualified spending, account for the increase in research spending. Estimates from the much smaller merged sample which makes use of the more precise tax data to calculate the tax component of the usercost suggest that qualified spending is responsive to the tax subsidy. A similar response in total spending is not statistically discernible in the merged sample. The inconsistency of estimates across datasets, instrument choice and specifications highlights the sensitivity of estimates of the tax-price elasticity of R&D spending.

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1 Introduction

In an attempt to stanch a decade-long decline in the GDP-share of private R&D spending, Congress adopted a tax credit for R&D expenditures in 1981. The Research and Experimentation Credit (R&D Credit) awards firms that increase their research spending a tax credit of up to 25 percent of their expenditures in excess of their past research spending. As the credit is incremental, the research credit offers no subsidy to firms that fail to increase their R&D spending. Along with existing provisions that allowed firms to expense R&D spending, the research credit lowers the after-tax cost of qualified research in hope of incentivizing firms to increase their R&D investments.

As the primary tax provision designed to encourage private R&D expenditures, the effectiveness of the Research and Experimentation Credit (R&D credit) has been of interest to both researchers and policymakers alike. Although early work (Eisner et al (1984)[1] and Mansfield (1986)[2]) suggested that the credit had an insignificant or modest impact on R&D spending, more recent studies have found surprisingly large user cost elasticities. Using confidential IRS data, Altshuler (1988) found that between 1981 and 1984 average effective credit rates were just a fraction—less than one-tenth—of the period's 25 percent statutory credit rate. Later studies, most notably Hines (1993) and Hall (1994), found that the R&D tax credit proffered much more bang-for-the-buck. Hines (1993) explored the effect of changes in the allocation rules of R&D expensing on the R&D activity of multinational firms. Using a special Compustat data panel describing foreign pretax earnings and foreign taxes paid

[1]Eisner, Albert and Sullivan (1984) took a natural experiment approach and made use of special survey data describing the composition of firm R&D spending to construct a difference-in-difference estimate of the effect of the R&D tax credit. They found that spending on research that qualified for the R&D tax credit grew 25.7 (5.0) percentage points faster than unqualified research spending between 1980 and 1981. They found that difference in spending growth was statistically insignificant in 1982, suggesting that the policy change did not fundamentally alter spending patterns. Comparing changes in aggregate qualified and unqualified R&D spending implicitly assumes that absent the introduction of the R&D tax credit these types of R&D spending would have increased identically; systematic spending trend differences among firms with different R&D spending mixes would violate this assumption.

[2]Mansfield (1986) compared the experiences of the US, Canada and Sweden using firm-level survey data; executives of a stratified sample of firms were asked to estimate the effect of the relevant tax incentives on the firm's R&D expenditures. According to the executives, each dollar of forgone tax revenue resulted in 30 to 40 cents of induced R&D spending.

between 1984 and 1989 for a subset of firms, Hines exploited variation in the fraction of U.S. R&D expenses firms can deduct against U.S. income for tax purposes to estimate the response of R&D spending to its after-tax price. His short-run estimates ranging from -1.2 to -1.6 and long-run estimates ranging from -1.3 to -2.0 suggest a tax-price elasticity of R&D that well exceeds unity. Although the changes in the allocation rules are conceivably exogenous, Hines' tack relies on variation in the tax treatment of R&D expenditures across firms—it essentially compares firms with and without excess foreign tax credits, an experiment that is different than the changes in the main statutory provisions of the R&D tax credit that are examined here.

The closest antecedent to this paper is Hall (1994), which used Compustat data from financial filings beginning in 1981 and ending in 1991. In her log first-difference specifications, Hall uses cross-time within-firm variation in tax positions and marginal R&D tax subsidies to estimate a short-run elasticity of -1.5 (0.3) and a long-run elasticity of -2.7 (0.8).

More recent work examining the impact of state tax credits and international experiences has found more modest elasticities (Wilson (2007), Bloom et al (2002)). Cross-country analysis by Bloom, Griffith and Van Reenen (2002) suggests much lower short- and long-run user cost elasticities. In their preferred dynamic specification they estimate a -0.14 short-run elasticity and a -1.09 long-run elasticity. Because the user cost of R&D is a function of the interest rate, which is positively correlated with R&D spending, Bloom et al worry that OLS estimates of the user cost elasticity would be biased upward. They instrument the R&D user costs with the tax component of the user cost to address this endogeneity issue as well as attenuation bias concerns. Although some countries in their sample have incremental R&D credit regimes, where high spending firms receive higher credit rates, Bloom et al do not address this potential source of bias due to the aggregate nature of their data. Wilson (2009) uses variation in state tax preferences for R&D to estimate both the impact of a state's R&D policy on R&D conducted in that state and the impact on R&D in neighboring states. Using state aggregate data he finds that R&D spending is negatively impacted by

tax preferences in other states, suggesting that firms shift R&D to proximate states with lower R&D user costs. The magnitude of this response nearly offsets the in-state response of R&D to changes in the in-state user cost. Wilson concludes that the aggregate R&D user cost elasticity is small and near-zero; state subsidies draw R&D across state borders rather than encouraging a new dollar of R&D spending. His state-level analysis yields an elasticity estimate of 0.17 in the short-run and 0.68 in the long-run. Wilson assumes that all R&D subject to an incremental R&D tax credit receives the highest statutory rate, abstracting from simultaneity between R&D spending and R&D user costs due to data limitations.

This paper re-examines the impact of federal tax advantages for R&D between the inception of the R&D tax credit in 1981 and 1991. Data after 1991 are excluded because the credit was allowed to first lapse in 1992. Since this and other lapses likely affected firms' expectations of the after-tax user cost of R&D, the analysis here is limited to only the first 11 years after the introduction of the research credit. Furthermore, during this period the R&D credit underwent several substantial revisions that allow for an instrumental variables strategy based on tax changes. Unlike previous efforts to assess the impact of tax subsidies on R&D spending, this paper incorporates restricted-access IRS corporate return data. As explained in more detail below, the structure of the R&D tax credit makes a firm's marginal tax subsidy difficult to infer from annual R&D spending as reported in its public financial statements alone. Data from the corporate tax return allows for accurate measurement of the tax subsidy each firm faces on its marginal R&D dollar each year and allows for unbiased assessment of the impact of the tax credit on R&D expenditures.

The main contributions of this paper are the use of IRS Statistics of Income (SOI) data that accurately describe marginal credit rates and a more direct correction for potential biases due to the simultaneity of R&D spending and marginal credit rates. Tax subsidy terms constructed using only publicly available Compustat data, and constructed using IRS data, differ and the differences often vary from year to year. This finding at a minimum suggests potential measurement error in subsidy rates calculated using public use data. Instrumen-

tal variable estimates suggest that different instrument sets produce different estimates of the effect of tax subsidies on R&D expenditures. These findings raise questions about the robustness of many panel data strategies for estimating the elasticity of R&D spending.

Using an instrumental variables strategy based on tax law changes to disentangle any potential simultaneity between R&D spending and its user cost, I estimate a short-run user cost elasticity for R&D spending. The results yield a range of estimates for the effect of tax incentives on R&D investment. The tax change-based instrumental variables strategy yields elasticities half the size of elasticities from previous studies using US financial filing data. Estimates from IRS SOI data, which only reports qualified research expenditures, suggest that a ten percent reduction in the user cost would lead the average firm to increase qualified spending by $2.0 (0.39) million. Analysis of the components of qualified research spending shows that wages and supplies, which comprise the bulk of qualified spending, account for the increase in research spending. Estimates from the much smaller merged sample, which makes use of the more precise tax data to calculate the tax component of the usercost, suggest that qualified spending is responsive to the tax subsidy. A similar response in total spending is not statistically discernible in the merged sample. The inconsistency of estimates across datasets, instrument choice and specifications highlights the sensitivity of estimates of the tax-price elasticity of R&D spending.

The paper proceeds as follows. Section 2 sketches the conceptual framework underlying the regression analysis. R&D is viewed as a durable input into the firm's production function. Tax subsidies are modeled as inducing relatively small changes in steady-state investments in R&D. Section 3 briefly describes key aspects of the R&D tax credit and their impact on the user cost of R&D spending. Section 4 discusses and contrasts public financial and restricted-access SOI data and details measurement issues. Section 5 lays out the empirical model and methodology, including a description of the instrumental variables used. Section 6 presents the results of different specifications using the two data sets. Section 7 concludes.

2 Conceptual Framework

Like most other R&D studies, this paper treats R&D, specifically the services of R&D capital, as an input into a firm's production function.[3] Research projects are undertaken by private firms to develop new products or new methods that increase sales. The output price is normalized to one. The output of firm i in time t, Y_{it}, is generated via a production function with a constant elasticity of substitution (σ) between the stock of R&D capital, S_{it}, and all other inputs, I_{it}:

$$Y_{it} = F\left(S_{it}, I_{it}\right) = \left[\theta_i S_{it}^{\frac{\sigma-1}{\sigma}} + \left(1-\theta_i\right) I_{it}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{1}$$

where θ_i is the firm-specific CES distribution parameter. Note that σ captures both the elasticity of substitution and the user cost elasticity of R&D spending. R&D investments, R_{it}, add to the R&D capital stock, S_{it}, without adjustment frictions; R&D capital depreciates at a constant rate δ. The R&D stock is governed by:

$$S_{it+1} = R_{it} - \left(1-\delta\right) S_{it} \tag{2}$$

The standard derivation of the Hall-Jorgenson user cost of capital formula can be extended to reflect both federal tax subsidies for R&D and the impact of the tax status of the firm. A firm that is taxable at marginal rate τ_{it} can expense its R&D spending in the current year and earn a tax credit at marginal rate c_{it}, which is indexed by firm because the marginal credit rate is a function of the firm's R&D spending as explained in further detail in section 3.[4] Firms discount the future at a common real interest rate, r_t, purchase R&D and other inputs at prices p_t^S and, p_t^I, and face a common constant depreciation rate on R&D

[3]Though only a small share of R&D spending is directly for capital goods, more than half of all expenditures consist of wages and fringe benefits and only 5 percent of costs are attributable to depreciation (NSF 2003), R&D expenditures are thought to buildup a stock of R&D knowledge. The service flows from this knowledge stock is the input into firm production.

[4]The corporate tax rate is indexed by firm to account for the progressivity of federal corporate taxes. In 2007 the 35 percent flat corporate tax rate applied to income greater than $18.333 million; incomes less than this level were taxed at a lower rate except for small intervals of more heavily taxed income. Some small firms subject to a marginal tax rate less than 35 percent do spend on R&D; their R&D credit rate reflects their smaller marginal tax rate.

capital, δ. The taxable firm maximizes the present discounted value of future profits:

$$max \sum_{s=t}^{\infty} \beta^{-(s-t)} \left[(1-\tau_{is}) \left(F(S_{is}, I_{is}) - p_s^I I_{is} \right) - p_s^S R_{is} (1-\tau_{is} - c_{is}) \right] \tag{3}$$

subject to the evolution of the R&D stock according to equation (**??**) and firms' static expectations of future tax policy.

From the requisite first-order conditions the analogous Hall-Jorgenson arbitrage condition for the optimal R&D capital stock can be written:

$$(1-\tau_{it} - c_{it}) \left(r_t + \delta - \pi_t^S \right) p_t^S = (1-\tau_{it}) F_{S_{it}} \tag{4}$$

where τ_{it} is the marginal corporate tax rate, c_{it} is the marginal research credit rate, r_t is the common real interest rate, δ is the depreciation rate of R&D capital, π_t^S is the time-varying growth rate of R&D input prices, p_t^S is the price of R&D inputs, and F_S is the first-derivative of the production function, $F(S_{it}, I_{it})$, with respect to R&D capital.

Note that the credit rate, c_{it}, enters the relation linearly because the depreciation base is not typically reduced by the amount of the credit. Firms are viewed as discounting at their real borrowing rates; although R&D is risky, the firms that account for the lion's share of R&D spending are large highly-rated firms that could fund their R&D by borrowing at generally low interest rates. The depreciation rate for R&D, δ, is thought to be high since a sizable fraction of R&D spending does not yield intellectual capital and goes to wages, supplies and equipment rental, none of which are durable. Since the wages comprise the bulk of R&D spending, R&D price inflation, π_t^S, should closely track wage growth for scientists and engineers.

Rearranging equation (**??**), the user cost of R&D capital, ρ_{it}, for a taxable firm can be written:

$$F_{S_{it}} = \rho_{it} = \frac{\left(r_t + \delta - \pi_t^S \right) p_t^S (1-\tau_{it} - c_{it})}{(1-\tau_{it})} \tag{5}$$

A nontaxable firm with k_{it} years of tax losses will not use the R&D expensing provision to offset income until those losses are exhausted; it will offset income in k_{it} years at the prevailing tax rate. Similarly, a firm that has insufficient tax liabilities to fully apply any R&D credit earned this year will carry its credit forward j_{it} years until it can fully use it. The tax terms in the user cost formula for nontaxable firms must be appropriately discounted to reflect the delayed use of the subsidies. The relevant user cost for a loss-laden firm that will not be taxable for k_{it} years is:

$$\rho_{it} = \frac{\left(r_t + \delta - \pi_t^S\right) p_t^S \left(1 - \tau_{it+k_{it}} \left(1 + r_t\right)^{-k_{it}} - c_{it} \left(1 + r_t\right)^{-j_{it}}\right)}{\left(1 - \tau_{it+k_{it}} \left(1 + r_t\right)^{-k_{it}}\right)} \tag{6}$$

where r_t is the interest rate, δ is the depreciation rate, p_t^S is the price of R&D inputs, τ_{it} is the marginal tax rate, k_{it} is the number of years until any losses are exhausted, c_{it} is the marginal research credit rate, and j_{it} is the number of years any R&D tax credits must be carried forward. Note that in the case of the taxable firm, k_{it} and j_{it} will be zero and the user cost formula will be identical to equation 5.

As noted above, the marginal R&D credit rate, c_{it}, varies across firms as well as over time. Initially, the marginal credit rate was a nonlinear function of the firm's current R&D spending, its recent R&D spending and its future R&D spending. Legislative modifications to the R&D credit's provisions changed the definition of the credit and the marginal credit rates firms faced. These changes are detailed below.

3 The R&D Tax Credit

In addition to direct federal support for R&D, such as research performed by federal agencies and grants for basic and applied research, the federal government provides indirect support for privately sponsored research through the tax code. Federal tax law offers two incentives for private R&D: a deduction for qualified research spending under Section 174 of the Internal

Revenue Code (IRC), and a non-refundable tax credit for qualified research spending above a base amount under IRC Section 41. These two tax advantages reduce the after-tax price of R&D investment; they are jointly referred to here as the "R&D tax credit" and their combined effect on the after-tax price of and impact on R&D spending is assessed.[5]

The Section 41 credit, known legislatively as the Research and Experimentation Tax Credit, was introduced as part of the Economic Recovery Tax Act of 1981, allowing firms to earn a tax credit on spending they were already able to expense under the existing Section 174 expensing provision. The credit is available for qualified research expenditures, which were defined as salaries and wages, certain property and equipment rental costs and intermediate materials expenses incurred in research undertaken to discover knowledge that is technological in nature for a new or improved business purpose. The tax credit was initially effective beginning July 1, 1981 and ending December 31, 1985.

In its original form the incremental tax credit was equal to 25 percent of qualified research expenditures (QREs) above a firm-specific base amount. A firm's base was its average nominal qualified spending on R&D in the previous three years, or 50 percent of current spending, whichever was greater. For the first nine years of the R&D tax credit the firm's base was defined as:

$$B_{it} = \text{Base for R\&D Credit} = max\left[\frac{1}{3}\left(R_{it-1} + R_{it-2} + R_{it-3}\right), 0.5R_{it}\right] \text{ for } t\text{=1981-1989} \tag{7}$$

where R_{it} is qualified R&D spending by firm i in year t.

Because a firm's base was a moving average of its past spending, additional qualified research spending in the current year increased the firm's base by one-third of the increase in each of the subsequent three years. This 'claw-back' muted the credit's incentive effects; some firms were even left with negative marginal credit rates.

[5]Net Operating Loss (NOL) carry-forwards resulting from Section 174 expensing can be carried forward up to 20 years—five years longer than Section 41 tax credits can be carried forward. Although this discrepancy in carry forward life has real implications for some firms, this level of detail is beyond the descriptive capability of the Compustat and IRS data used here and is ignored.

The marginal credit rate between 1981 and 1988 is:

$$c_{it} = \begin{cases} 0 & \text{if } R_{it+m} < B_{it+m} \text{ for } m = 0\text{–}3 \\ -s_t\left\{\frac{1}{3}\sum_{m=1}^{3}(1+r_t)^{-(m+k_{it})}\right\} & \text{if } R_{it} < B_{it} \text{ and } B_{it+m} < R_{it+m} \\ & \text{and } R_{it+m} < 2B_{it+m} \text{ for any } m = 1\text{–}3 \\ s_t\left\{(1+r_t)^{-j_{it}} - \frac{1}{3}\sum_{m=1}^{3}(1+r_t)^{-(m+k_{it})}\right\} & \text{if } B_{it+m} < R_{it+m} < 2B_{it+m} \\ & \text{for any } m = 0\text{–}3 \\ s_t\left\{\frac{1}{2}(1+r_t)^{-j_{it}} - \frac{1}{3}\sum_{m=1}^{3}(1+r_t)^{-(m+k_{it})}\right\} & \text{if } R_{it} > 2B_{it} \text{ and } B_{it+m} < R_{it+m} \\ & \text{and } R_{it+m} < 2B_{it+m} \text{ for any } m = 1\text{–}3 \end{cases}$$

where s_t is the statutory credit rate, k_{it} is the number of years until any tax losses are exhausted, j_{it} is the number of years the credit must be carried forward (it will be negative if it can be carried back), and r_t is the real interest rate. The negative summation term in the above equation represents the claw-back provision.

In the credit's original incarnation, a firm's marginal credit rate was highest when its current year qualified R&D spending, R_{it}, exceeds its current base amount, B_{it}, but is anticipated to not exceed its base in the following three years. Spending less than its base amount, the firm would not be eligible for credits in the next three years and thus not subject to the claw-back provision. In this case, if it has sufficient tax liabilities to fully offset its R&D tax credit, the firm's marginal credit rate is the statutory credit rate, s_{it}, or half the statutory credit rate if its current year spending exceeds twice its base. In terms of the preceding equation, if the firm is eligible for the full statutory rate, its current spending would exceed its base but be less than twice its base, and sufficient tax liabilities would mean j_{it} is zero. If the firm expected its qualified spending in the subsequent three years to be below its base amounts, the second summation term would be zero. From 3.5 to 9.5 percent of firms (5 to 16 percent of firms earning a credit) between 1981 and 1990 had marginal

credit rates equal to the statutory rate, depending on the year.

Because a firm's base can never be less than half of current expenditures, when R&D spending exceeds twice its historically defined base, the redefined base is increased 50 cents for every additional dollar of R&D spending. When this is the case, the first additive term of the preceding equation is halved, and the maximum marginal credit rate is reduced from 25 percent to 12.5 percent.

A firm that claimed the tax credit but had insufficient current-year tax liabilities to offset was allowed to carry the excess credit back up to three tax years and/or forward up to 15 tax years (j_{it} can range from -3 to 15). Carrying back (forward) the credit increases (decreases) the present value of the R&D credit.

The Tax Reform Act of 1986 extended the credit through 1988, but also reduced the statutory credit rate from 25 to 20 percent.[6] This rate reduction was not motivated by any careful assessment of the tax credit, but was instead part of one of the primary goals of TRA86—reducing the differences in tax burdens among major business asset categories (CRS 2007). The tax credit was extended through 1989 by the Technical and Miscellaneous Revenue Act of 1988, which also reduced the total tax preference for R&D by requiring firms to reduce the tax credit they claim by half the value of any deductions they claim under Section 174.[7] This partial recapture of the credit effectively cut a firm's marginal credit rate from 20 percent to 16.6 percent if its qualified R&D spending exceeded its base by less than 100 percent, and from 10 to 8.3 percent if its qualified R&D spending exceeded its base by

[6]TRA86 also folded the tax credit into the General Business Credit under IRC Section 38, subjecting the credit to a yearly cap. The tax credit was also expanded to include research contracted to universities and certain other nonprofits. The definition of QREs was also changed so that it applied to research aimed at producing new technical knowledge deemed useful in the commercial development of new products and processes. These changes in the definition of QRE are beyond the capability of the data, including the IRS data, used here as research expenditures are only reported in terms of contemporaneous definitions.

[7]Firms could alternatively reduce the depreciation basis of their R&D expenses by the value of the credit; this was less tax advantageous since losses have longer carry-forward periods than credits. Firms are assumed to have reduced the value of their credit rather than the value of their deduction.

more than 100 percent. The marginal credit rate in 1989 is:

$$c_{it} = \begin{cases} 0 & \text{if } R_{it+m} < B_{it+m} \\ & \text{for } m = \text{0-3} \\ -s_t\left(1-\frac{1}{2}\tau_{it}\right)\frac{1}{3}\sum_{m=1}^{3}\left(1+r_t\right)^{-(m+k_{it})} & \text{if } R_{it} < B_{it} \text{ and } B_{it+m} \leq R_{it+m} \\ & \text{and } R_{it+m} < 2B_{it+m} \text{ for any } m = \text{1-3} \\ s_t\left(1-\frac{1}{2}\tau_{it}\right)\left\{\left(1+r_t\right)^{-j_{it}} - \frac{1}{3}\sum_{m=1}^{3}\left(1+r_t\right)^{-(m+k_{it})}\right\} & \text{if } B_{it+m} \leq R_{it+m} < 2B_{it+m} \\ & \text{for any } m = \text{0-3} \\ s_t\left(1-\frac{1}{2}\tau_{it}\right)\left\{\frac{1}{2}\left(1+r_t\right)^{-j_{it}} - \frac{1}{3}\sum_{m=1}^{3}\left(1+r_t\right)^{-(m+k_{it})}\right\} & \text{if } R_{it} \geq 2B_{it} \text{ and } B_{it+m} \leq R_{it+m} \\ & \text{and } R_{it+m} < 2B_{it+m} \text{ for any } m = \text{0-3} \end{cases}$$

where τ_{it} is the marginal tax rate, s_t is the statutory credit rate, k_{it} is the number of years until any tax losses are exhausted, j_{it} is the number of years the credit must be carried forward (it will be negative if it can be carried back), and r_t is the real interest rate. The additional corporate tax rate term, $\left(1-\frac{1}{2}\tau_{it}\right)$, in the marginal credit formula for 1989 reflects the recapture of half of the deduction. In 1989 the credit was revamped. The claw-back provision created dynamic disincentives for current qualified R&D spending, leading to negative marginal credit rates for some firms and lower than statutory rates for many others. Addressing this concern, the Omnibus Budget Reconciliation Act of 1989 altered the base formula, replacing the moving average with a base unrelated to recent R&D spending. The new formula for the base was the greater of 50 percent of current qualified spending, and the product of the firm's average gross receipts in the previous four tax years and the firm's "fixed-base percentage," a measure of historic research intensity. The firm's fixed base percentage is its ratio of total qualified R&D expenditures to total gross receipts between

1984 and 1988, subject to a 16 percent ceiling. The base formula from 1990 on is:

$$B_{it} = max\left[\frac{1}{4}\sum_{m=1}^{4} G_{it-m}\min\left(\left(\sum_{n=1984}^{1988} R_{in}/\sum_{n=1984}^{1988} G_{in}\right), 0.16\right), \frac{1}{2}R_{it}\right] \tag{8}$$

where G_{it} is gross receipts or sales and R_{it} is the qualified R&D expenditures of firm i in year t. As the base definition changed, the tax credit subsidy on the marginal dollar of R&D spending changed as well. Beginning in 1990 the marginal credit rate is:

$$c_{it} = \begin{cases} 0 & \text{if } R_{it} < B_{it} \\ s_t\left(1-\tau_{it}\right)\left(1+r_t\right)^{-j_{it}} & \text{if } B_{it} < R_{it} < 2B_{it} \\ \frac{1}{2}s_t\left(1-\tau_{it}\right)\left(1+r_t\right)^{-j_{it}} & \text{if } R_{it} > 2B_{it} \end{cases}$$

where again, s_{it} is the statutory R&D credit rate in year t, r_t is the interest rate, τ_{it} is the firm's marginal corporate tax rate, and j_{it} is the number of years of tax losses.

Start-ups, firms lacking gross receipts or QREs for three of the five years between 1984 and 1988, were assigned a three percent fixed-base percentage. OBRA89 extended the credit through 1990 and required firms to reduce their Section 174 deduction by the entire amount of research credits claimed. The Omnibus Budget Reconciliation Act of 1990 and Tax Extension Act of 1991 extended the research credit through 1991 and 1992 respectively. Pay-as-you-go rules adopted as part of OBRA90 were a major obstacle to more lasting extension (CRS 2007). From its inception until 1992 the credit was always extended before it expired. The first of several retroactive extensions occurred in 1993 after the credit was allowed to lapse in 1992. Even the retroactive extension covered only the last two quarters of 1992. Because this and other lapses likely affected firm expectations, the analysis here is limited to just the first 11 years of the R&D tax credit. Table 2.1 provides a summary of the legislative history of the R&D tax credit.

If at the time of R&D investment corporate tax rates are expected to remain constant in the future, they have no impact on R&D spending decisions—firms expect to expense their

investments and pay taxes on the income from those investments at the same rate. The 1980s, however, were a time of changing corporate tax rates. The value of the Section 174 expensing provision was reduced by the Tax Reform Act of 1986; as the corporate tax rate was reduced to 40 percent in 1987 and to 34 percent in 1988, the benefit of expensing fell in parallel. If firms expected these reductions in the corporate tax rate, they would have invested in R&D with a higher cost of capital in mind. These corporate tax rate changes and their impact on the after-tax cost of R&D are assumed to have been unexpected by firms and are part of the analysis presented here. Taken together, changes in the expensing provision and tax credit significantly affected the user cost of qualified R&D; their joint impact on the user cost of the marginal dollar of R&D spending is assessed below.

4 Data

The analysis presented here draws on two data sources, public data that has previously been used to assess the impact of the R&D tax credit and restricted-access IRS Statistics of Income (SOI) data that has not previously been used to estimate the user cost elasticity of the R&D credit. Each of these data sets has its advantages and disadvantages as does their combined use.

4.1 IRS Statistics of Income (SOI) Data

The IRS SOI data are drawn from a panel sample of corporate tax returns. The data for each firm-year observation comes from the firm's basic tax return, Form 1120. Data items relating to R&D spending are pulled from the firm's Form 6765, part of its Form 1120. The data report the firm's annual qualified R&D expenditures, base amount, tentative R&D tax credit, and limitations due to insufficient tax liabilities among other details. SOI data provide an accurate measure of the actual credit rates firms face each year on their marginal dollar of R&D spending. Only SOI data describe qualified spending with enough detail for

this level of accuracy. But for all the detail and accuracy the SOI data afford, they have limitations as well. First, is the issue of censoring. A firm only reports the details of its research spending in those years when it applies for the R&D tax credit; in years where it will not earn a credit, it is unlikely to complete Form 6765. Thus in years when the firm does not apply for a credit, its qualified spending is not known (SOI data report missing values as zeros.) So as not to drop these observations, I assign firms that have previously claimed the R&D credit, but did not complete Form 6765 a zero marginal credit rate. Effectively, I assume that firms are not leaving potential R&D tax credits on the table. Only firms that have ever claimed the R&D tax credit, that is filed a form 6765 as part of its 1120 are included in the sample used in the analysis. This amounts to a sample of 3,500 and 6,500 firms per year; the exact count is reported in the tables. The qualified spending of these 'missing' firms remains unknown, however. It is treated as it appears in the data, as a zero, but this likely understates R&D spending; robustness checks that limit the sample to only those firms that complete Form 6765 each year and analysis that also makes use of public data provide checks for this treatment. Second, IRS data only report qualified research expenditures. Although these are exactly the type of expenditures that are needed to accurately calculate the marginal credit rate, we are not only interested in the impact of tax subsidies on these expenditures. If firms respond to larger tax subsidies by shifting their R&D spending from unqualified to qualified spending, we will interpret the impact of the R&D tax credit differently than if they are increasing total research spending by the same amount they are increasing qualified spending. IRS data do not provide any sense of how a firm's non-qualified spending responds to subsidies for qualified spending.

4.2 Compustat Data

Compustat data are drawn from firms' annual SEC (10-K) filings. The Compustat sample includes essentially all publicly traded firms that report the information required to compute their marginal R&D tax credit rates. There are roughly between 1,200 and 1,800 firms per

year in the Compustat sample. These data have two key advantages. Compustat data are available for years prior to the introduction of the R&D credit in 1981. Financial statements provide a more comprehensive measure of R&D spending. Nonetheless, Compustat data have three major weaknesses.

First, because Compustat data describe only publicly traded firms, large firms are over-represented in the sample. NSF surveys report that between 1981 and 1992 firms with at least 5,000 employees conducted more that 80 percent of all R&D, suggesting that data concerning large public firms will describe the lion's share of R&D dollars. Nonetheless, if private firms are more (or less) responsive to changes in the tax-price of R&D, estimates based on the Compustat data understate (or overstate) the effectiveness of the tax credit.

Second, the accounting rules that govern financial reporting differ from the Internal Revenue Code (IRC) in their definition of R&D. A firm's marginal credit rate is a function of its qualified R&D spending, not its total spending as reported in its financial statements. To qualify for the federal tax credit, R&D expenditures must meet a set of criteria relating to the experimental and technological nature of the project and the stage of the product development it aims to enhance. The R&D expenses reported in financial filings (referred to here as total R&D spending) conform to a broader definition that includes both R&D conducted abroad and domestic research expenditures that do not qualify for the R&D tax credit because they fail to meet the experimental and technological criteria.

If firms respond to changes in subsidies for qualified R&D by changing their qualified and non-qualified spending shares, constructing the tax component of the firm's user cost of R&D using only data describing total R&D spending will lead to a biased measure of the user cost. For example, if firms increase the qualified share of their spending when subsidies are high, the effective credit rate could be understated if this disproportionate increase in qualified spending lifts the firm's spending above its base or the effective credit rate could be overstated if the increase in qualified spending leaves the firm above twice its base level. Because a firm's credit rate is determined by its relative QREs, changes in the composition

of spending can affect credit rates.

Using the broader measure of R&D will result in non-classical mis-measurement of the tax-price, which is a function of qualified R&D spending. Only SOI data can overcome this measurement issue. Similarly, because financial data do not describe unused previously earned tax credits, the present value of currently earned R&D tax credits may be overstated; overstating the value of the credit understates the price of R&D, potentially under-estimating the magnitude of the tax-price elasticity.[8]

Third, firms only report R&D expenditures in their financial statements if these expenditures are "material" by accounting standards. The data are therefore censored with a firm-specific threshold. To assess the influence of materiality censoring, robustness checks report the results of a specification limited to only those firms with data in all years and a specification employing a control function to correct for selection.

Combining IRS and Compustat data overcomes many of the weaknesses of the individual datasets. Measuring the impact of the accurately measured after-tax user cost (from SOI data) on total R&D spending (from Compustat data) can gauge whether any responsiveness of qualified spending is due primarily to shifting. Furthermore, research spending is likely to be reported in Compustat even in years when the firm does not complete its Form 6765 because it fails to earn a credit. Materiality remains an issue, however. The main disadvantage of the merged sample is size. Because the IRS data sample describes private and public firms, only a fraction are public firms and a smaller fraction still ever apply for the R&D tax credit and have sufficient data to compute their marginal credit rates. Thus the merged sample consists of fewer than one thousand firm-year observations.

[8]This lack of information on other tax credits is even more important after 1986 when the R&D tax credit was folded into the General Business Credit (GBC). The GBC not only caps the total amount of credits that can be used in any year but also prescribes the order in which they must be used. A firm that has a lot of higher priority credits would value currently earned R&D credits less.

4.3 Measuring R&D Expenditures

Using Compustat data to determine whether a firm's current year spending qualifies it for an R&D tax credit and if it is subject to the 50 percent of current year spending limitation (i.e. whether current year qualified spending exceeds the firm's base or twice its base) incorrectly assesses the firm's credit status for 44 percent of the 755 firm-year observations that appear in both the Compustat data, drawn from financial statements, and the IRS data. For the average firm over the whole period, qualified research was 38 percent of total research. Among firms with positive QREs, the average firm spent 68 percent of its total research expenses on qualified research, but weighting by QRE the average falls to 56 percent, meaning that qualified spending represented a smaller a share of total spending for firms with high QREs.

Table 2 illustrates the heterogeneity in the ratio of QREs to total R&D for the subset of firms that appear in both data sets and have sufficient data to be included in later regression analysis.[9] For five of the sample's eleven years more than half of the firms reported no QREs but did report R&D expenditures in their financial statements; most of these years follow the 1986 absorption of the R&D credit into the General Business Credit (GBC). Qualified research ranged between 40 and 80 percent of total research for the lion's share of the sample that reported non-zero QREs. For a non-trivial share of the sample, on average 12 percent, qualified spending represented more than 90 percent of its total spending.

The distribution of qualified spending shares varies over time, including between years when the parameters of the R&D credit changed. In 1986 when the R&D credit was folded into the GBC the share of firms reporting no QREs but still reporting research expenses for financial purposes rose by more than 11 percentage points while the share of firms for which qualified research represented between 20 and 80 percent fell by more than 12 percentage points. Again in 1990 when the credit was revamped and base amounts were redefined, the

[9] The accounting definition of R&D includes all the categories that comprise IRS QREs but is less strict in terms of the experimental and technological nature of these expenditures. For example, expenses related to testing and the modification of alternative products is classified as R&D for accounting purposes but generally do not qualify for the R&D tax credit.

distribution changed markedly. The fraction of firms reporting no QREs fell by more than ten percentage points, mostly accruing to the 20 to 40 percent and 60 to 80 percent categories. The distribution varied in other years as well, some when other policy changes occurred such as 1985, but also between years when the credit's structure remained unchanged such as between 1983 and 1984. Although Table 2 only describes the evolution of the distribution of qualified spending shares for the limited sample of firm that report R&D spending in both data sets, it shows that the ratio of qualified to total R&D spending varied considerably from year to year. This type of variation makes clear that using Compustat data describing total R&D expenditures to construct marginal credit rates will often lead to incorrect measures of the marginal tax subsidy for R&D investment.

4.4 Computing the User Cost

Each firm's marginal credit rate is computed according to the prevailing structure of the R&D tax credit and its tax position as described in the marginal credit rate equations above. Credit rates are computed both using Compustat data and IRS data; as explained above, credit rates constructed from Compustat data are likely to be inaccurate but are widely used in previous studies that rely on publicly available data. Further details of the formulas' components can be found in the appendix.

Table 3 reports the average percentage reduction in R&D user costs due to tax preferences, the share of firms eligible for an R&D tax credit and the fraction with negative marginal credit rates. Because actual receipt of a credit is not observed in public financial data, a firm is considered eligible for an R&D credit if its R&D spending exceeds its base; firms not receiving a credit are firms who report enough information to calculate their marginal credit rates, but whose R&D expenditures do not exceed their base amounts. In the SOI panel data a firm is considered eligible for an R&D tax credit if it claims a positive tentative R&D tax credit on form 6765 of its corporate return.[10] Changes in tax policy and

[10] A firm's tentative tax credit is the product of the statutory credit rate (including any decrease in the rate

changes in R&D spending both drive changes in the tax-adjustment term of the user cost of R&D, making it difficult to infer the impact of policy changes from observed user costs. When only the expensing allowance was in place, tax factors did not affect the user cost of a firm that had sufficient tax liabilities in the year it expensed its R&D spending; changing tax rates did affect the user costs of firm who carried forward their losses. The introduction of the R&D credit in 1981 reduced the average tax-adjustment term from near unity to 0.914 according to IRS SOI corporate return data as shown in Table 3.

The average tax-adjustment term according to the Compustat data, which only reports total R&D spending, was 0.884 in 1981, three percentage points less than the average in the IRS sample. This is largely because the IRS sample contains a larger fraction of firms that face negative marginal credit rates, 24.1 versus 14.9 percent, which reduces the average subsidy level. These negative rates are driven by firms that fail to earn a credit in 1981 but face higher bases in subsequent years when they do qualify for a credit; in the Compustat data 65.7 percent of firms earned a credit in 1981, but according to the IRS sample only 52.1 percent for firms earned a credit. The two samples are comprised of largely different firms and dissimilarities in the averages in Table 3 reflect both the inaccuracy of calculations based on the Compustat data and differences in the composition of the samples. Between 1982 and 1984 the Compustat data suggest a higher average user cost than the IRS data with differences between three and six percentage points; in part this is driven by a much larger share of negative credit rate firms in the Compustat sample during these years. Average user costs converge beginning in 1985 and continue to track through 1988. For the last three years of the sample, average user costs are four to five percentage points higher in IRS sample

due to expensing after 1989) and the excess of its qualified research spending over its base amount, subject to the 50 percent of current research spending limit. It is the IRS analogue to the definition of eligibility I use in the Compustat data. The actual credit a firm realizes in a given tax year also includes any R&D credits carried back or forward and any flow-through credits from partnerships, subchapter S corps, estates or trusts, and is limited by its current year pre-credit tax liability. The order in which credits are applied in calculating the firm's pre-R&D tax credit tax liability varied slightly from year to year, but in general the R&D credit was a more senior credit. Eligibility was measured using tentative rather than total allowable R&D credit for comparability reasons and because total allowable credit data is not available for all years, particularly after the R&D tax credit was folded into the GBC.

than the Compustat sample.

Examining the variation in average tax-adjustment factors over time in the IRS sample provides a sense of how the tax subsidy affected true user costs. The five percentage point reduction in the statutory R&D credit rate in 1986 coincided with a rise in the tax-adjustment term from 0.906 in 1985 to 0.94 in 1986 and finally to 0.947 in 1987 the first year the rate reduction was in place for a full year; the nearly nine percentage point drop in the share of firms eligible for the R&D credit over the two-year period, however, suggests other forces were also at play. Other factors countervailed the impact of partial credit recapturing in 1989, leading to only a small increase in the tax-adjustment term of the user cost. The 1990 reformulation of the R&D credit, which eliminated the claw-back provision and complete credit recapture, barely affected average tax subsidy or the credit recipiency rate.

Although the Compustat tabulations show a nearly twelve percentage point decline in the fraction of firms qualifying for a credit—a pattern consistent with the findings of Gupta, Hwang and Schmidt (2004)—this decline in 1990 is not apparent in the more accurate IRS data. Between five and ten percent of firms were subject to negative credit rates between 1982 and 1990, when the claw-back provision was eliminated; their average marginal credit rate was roughly -8 percent. Firms in several situations could face negative marginal credit rates. For example, assuming tax liabilities in all years and a three percent real interest rate, a firm whose spending this year exceeds twice its base but for the next three years lies between 100 to 200 percent of its base would have faced a marginal credit rate of -11.1 percent under the 1982 to 1985 regime, -8.9 percent under the1986 to 1988 regime and -7.4 percent in 1989. The unusually high fraction of firms that had negative credit rates in 1981, nearly a quarter of firms were tax disadvantaged by marginal R&D spending, may be due by delays in increasing research spending in reaction to the credit's introduction. Firms may not have been able increase their spending enough to qualify for a credit in 1981 but every dollar they did spend increased base amounts in subsequent years, leading to negative marginal credit rates. The 1990 reformulation improved incentives for marginal R&D investment for

a substantial fraction of firms.

The averages presented in Table 3 belie substantial heterogeneity in the impact of tax preferences on firm user costs. Using confidential IRS data Altshuler (1988) also found substantial heterogeneity in the effective R&D tax credit rates firms faced depending on their near-term R&D spending pattern and tax status. Table 4 provides more detail regarding the dispersion of tax-adjustment factors each year according to the IRS data. In 1980, prior to the introduction of the R&D credit, in the Compustat sample tax policy had no impact on R&D user costs for more than 80 percent of firms; tax loss carry-forwards decreased the present discounted value of the Section 174 deduction and increased R&D user costs for the remaining firms. Once the R&D tax credit was adopted in 1981, in the IRS sample few firms—roughly five percent—had user cost tax-adjustment factors of one since even firms ineligible for a credit in the current year were increasing their bases for the following three years with every additional dollar they spent on R&D. Between 1981 and 1989, 53.2 percent of firms on average had tax-adjustment factors that ranged between 0.95 and 1.25. Average tax-adjustment factors were above 0.75 and below 1.25 for nearly 89 percent of firms over the same period. A substantial fraction of firms, however, experienced much higher and much lower user costs due to tax factors prior to the 1990 reform. Some firms, as many 11.1 percent of firms in 1981, experienced marginal credit rates so negative as to push their tax-adjustment factors above 1.25; for eight firms between 1981 and 1985 tax factors increased their user costs by more than 150 percent. During the same period, up to 18.8 percent of firms had marginal R&D tax credit rates so high that tax preferences reduced their user cost by 25 percent or more. After the 1990 reform, no firm was subject to a negative marginal credit rates, depopulating the right tail of the tax-adjustment factor distribution. Some firms, as many or even more than before, continued to have tax-adjustment factors that modestly exceeded unity after the 1990 base redefinition—firms with zero (99.2 percent) or low marginal credit rates (0.8 percent) and at least one year of tax losses—the mean tax-adjustment factor of these firms was 1.033. Starting in 1990, all firms in the sample had tax

factors between 0.75 and 1.25 as fewer firms had tax factors in the tails of the distribution; firms were more concentrated between 0.75 and unity than in the preceding half-decade. In effect the 1990 reformulation eliminated both very high and very low tax-adjustment factors, but largely left the fraction of firms receiving a credit and average tax subsidy rates unchanged.

5 Empirical Model

Applying the arbitrage condition described in equation (**??**) to the CES production function yields the factor demand equation: $S_{it} = \theta_i^{\sigma} Y_{it} \rho_{it}^{-\sigma}$. The user cost, as laid out in Section 2, is a function of the firm's current qualified R&D spending, the relationship between the firm's spending and its base this year and for as long as the next three years, its loss position, and the corporate tax rate. Again, the Hall-Jorgenson tax-adjusted user cost of R&D capital per dollar of investment is:

$$\rho_{it} = \frac{\left(r_t + \delta - \pi_t^S\right) p_t^S \left(1 - \tau_{it+k_{it}} \left(1 + r_t\right)^{-k_{it}} - c_{it} \left(1 + r_t\right)^{-j_{it}}\right)}{\left(1 - \tau_{it+k_{it}} \left(1 + r_t\right)^{-k_{it}}\right)} \tag{9}$$

where r_t is the interest rate, δ is the depreciation rate, π_t^S is the one-year growth rate in the prices of R&D inputs, P_t^S is the price of R&D inputs, τ_{it} is the marginal corporate tax rate, j_{it} is the number of years the credit must be carried forward (it will be negative if it can be carried back), k_{it} is the number of years until any tax losses are exhausted and c_{it} is the marginal R&D credit rate. The log linear form of the factor demand equation forms the empirical foundation of most previous empirical analyses of the user cost elasticity of R&D and is the initial basis of the analysis presented here. Differencing the log linear equation to purge any unobserved firm heterogeneity yields the following regression equation:

$$\log\left(\frac{S_{it}}{S_{it-1}}\right) = \sigma \log\left(\frac{\rho_{it}}{\rho_{it-1}}\right) + \eta \log\left(\frac{Y_{it}}{Y_{it-1}}\right) + \epsilon_{it} \tag{10}$$

In the absence of adjustment costs, the optimal stock of R&D capital will be attained each period in accordance to any changes in the tax or non-tax terms of the user cost. I assume that the flow of R&D services in a year is proportional to R&D investment. Under these assumptions, the change in the R&D capital stock will be captured by the change in R&D investment. Equation 10 can be written instead in terms of the log-difference in R&D investment:

$$\log\left(\frac{R_{it}}{R_{it-1}}\right) = \sigma \log\left(\frac{\rho_{it}}{\rho_{it-1}}\right) + \eta \log\left(\frac{Y_{it}}{Y_{it-1}}\right) + \epsilon_{it} \tag{11}$$

Aggregate macroeconomic factors such as technology opportunities, changes in U.S. patent policy and IRS regulations, and aggregate demand will affect firm R&D decisions. Year fixed effects are added to the model to absorb these potentially confounding factors. I assume that the non-tax components of the cost of capital, $\left[r_t + \delta - \pi_t^S\right] p_t^S$, together vary over time but not across firms and time. Since ρ_{it} enters the regression in log form, under my assumptions, $\left[r_t + \delta - \pi_t^S\right] p_t^S$ is fully absorbed by the year fixed effects, leaving just the tax factor:

$$\lambda_{it} = \frac{\left(1 - \tau_{it+k_{it}} \left(1 + r_t\right)^{-k_{it}} - c_{it} \left(1 + r_t\right)^{-j_{it}}\right)}{\left(1 - \tau_{it} \left(1 + r_t\right)^{-k_{it}}\right)} \tag{12}$$

to vary across firms and over time. The regression equation becomes:

$$\log\left(\frac{R_{it}}{R_{it-1}}\right) = \sigma \log\left(\frac{\lambda_{it}}{\lambda_{it-1}}\right) + \eta \log\left(\frac{Y_{it}}{Y_{it-1}}\right) + \chi_t + \epsilon_{it} \tag{13}$$

As was explained in Section 3, a firm's R&D tax credit rate is a non-monotonic function of its R&D spending. A firm whose spending is less than its base receives a zero credit and has a zero marginal credit rate; a firm whose spending exceeds its base, but is less than twice its base receives a credit equal to the product of the effective statutory rate and its spending above its base and has a marginal credit rate equal to the effective statutory rate; a firm whose spending exceeds twice its base receives a credit equal to the product of the effective statutory rate and its spending above its base and has a marginal credit rate equal to one-

half of the effective statutory rate. A firm's marginal R&D credit rate and it R&D spending level are clearly jointly determined; the term capturing the tax-price change, $\log(\lambda_{it}/\lambda_{it-1})$, is correlated with ϵ_{it}. For example, if there is a positive shock to R&D spending ($\epsilon_{it} > 0$) then, due to the structure of R&D tax credit, the marginal credit rate could mechanically increase if the firm was otherwise below its base or decrease if the firm was otherwise above its base. An OLS regression of equation (**??**) would therefore lead to a biased estimate of the behavioral elasticity.

To disentangle this endogeneity I rely on an instrumental variables strategy similar to those Auten and Carroll (1999) and Gruber and Saez (2002) use in studying individual taxpayer decisions. The strategy to build instruments for the user cost variable, $\log(\lambda_{it}/\lambda_{it-1})$, is to compute λ_{it}^{S}, the marginal tax-price the firm would face in year t if its real R&D spending did not change from the previous year. The natural instrument for the actual change in the tax factor of the after-tax user cost, $\log(\lambda_{it}/\lambda_{it-1})$ is the difference in the logarithms of the firm's "synthetic" tax factor under current law and their actual lag tax price, $\log\left(\lambda_{it}^{S}/\lambda_{it-1}\right)$. The instrument by construction eliminates the effect of R&D spending changes on the change in tax price so that the synthetic change in tax price only reflects the exogenous changes in the provisions of the R&D tax credit. It is the exogenous changes in the effective tax price of R&D spending due to changes in the corporate tax code and provisions of the R&D credit that are the source of identification of the behavioral response. First-differencing purges firm-specific correlation in the evolution of R&D spending while time fixed effects purge changes in R&D spending common across all firms. The resulting residual variation in the tax-price that identifies the estimated elasticity arises from within-firm changes in the tax-price of R&D relative to the changes experienced by the average firm. In other words, the identifying variation measures how a firms tax subsidy compares with its own average subsidy across time and the average subsidy of other firms within a given year.

Only observations from years where a tax policy change went into effect are used in the

analysis.[11] The key exclusion restriction is that the constructed synthetic tax factor does not affect R&D spending other than through the actual tax factor, conditional on firm and year fixed effects and sales. In later regressions, as explained in section 6, a polynomial in lagged R&D spending is added as a control to account for reasons other than the tax price why firms in different parts of the R&D spending distribution might experience different patterns of R&D growth. These added controls tighten the exclusion restriction; the identifying assumption now only assumes that the R&D spending distribution is not evolving on its own in a way that is correlated with the year-specific changes in the tax treatment of R&D. Given the strong nonlinearities of the firm-specific credit function, this assumption seems innocuous.

Table 5 presents a comparison of average actual and synthetic tax-adjustment factors by year; the actual tax-adjustment factor averages differ from those in Table 2 because the sample of firms is constrained to those that report sufficient data to also construct the synthetic factor, namely the first lag of R&D spending. Between 1985 and 1986, when the statutory credit rate fell from 25 to 20 percent, the actual tax-adjustment term increased by 3.8 and 4.5 percentage points in the Compustat and SOI data respectively while the synthetic tax-adjustment term increased similarly in the SOI data but by more than 15 percentage points in the less accurate Compustat data. Comparing 1986 synthetic tax factors to 1985 actual tax factors, which are both a function of 1985 R&D spending, shows that in the IRS data tax changes led to a decrease in average user costs while the Compustat data point to a marked nearly 10 percentage point increase, further highlighting the difficulty of using Compustat data.[12] In the Compustat data average actual tax factors fell by 1 percentage point with the introduction of recapturing in 1989 but barely moved in the IRS data; in both datasets synthetic factors increased by roughly 1.5 percentage points. The

[11] The years used are 1982, 1986, 1987, 1988, 1989 and 1990. For a summary of the changes made to the R&D tax credit in these years, please see Section 2 or Table 2.1. Data from 1982 are used in lieu of data from 1981 because the 1982 was the first full year the credit was in effect.

[12] In the much smaller sample of observations found in both the Compustat and SOI data the pattern of a decrease between 1985 actual and 1986 synthetic in IRS data and an increase in Compustat data also holds.

1990 base redefinition reduced user costs as is made clear by the 2.4 and 5.4 percentage point differences between 1989 actual and 1990 synthetic tax factors in the Compustat and SOI data, respectively. Actual tax factors fell by less or increased slightly in the case of the SOI data, signaling that firms also changed their R&D spending such that their marginal credit rates decreased.

6 Results

6.1 Compustat Data from Financial Filings

The framework of the analysis presented here is similar to earlier studies, including Hall (1994). As a baseline, my best effort to replicate the relevant Hall results and reconcile them with my own estimates is presented in Table 7. Hall used instrumental variables for several reasons: first, the simultaneity of her regressors with the firm's future R&D expenditure path; second, measurement error in the tax price due to the inaccuracy of using financial data to calculate tax prices; third, measurement error due differences between the tax price as forecasted by the firm when making its spending decisions and observed by the econometrician. To address these issues she instruments for all right hand side variables with the regressors lagged two and three times as well as with lagged tax status and lagged growth rates in R&D and sales. Column 1 of Table 7 reports the results of my attempt to replicate the results in column 4 of Table 6 in Hall (1994), which corresponds to the first-differenced log-log specification.

Column 2 instruments with lagged right-hand side variables and uses data from the entire decade after 1981 but includes non-manufacturing firms; the addition of these firms does not significantly affect the estimated tax-price elasticity. Years where the parameters of the R&D tax credit remained unchanged are dropped in column 3's specification as my instrumenting strategy relies on tax changes. Again limiting the sample to 1982 and 1986-1990 does not dramatically affect the estimated elasticity. Column 4 uses the synthetic

tax-price instruments, which are described in detail in Section 3. These instruments, which are more plausibly exogenous than the instruments used in columns 1-3, reduce the tax-price elasticity estimate by nearly fifty percent. The causal impact of tax subsidies on research spending appears to be substantially less than other studies using public data have suggested. Because the change in sales, which is included as a control in equation (**??**) could conceivably be endogenous, column 5 reports the results from a model that does not include contemporaneous or lagged sales as a regressor. Dropping the log-change in sales has no impact on the estimate.

The IV regression of equation (**??**) might itself be biased if ϵ_{it} and R_{it-1} are correlated. Mean reversion, for example, would lead to a negative correlation between the error term and R&D spending the previous year. If ϵ_{it} and R_{it-1} are correlated then the instrument will be also be correlated with the error term since the instrument is constructed using spending last period. Like Auten and Carroll (1999), and Gruber and Saez (2002) last period spending, $\log R_{it-1}$, is added as a control. Because changes in the R&D tax credit may affect any relationship between current and last period spending, these controls are allowed to vary by year as a robustness check (see column 2 of Table 8). Of course including a control for the lag dependent variable in a differenced model leads to a biased estimator in finite samples. I instrument for lag spending as suggested by Hausman, Hahn and Kuersteiner (2001) using further lags. The results of this regression are reported in column 6 of Table 7. Again the inclusion of these further controls does not change the estimated elasticity.

To investigate the sensitivity of the relationship between R&D spending and its user-cost to alternative specifications a series of robustness checks were conducted; the results are presented in Table 8. The baseline specification from column 6 of Table 7, which instruments for the endogenous tax-price with the synthetic tax-adjustment factor and includes controls for the logs of lag R&D spending and lag sales, is reported in column 1 to facilitate comparisons. As described above, because changes in tax policy may affect the underlying relationship between current and lag R&D spending, for example if more generous tax treat-

ment leads to the undertaking of new projects that require many years of funding, column 2 interacts the lag spending terms with year fixed effects. Allowing the effect of $\log R_{it-1}$, to vary from year to year has virtually no impact on the user cost elasticity estimate. Columns 3 and 4 control for industry specific factors. Neither industry fixed effects, column 3, nor linear industry time trends, column 4, appreciably impact the elasticity estimate. Because only firms with material R&D expenditures must report their R&D expenditures in financial filings, the data are censored by a firm-specific threshold. Column 5 reports estimates from a specification that includes a control function to correct for selection; identification is from functional form. Correcting for selection reduces the magnitude of the point estimate by a statistically insignificant 1.2 percentage points. Column 6 assess the impact of selective reporting by limiting the sample to only those firms that report R&D spending in all years. The estimated elasticity is roughly 1.7 percentage points larger, but again the difference is statistically insignificant. Firms end their fiscal years in all months of the year; tax policy is largely tied to the calendar year. Tax-price variables are likely to be mis-measured for firms whose fiscal years do not coincide with the calendar year. To assess the impact of this mis-measurement the model is estimated using only firms with December fiscal year ends. As column 7 reports, the point estimate is statistically indistinguishable from the baseline estimate.

The log-log specification includes only observations with non-zero R&D expenditures. In the Compustat data this does not necessitate dropping many firms, in fact only 40 firm-year observations have zero R&D expenses but report all other necessary data, including previous spending, to be included in a regression of the form of Column 4 of Table 6. In other words, if a firm ever reports R&D expenses in its SEC filings, it does so in every year and once it engages in material R&D it continues to do so. The log-log specification is less appropriate for analysis of the IRS data. Firms only report the specifics of their R&D spending and credit status in years they claim the credit; if a firm does not qualify for a R&D tax credit it likely does not file a form 6765 and it does not disclose the details of its research activities.

The IRS data in short has many more zeros than the Compustat data. Though a firm that does not file a 6765 form likely has non-zero research expenditures, in the main analysis using only the IRS data these observations are treated as the appear in the data, as zeros. The appropriateness of this treatment is assessed in later analysis that uses both Compustat and IRS data. To retain observations with zero spending but also scale for disparate firm size in the remaining analysis the dependent variable of regression equation (**??**) is replaced with the change in R&D spending divided by first lag of sales. Sales is a natural choice for the scaling variable since research-intensity, the ratio of R&D to Sales, has been an outcome of interest in previous research including (Griliches (1984)) and is used as a benchmark, the fixed base percentage, in the formula for the R&D credit as well.

The regressions reported in Tables 9-12 are of the basic form:

$$\left[\frac{R_{it} - R_{it-1}}{S_{it-1}}\right] = \alpha + \sigma\left[\lambda_{it} - \lambda_{it-1}\right] + \eta\left[\frac{S_{it} - S_{it-1}}{S_{it-1}}\right] + \gamma R_{it-1} + \chi_t + \epsilon_{it} \tag{14}$$

Table 9 reports the results of regressions of the above form using only Compustat data. These estimates gauge how sensitive estimated tax-price elasticities are the regression model. Column 1 reports the OLS results, which suggest that a ten percent decrease in the tax component of the user cost of R&D would increase the average firm's R&D-to-lagged-Sales ratio by 4.3 percent. Adding flexible time controls, as in column 2, does not affect the estimated coefficients. Because a firm's credit rate is a function of its R&D spending column 3 instruments for the firm's tax component to disentangle this simultaneity. As described earlier, the instrument is constructed using the first lag of R&D spending, which must be controlled for in the regression. Because the first lag of R&D spending is also a lagged dependent variable, it must also be instrumented for with other lags.[13] Instrumenting for both the endogenous tax component and the first lag of R&D expenditures shrinks the point estimate from -0.045 (0.01) to -0.035 (0.008), a statistically insignificant reduction in

[13] Here the third lag of R&D spending is used, but the results are invariant to instrumenting with other lags.

magnitude. The estimates reported in column 3 imply that a ten percent decrease in the user cost, or a 9.36 percent subsidy, would result in a 3.56 percent increase in the average firm's R&D intensity. In other words, if sales levels remained unchanged, the average firm's R&D expenditures would increase by roughly $10.7 million. The estimates from column 4 of Table 8 suggest that a ten percent decrease in the usercost would result in a $3.5 million increase in R&D spending; the specification differences lead to somewhat different answers. Estimating the specification of column 3 of Table 9 on the 6,339 observations from the sample of column 4 of Table 7 that have sufficient data, yields a coefficient of -0.036 (0.008)—almost identical to the estimates reported in column 3 of Table 8.[14] It is not the difference in selection resulting from dropping the zero spending firms that drives the difference in elasticity estimates but the difference in specification. Different specifications clearly yield different estimates of the impact of tax subsidies on R&D spending–though all estimated elasticities are substantially smaller than prior studies. Although the estimates are robust within a class of specifications, as illustrated by Table 8 for the log-log specification, using R&D intensity as the outcome of interest roughly triples the implied effect in terms of dollars of R&D spending of a ten percent reduction in user cost.

6.2 IRS SOI Data

Table 10 reports the results of regressions of the basic form of equation (**??**) but uses only IRS data. While providing unbiased measures of the subsidies to qualified R&D spending, the IRS data does not describe total R&D spending by firms. The IRS data come from the research credit form, Form 6765, and describe only qualified research expenditures, in other words only the spending to which the credit applies. Though using IRS data alone cannot capture how tax subsidies affect total R&D spending, they can describe how subsidized R&D spending responds to its subsidy. OLS estimates reported in columns 1 and 2 of Table 10

[14] Estimating the specification of column 4 of Table 6 using just the 6,171 observations that have sufficient data for both specifications yields an elasticity of -0.461 (0.032), virtually identical to the estimate reported in column 4 of Table 6.

suggest that a ten percent decrease in the user cost of R&D would result in approximately $3.8 million in additional qualified research spending by the average firm. Column 1 includes only the listed regressors while column 2 also includes year fixed effects. Instrumenting for the tax factor, however, halves the estimate, suggesting a ten percent reduction in user cost only increases average qualified research spending by $2 million. The average firm in the sample reports roughly $8 million in QREs; among firms with non-zero QREs average qualified spending is $27.5 million. Although the coefficient estimates in Table 10 are similar in magnitude to those of Table 9, because qualified research expenditures (QREs) comprise less than forty percent of total R&D expenditures, the implied elasticities of Table 10 are much larger than those of Table 9.[15] The fully instrumented specifications have standard errors too large to make precise comparisons, but the point estimates of the two tables suggest that qualified research spending is more elastic that total R&D. These comparisons should also be caveated by the fact that the regressions in Table 9 make use of an inaccurate measure of the tax component of the user cost.

IRS data report as many as five categories of QREs. Using the same regression specification as column 3 of Table 10, but replacing total QREs with each component of spending, the impact of tax subsidies on different types of qualified research spending is reported in Table 11. Qualified spending broken down by category was unavailable for 1990, so the number of observations reporting R&D spending on wages and salaries, supplies, equipment rental, and contracted research is only 14,394 rather than 18,691 as in column 3 of Table 10. Data regarding research payments to universities and other eligible nonprofit organizations for the conduct of basic research were not reliably available after 1986, hence only one year of data is included in the column 5 regression. Interestingly, changes in user cost only significantly impact wages and salaries and supplies, columns 1 and 2 respectively. Wages and salaries and supplies, comprising 66.6 and 19.2 percent of qualified R&D respectively, are the two largest categories of research spending. Although contracted research accounts for

[15] Qualified R&D comprises 39 percent of total R&D for the subsample of 953 firms found in both data sets that report both measures of research expenditures.

11.6 percent of QREs, user cost does not appreciably affect contracted research spending as shown in column 4.

The elasticities reported in Tables 10 and 11 show that qualified research spending is responsive to tax-based subsidies. The magnitude of the elasticity is larger than that of total spending as measured in the Compustat data and reported in Table 9, suggesting that the portion of research that the credit is applied to is measurably more responsive than overall spending. It is notable that the same choice of instruments that reduced the elasticity estimated in the public data still yields a large elasticity estimate for qualified research. The different impacts of different choices of instruments, specifications and research spending measures make it difficult to draw strong comparative conclusions, but highlight the fact that estimates of the elasticity of R&D spending with respect to the tax-price are sensitive to these choices.

6.3 Merged Sample of Compustat and IRS SOI Data

By merging the Compustat and SOI samples the impact of tax subsidies on total and qualified R&D spending can accurately be assessed using a common sample as described in Section 4. Because the SOI data is a sample of firms that includes both public and private firms, and more important because only a fraction of firms report R&D spending in their financial filing or file for the R&D tax credit, only 953 observations can be matched between the two data sets. The instrumenting strategy I employ, which requires multiple lagged values of R&D spending as well as other data, further reduces the sample. Table 12 presents estimates from regressions identical to those of Table 11 but restricted to this merged sample. IRS data is used to construct the tax factor for all four columns of estimates. Columns 1 and 2 and describe the impact of changes in the tax factor on total R&D spending while columns 3 and 4 describe the impact on qualified research spending. Interestingly, for both the OLS and IV specifications changes in user cost have no statistically discernible impact on total R&D spending, despite the relatively small standard errors. Estimating the specification

of Column 3 of Table 9, which is identical to column 2 of Table 12 except the user cost measures are based on Compustat rather than the more accurate IRS data, on the sample of roughly 200 merged firm-years yields a coefficient estimate of -0.058 (0.028)—a statistically significant estimate similar to those of Table 7. This suggests that the mis-measurement of the tax subsidy in Table 8 may play a role in generating statistically significant estimates that are not apparent when the correct tax subsidy measure is used as in Table 12.

Columns 3 and 4 of Table 12 report estimates for the impact of changes in the user cost on qualified research expenditures. Again, much like Table 10, user cost decreases result in statistically significant increases in R&D spending according to both the OLS and IV specifications. The results reported in columns 2 and 4 suggest that when the correct measure of the tax-adjustment factor is used, only qualified research spending is significantly affected by tax subsidy for qualified spending. Total R&D expenditures include other forms of unqualified research spending, such as R&D conducted abroad or by subsidiaries unconsolidated for tax purposes or R&D that is not deemed experimental or technological enough. It is important to note that these different measured impacts come from a small sample. Because the merged sample is so small, the pattern of these estimates is more suggestive than definitive. They do show, however, that the estimated impact of tax subsidies for R&D is sensitive to the choice of spending measure.

7 Conclusion

This paper uses public data from financial filings and new restricted-access data from tax returns to assess the impact of tax credits on R&D expenditure decisions. An instrumental variables strategy that relies on tax policy changes disentangles the simultaneity of incremental credit rates and R&D spending. The empirical findings demonstrate that tax-price elasticity estimates for R&D are sensitive to choices of instruments, specifications and spending measures. Estimates using only publicly available data suggest that a ten percent tax

subsidy for R&D yields between \$3.5 (0.24) million and \$10.7 (1.79) million in new R&D spending–and suggest that R&D is much less responsive to tax subsidies than previous studies imply. Estimates from IRS SOI data, which only reports qualified research expenditures, suggest that a ten percent reduction in the user cost would lead firms to increase qualified spending by \$2.0 (0.39) million. Analysis of the components of qualified research spending shows that wages and supplies, which comprise the bulk of qualified spending, account for the increase in research spending. These estimates come from different samples and use different data to construct measures of the tax component of the user cost of R&D. Estimates from the much smaller merged sample which makes use of the more precise tax data to calculate the tax component of the user cost suggest that qualified spending is responsive to the tax subsidy. A similar response in total spending is not statistically discernible in the merged sample.

These disparate and inconsistent results from different data samples illustrate the sensitivity of estimates of the tax-price elasticity of R&D to choices of instrumental variables, specifications and spending measures. Rather than yielding a single, consistent, number for the elasticity, the various analyses presented here instead show that estimates of the tax price elasticity are not robust across datasets and methods. Nonetheless, some conclusions can be drawn. First, there is considerable evidence that qualified research spending—the exact research efforts that are subsidized by the tax credit—is responsive to the reductions in the user cost due to the R&D credit. Second, comparisons between Compustat and SOI data show that relying on the public data results in significant mis-measurement of the tax-adjustment factor of the usercost. Third, non-qualified research spending is a significant fraction of total research spending as reported in financial filings, averaging more than 60 percent, and is a potentially important margin of adjustment when firms increase research spending in light of tax subsidies.

The empirical findings reported here bear on short-run research spending decisions, and there are several important considerations regarding broader interpretations. First, longer

run impacts may differ from the short-run response investigated here. Long-run elasticities may exceed the one-year response if changes in research spending incur adjustment costs. Long-run elasticities could conceivably be smaller than the one-year response if firms react to changes in their effective R&D tax subsidies by simply retiming research spending to maximize their credits. Second, the analysis here uses changes in the provisions of the research credit from the 1980s to identify the user-cost elasticity; research patterns from up to 30 years ago may not represent current R&D patterns in terms of shares of spending by firms in different industries, of different sizes, etc. Third, throughout the analysis firms' expectations of the future of the R&D tax credit are ignored. During its first decade the R&D credit was always renewed before it expired. Since then the credit has been allowed to lapse several times, most of the time being put into place retroactively, but on one occasion the credit was simply allowed to expire for a year. In the current, less predictable environment, firms' expectations regarding the future of the R&D credit likely impact how they react to the subsidy while it is in place. Estimates from an era of greater certainty may not be fully applicable today.

The inconsistency of estimates across the datasets and specifications make clear that further work is needed to assess the impact of tax subsidies on R&D spending. Larger datasets that allow for accurate measurement of the tax subsidy each firm faces and broad measures of R&D spending would allow researchers to better assess how non-qualified research spending reacts to subsidies for qualified spending. While it may be worthwhile to incentivize firms to direct nonqualified spending toward activities that qualify for the credit, if the increase in qualified spending reported here comes largely at the cost of nonqualified spending, the effect of the policy has a very different interpretation than if the increase in qualified spending was new research dollars. The degree to which spending is being redirected to qualified research is an important open question for future work. The question of relabeling has also drawn attention in policy circles. If firms are not even redirecting research, but just relabeling activities as qualified activities, the policy would be ineffective. Perhaps assessments of how

IRS audit outcomes change with subsidy rates could help shed some light on how the R&D tax credit creates incentives for relabeling. These are issues I would like to pursue in future work.

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Table 1: Legislative History of the Research and Experimentation Credit

	Credit Rate*	Corporate Tax Rate	Definition of Base	Qualified Research Expenditures	Sec. 174 deduction**	Foreign Allocation Rules	Carryback/Carryforward
July 1981 to Dec 1981	25%	48%	Maximum of previous 3-year average or 50% or current year	Excluded: research performed outside US; humanities and soc. science research; research funded by others	None	100% deduction against domestic income	3 years/15 years
Jan 1982 to Dec 1985	Same	46%	Same	Same	Same	Same	Same
Jan 1986 to Dec 1986	20%	34%	Same	Definition narrowed to technological research. Excluded leasing	Same	Same	Same
Jan 1987 to Dec 1987	Same	Same	Same	Same	Same	50% deduction against domestic income; 50% allocation	Same
Jan 1988 to Apr 1988	Same	Same	Same	Same	Same	64% deduction against domestic income; 36% allocation	Same
May 1988 to Dec 1988	Same	Same	Same	Same	Same	30% deduction against domestic income; 70% allocation	Same
Jan 1989 to Dec 1989	Same	Same	Same	Same	-50% credit	64% deduction against domestic income; 36% allocation	Same
Jan 1990 to Dec 1991	Same	Same	1984-1988 R&D to sales ratio times current sales (max of 16%); 3% of current sales for startups	Same	-100% credit	Same	Same
Jan 1992 to Dec 1993	Same	Same	Startup rules modified	Same	Same	Same	Same
Jan 1994 to June 1995	Same	35%	Same	Same	Same	50% deduction against domestic income; 50% allocation	Same
July 1995 to June 1996	0%	Same	None	-	-	Same	Same
July 1996 to June 1999	20%	Same	1984-1988 R&D to sales ratio times current sales (max of 16%); 3% of current sales for startups	Same as before lapse	-100% credit	50% deduction against domestic income; 50% allocation	Same
July 1999 to June 2004	Same	Same	Also includes research undertaken in Puerto Rico and U.S. posessions.	Same	Same	Same	Same
July 2004 to Dec 2005	Same	Same	Same	Same	Same	Same	Same
Jan 2006 to Dec 2007	Same	Same	Same	Transition rules altered slightly and alternative credits modified as outlined on next sheet.	Same	Same	Same

* In all years the firm can apply the credit rate to 50% of current QREs if the base amount is less than 50% of current QREs.

** Section 174 of the IRC provides an immediate deduction for most research and experimentation expenditures. Taxpayers can also elect to amortize these expenditures over 60 months, but in practice most firms immediately expense R&D. However, the IRC does not define what qualifies as R&D expenditures. Treasury regulations have generally interpreted them to mean "R&D costs in the experimental or laboratory sense."

Note: Based on Hall (1994), the Senate Budget Committee's 2006 Tax Expenditures compendium and Thomas legislative summaries.

Table 2: Distribution of Firms by Qualified Share of Total R&D Expenditures, Merged Sample of Compustat and IRS SOI Data

	Observations	0	0.00-0.20	0.20-0.40	0.40-0.60	0.60-0.80	0.80-0.90	≥ 0.90
1981	61	0.279	0.148	0.262	0.164	0.049	0.016	0.082
1982	70	0.343	0.014	0.057	0.186	0.200	0.029	0.171
1983	76	0.263	0.013	0.026	0.224	0.224	0.092	0.158
1984	75	0.360	0.013	0.053	0.227	0.213	0.040	0.093
1985	43	0.419	0.000	0.093	0.140	0.209	0.047	0.093
1986	75	0.533	0.013	0.013	0.147	0.160	0.040	0.093
1987	65	0.538	0.000	0.077	0.123	0.154	0.031	0.077
1988	61	0.525	0.000	0.082	0.098	0.131	0.016	0.148
1989	64	0.563	0.016	0.078	0.156	0.063	0.016	0.109
1990	59	0.458	0.017	0.102	0.169	0.119	0.017	0.119
1991	57	0.544	0.018	0.105	0.123	0.070	0.000	0.140
Total	706	0.435	0.023	0.082	0.163	0.147	0.033	0.118

Note: The above shares are the ratio of qualified research expenditures (QREs) as reported in the firm's corporate tax return to the firm's total R&D expenditures as reported in its financial filings. The firm's research credit and marginal research credit rate are determined by QREs. Total research expenditures as reported in financial statements includes foreign research spending and expenditures that do not satisfy the experimental and technological requirements of the R&D credit. The sample consists of all firms that can be successfully merged by Employer Identification Number between the Compustat and IRS datasets and report enough data to be included in later regression analysis.

Table 3: Average User Costs, Credit Recipiency Rates and Shares With Negative Credit Rates by Year, Compustat and IRS SOI Data

		Compustat Data				IRS SOI Data			
		Observations	User Cost (Tax Price Component)	Fraction Receiving R&D Tax Credit	Fraction with Negative Marginal Credit Rates	Observations	User Cost (Tax Price Component)	Fraction Receiving R&D Tax Credit	Fraction with Negative Marginal Credit Rates
Regime 1: Statutory rate of 25% and expensing, clawback	1981	1,537	0.884	0.657	0.149	6,300	0.914	0.521	0.241
	1982	1,371	0.907	0.636	0.182	6,056	0.849	0.540	0.083
	1983	1,239	0.921	0.621	0.215	6,209	0.869	0.480	0.087
	1984	1,238	0.906	0.613	0.191	6,166	0.878	0.441	0.076
	1985	1,304	0.904	0.604	0.194	3,929	0.906	0.376	0.080
Regime 2: Statutory rate of 20% and expensing, clawback	1986	1,317	0.942	0.568	0.209	6,048	0.940	0.329	0.086
	1987	1,347	0.957	0.532	0.220	5,964	0.947	0.289	0.076
	1988	1,466	0.933	0.564	0.158	5,789	0.949	0.299	0.076
Regime 3: Statutory rate of 20% OR expensing, clawback	1989	1,538	0.923	0.577	0.114	5,601	0.955	0.309	0.050
Regime 4: Statutory rate of 20% or expensing, NO clawback	1990	1,821	0.918	0.459	0.000	5,467	0.961	0.283	0.000
	1991	1,831	0.926	0.419	0.000	4,759	0.958	0.248	0.000
Overall		16,009	0.920	0.561	0.138	62,288	0.919	0.379	0.081

Note: Samples consist of all firm-year observations that report sufficient data to be included in later regression analysis. The tax component of the user cost formula, labelled λ_t in the text, takes both expensing provisions and the research credit into account, in addition to reflecting any losses that reduces the value of tax advantages. In the Compustat sample firms receiving R&D tax credits are all firms that report current year R&D expenses that exceeed their calculated base amounts. In the IRS sample all firms who report a tentative R&D tax credit are considered credit recipeints. Negative marginal credit rates arose for firms prior to the revamping of the credit in 1990 when they failed to qualify for a credit in the current year but their current year spending increased base amounts for the subsequent three years when they did qualify for the credit.

Table 4: Average User Costs, Credit Recipiency Rates and Shares With Negative Credit Rates by Year, Merged Sample of Compustat and IRS SOI Data

	Year	Observations	Compustat Data			IRS Data		
			User Cost (Tax Price Component)	Fraction Receiving R&D Tax Credit	Fraction with Negative Marginal Credit Rates	User Cost (Tax Price Component)	Fraction Receiving R&D Tax Credit	Fraction with Negative Marginal Credit Rates
Regime 1: Statutory rate of 25% and expensing, clawback	1981	67	0.880	0.821	0.104	1.025	0.657	0.433
	1982	60	0.942	0.733	0.167	0.888	0.600	0.150
	1983	58	0.945	0.759	0.224	0.864	0.638	0.138
	1984	49	0.974	0.694	0.245	0.883	0.571	0.163
	1985	31	0.980	0.677	0.226	0.919	0.516	0.161
Regime 2: Statutory rate of 20% and expensing, clawback	1986	53	0.957	0.698	0.094	0.935	0.509	0.132
	1987	45	1.000	0.622	0.289	0.926	0.422	0.133
	1988	45	0.951	0.711	0.178	0.916	0.489	0.111
Regime 3: Statutory rate of 20% OR expensing, clawback	1989	45	0.944	0.667	0.178	0.940	0.444	0.067
Regime 4: Statutory rate of 20% or expensing, NO clawback	1990	51	0.876	0.667	0.000	0.937	0.451	0.000
	1991	49	0.902	0.551	0.000	0.929	0.388	0.000
Overall		553	0.937	0.698	0.150	0.926	0.526	0.145

Note: The sample consists of all firms that can be successfully merged by Employer Identification Number between the Compustat and IRS datasets and report enough data to be included in later regression analysis. The tax component of the user cost formula, labelled λ_t in the text, takes both expensing provisions and the research credit into account, in addition to reflecting any losses that reduces the value of tax advantages. In the Compustat sample firms receiving R&D tax credits are all firms that report current year R&D expenses that exceeed their calculated base amounts. In the IRS sample all firms who report a tentative R&D tax credit are considered credit recipeints. Negative marginal credit rates arose for firms prior to the revamping of the credit in 1990 when they failed to qualify for a credit in the current year but their current year spending increased base amounts for the subsequent three years when they did qualify for the credit.

Table 5: Distribution of Firms by Tax Component of User Cost, Merged Sample of Compustat and IRS SOI Data

	Observations	< 0.75	0.75-0.80	0.80-0.875	0.875-0.95	0.95-1.00	1.00-1.25	≥ 1.25
1981	6,300	0.099	0.313	0.134	0.131	0.076	0.136	0.111
1982	6,056	0.167	0.270	0.170	0.105	0.152	0.125	0.011
1983	6,209	0.172	0.200	0.151	0.094	0.191	0.178	0.015
1984	6,166	0.188	0.155	0.122	0.061	0.214	0.244	0.016
1985	3,929	0.154	0.116	0.107	0.054	0.232	0.320	0.018
1986	6,048	0.108	0.021	0.142	0.081	0.282	0.357	0.009
1987	5,922	0.059	0.054	0.113	0.128	0.092	0.553	0.002
1988	5,789	0.056	0.056	0.115	0.123	0.236	0.410	0.003
1989	5,601	0.065	0.032	0.079	0.152	0.280	0.392	0.000
1990	5,465	0.000	0.000	0.043	0.314	0.265	0.378	0.000
1991	4,756	0.000	0.000	0.158	0.102	0.300	0.440	0.000
Total	62,241	0.0989	0.1157	0.1222	0.1228	0.2068	0.3158	0.0177

Note: The sample consists of all firm-year observations from the Compustat dataset that report sufficient data to be included in later regression analysis. The tax component of the user cost formula, labelled λt in the text, takes both expensing provisions and the research credit into account, in addition to reflecting any losses that reduces the value of tax advantages. Research credit rates are calculated using total R&D spending as reported in firm financial statements.

Table 6: Comparison of Average Actual and Synthetic User Cost Tax-Adjustment Factors, Compustat and IRS SOI Data

	Compustat Data				IRS Data		
	Year	Observations	Actual User Cost Tax-Adjustment Factor	Synthetic User Cost Tax-Adjustment Factor	Observations	Actual User Cost Tax-Adjustment Factor	Synthetic User Cost Tax-Adjustment Factor
Regime 1: Statutory rate of 25% and expensing, clawback	1981	1,520	0.882	0.765	-	-	-
	1982	1,371	0.907	0.792	5,529	0.855	0.885
	1983	1,239	0.921	0.817	5,519	0.875	0.868
	1984	1,238	0.906	0.841	5,251	0.886	0.868
	1985	1,304	0.904	0.846	3,747	0.906	0.865
	1986	1,317	0.942	1.002	3,501	0.951	0.885
Regime 2: Statutory rate of 20% and expensing, clawback	1987	1,347	0.957	1.013	5,277	0.952	0.888
	1988	1,466	0.933	0.926	5,249	0.953	0.897
Regime 3: Statutory rate of 20% OR expensing, clawback	1989	1,538	0.923	0.940	5,184	0.957	0.913
Regime 4: Statutory rate of 20% or expensing, NO clawback	1990	1,692	0.916	0.899	5,030	0.962	0.903
	1991	1,699	0.923	0.901	4,488	0.959	0.902
Overall		15,731	0.919	0.886	48,775	0.924	0.888

Note: Actual user cost tax-adjustment factors reflect both prevailing expensing and research credit provisions and contemporaneous research spending. Research credit rates are calcultated using contemporaneous total R&D spending in the case of Compustat data and qualified research expenditures in the case of IRS SOI data. Synthetic user cost tax-adjustment factors are constructed using prevailing expensing and research credit provisions, but the first lag of research spending (total R&D spending in Compustat data and QREs in the IRS SOI data).

Table 7: Tax-Price Elasticity Estimates Using Compustat Data and Different Instrument Sets

IV:	Lag RHS Vars	Lag RHS Vars	Lag RHS Vars	Synthetic IVs	Synthetic IVs	Synthetic IVs
	(1)	(2)	(3)	(4)	(5)	(6)
$\log(\rho_{it} / \rho_{t-1})$	-0.844	-0.822	-0.734	-0.449	-0.466	-0.453
	(0.097)	(0.088)	(0.100)	(0.035)	(0.032)	(0.031)
$\log R_{it-1}$	0.003	0.002	-0.001	-0.035	-0.002	-0.042
	(0.006)	(0.004)	(0.006)	(0.007)	(0.002)	(0.007)
$\log(S_{it} / S_{it-1})$	-0.006	-0.004	-2.47E-04	0.007	-	0.042
	(0.007)	(0.005)	(0.007)	(0.009)	-	(0.007)
Years	1981-1991	1981-1991	1982, 1986-90	1982, 1986-90	1982, 1986-90	1982, 1986-90
Industry	Manufacturing	All	All	All	All	All
Observations	5,615	6,398	3,131	6,339	6,248	6,207

Note: The specification in column 1 corresponds to my best effort to replicate the results of an earlier study, Hall (1994). That specification instrumented for all three regressors with their second and third lags as well as with lagged tax status and lagged growth rates in R&D and sales. It limited the analysis to only manufacturing firms but included observations from all years between 1981 and 1991. The instrumenting strategy based on synthetic tax-adjustment user cost factors, used in columns 4-7, is laid out in Section 2.2 and is only valid in years where the provisions of the tax credit were altered. The basic specification of columns 4-7 is:

$$\log\left(\frac{R_{it}}{R_{it-1}}\right) = \sigma \log\left(\frac{\lambda_{it}}{\lambda_{it-1}}\right) + \chi_t + \eta \log\left(\frac{Y_{it}}{Y_{it-1}}\right) + \varepsilon_{it}$$

These regressions include all firms, though the vast majority are manufacturing firms. Column includes the log growth in sales as a control as well as lag R&D spending. Lag R&D is included because the synthetic instruments are only exogenous conditional on the lag of R&D which was used in constructing the instruments. Column 5 resestimates the specification of column 4 dropping the control for log sales growth. Column 6 instruments for the potentially endogenous lag of R&D. All regressions include year fixed effects and a constant. Standard errors are clustered at the two-digit industry level; there are 20, 48, 46 clusters in columns 1-3, respectively and 52 clusters for columns 4-6.

Table 8: Tax-Price Elasticity Estimates Using Compustat Data, Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\log(\rho_{it}/\rho_{t-1})$	-0.453	-0.44	-0.401	-0.400	-0.441	-0.470	-0.460
	(0.031)	(0.057)	(0.057)	(0.058)	(0.067)	(0.038)	(0.065)
Year-specific $\log R_{it}$		X					
Industry FE			X				
Industry time trend				X			
Control function					X		
Reports in all years						X	
December FY end							X
Observations	6,207	6,207	6,207	6,207	6,207	3,360	3,305

Note: The specification in column 1 is the baseline estimate and corresponds to column 6 of Table 1.7. The log-change in the tax-adjustment factor, $\log(\rho_{it}/\rho_{t-1})$, is the instrumented with the synthetic change in the tax-adjustment factor, as explained in Section 1.2.2. The specification of column 1 is:

$$\log\left(\frac{R_{it}}{R_{it-1}}\right) = \sigma \log\left(\frac{\lambda_{it}}{\lambda_{it-1}}\right) + \chi_t + \eta \log\left(\frac{Y_{it}}{Y_{it-1}}\right) + \varepsilon_{it}$$

where χ_{it} includes year fixed effects and the first lag of log R&D spending, $\log R_{it}$. Additional terms are included in the specifications corresponding to columns 2 through 6. Column 2 adds a cubic in $\log R_{it-1}$ for each year. Column 3includes industry fixed effects and column 4 further adds a linear time trend for each NAICS two-digit industry. Column 5 adds a control function to corrects for selection. Column 6 limits the sample to only firms that report data for all five years. Column 7 limits the sample to firms with December fiscal year ends. All regressions also include a constant. Standard errors are clustered at the two-digit NAICS industry level.

Table 9: Impact on Total R&D Spending (COMPUSTAT Data Only)
Dependent Variable: (Δ Total R&D Exp./$Sales_{t-1}$)

	OLS (1)	OLS (2)	IV (3)
Δ Tax Part of Usercost	-0.043	-0.045	-0.035
	(0.010)	(0.011)	(0.007)
Sales Growth	2.28E-02	2.40E-02	0.021
	(1.25E-02)	(1.24E-02)	(0.013)
First Lag Total R&D	-	-	3.24E-07
			(8.72E-07)
Usercost Elasticity	-0.436	-0.453	-0.356
	(0.101)	(0.104)	(0.078)
Impact of a 10% decrease in usercost in $M R&D	13.182	13.705	10.749
	(3.059)	(3.145)	(1.787)
Observations	7,767	7,767	7,631

Note: All regressions include a constant. All data are inflated using the GDP index. Standard errors are clustered at the two-digit industry level according to NAICS codes from Compustat; these data span 59 industries.

Table 10: Impact on Qualified R&D Spending (IRS Data Only)
Dependent Variable: (Δ Qualified R&D/$Sales_{t-1}$)

	OLS (1)	OLS (2)	IV (3)
Δ Tax Part of Usercost	-0.046 (0.007)	-0.045 (0.007)	-0.024 (0.005)
Sales Growth	0.026 (0.011)	0.026 (0.011)	0.029 (0.014)
First Lag Qualified R&D	-	-	7.93E-07 (1.61E-06)
Usercost Elasticity	-3.424 (0.522)	-3.316 (0.503)	-1.673 (0.332)
Impact of a 10% decrease in usercost in $M R&D	3.836 (0.585)	3.715 (0.564)	1.960 (0.389)
Observations	28,371	28,371	18,691

Note: All regressions include a constant. All data converted to real dollars using the GDP index. Standard errors clustered at the two-digit industry level according to SOI industry codes; these data span 69 industries.

Table 11: Impact on Qualified R&D Spending Components (IRS Data Only)

Dependent Variable: (Δ Qualified R&D/$Sales_{t-1}$)

	Wages & Salaries (1)	Supplies (2)	Equipment (3)	Contracted (4)	University (5)
Δ Tax Part of Usercost	-0.016	-0.005	-5.42E-04	-9.11E-04	-9.67E-04
	(0.004)	(0.001)	(4.78E-04)	(9.49E-04)	(6.09E-04)
First Lag Total QRE	5.34E-07	-3.13E-07	-1.14E-07	8.96E-07	1.66E-07
	(1.10E-02)	(5.12E-07)	(1.42E-02)	(3.52E-07)	(2.58E-07)
Sales Growth	0.025	0.005	0.000	0.002	1.99E-05
	(0.013)	(0.003)	(0.000)	(0.001)	(1.48E-05)
Usercost Elasticity	-1.655	-1.926	-6.300	-1.069	1.17E-04
	(0.449)	(0.454)	(5.560)	(1.111)	(1.15E-04)
Impact of a 10% decrease in usercost in $M R&D	1.431	0.417	0.049	0.083	0.088
	(0.389)	(0.098)	(0.044)	(0.087)	(0.056)
Observations	14,394	14,394	14,394	14,394	2,882

Note: All regressions include a constant. All data converted to real dollars using the GDP index. Standard errors clustered at the two-digit industry level according to SOI industry codes; these data span 69 industries.

Table 12: Impact on Total R&D Spending (Merged Data)

Dependent Variable:	(Δ Total R&D Exp./Sales$_{t-1}$)		(Δ Qualified R&D/Sales$_{t-1}$)	
	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)
Δ Tax Part of Usercost	-0.002	-0.015	-0.047	-0.093
	(0.010)	(0.011)	(0.014)	(0.042)
Sales growth	-0.003	-0.002	0.027	0.022
	(0.001)	(0.001)	(0.013)	(0.020)
First Lag Total R&D	-	1.47E-05	-	-4.11E-06
		(1.24E-05)		(1.47E-05)
Usercost Elasticity	-0.043	-0.315	-2.330	-5.940
	0.211	0.254	(0.700)	(2.435)
Impact of a 10% decrease in usercost in $M R&D	-0.330	2.168	8.156	16.260
	(1.614)	(1.743)	(2.451)	(7.182)
Observations	314	217	314	216

Note: All regressions include a constant. All data are inflated using the GDP index. Standard errors are clustered at the two-digit industry level according to NAICS codes from Compustat; these data span 59 industries. No observations from 1986 were found in both samples with sufficient lag and leading data for the IV specification.

Appendix

Several variables used to calculate a firm's marginal R&D tax credit rate are not reported directly and must instead be inferred from other variables. These variables, and their instrument analogue were calculated as follows:

j_{it}: the number of years the firm will carry forward any earned R&D tax credits

If a firm does not pay federal taxes, it is assumed to not have taxable income and must therefore carry-back (then carry-forward) its R&D tax credit. The R&D tax credit can be carried back up to 3 years and carried forward up to 15 years. The analysis presented here only calculates up to 6 carry-forward years; firms who would carry the credit forward more than 6 years are assigned a six-year carry-forward period. The firm will first offset taxes paid (Compustat Data63) three years prior. If its taxes paid three years prior are insufficient to offset the credit, it will offset taxes paid two years prior, then one year prior. Any remaining R&D tax credit will then be carried forward.

To construct the synthetic tax rate, j_{it} is replaced by a constant (0.5) for all firms in all years.

k_{it}: the number of years until any tax losses will be exhausted

Compustat reports a firm's stock of net operating loss carry-forwards (Data 52) but not their time to expiration. Net operating losses (NOLs) can be carried forward up to 20 years. All NOL carry-forwards are assumed to be used before they expire. NOLs are first used to offset the following year's pre-tax income (Data272). If next year's pre-tax income is insufficient to offset all NOL carry-forwards, the remaining NOL carry-forwards are offset against the second leading year's pre-tax income and so on. The analysis presented here only calculates up six years of tax losses; firm who may have more than six years of tax losses are assigned a tax loss period of six years.

To construct the synthetic tax rate, k_{it} is replaced by a constant (0.5) for all firms in all years.