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Do tax credits stimulate R&D spending? The effect of the R&D tax credit in its first decade☆

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ABSTRACT

This paper examines the impact of the U.S. federal R&D tax credit between 1981–1991 using confidential IRS data from corporate tax returns. The empirical analysis makes two key advances on previous work. First, it implements a new instrumental variables (IV) strategy based on tax changes that directly addresses the simultaneity of R&D spending and marginal credit rates. Second, the analysis makes use of new restricted-access IRS corporate return data describing R&D expenditures. Estimates imply that a10% reduction in the user cost of R&D leads the average firm to increase its research intensity—the ratio of R&D spending to sales—by 19.8% in the short-run. Long-run estimates imply that the average firm faces adjustment costs and increases spending over time, though small and young firms show evidence of reversing initial increases. Analysis of the components of qualified research shows that wages and supplies account for the bulk of the increase in research spending. Elasticities of qualified and total research intensities from a smaller sample suggest firms respond to user cost changes largely by increasing their qualified spending, meaning that the type of R&D the federal credit deems qualified research is an important margin on which the credit affects firm behavior.

1. Introduction

How much the U.S. spends on R&D—relative to past levels and relative to other nations—attracts considerable interest from industry leaders, policymakers and researchers. Business has long performed the lion's share of U.S. R&D and has been the primary funder since the late 1970s. Nonetheless, the federal government plays a significant role in promoting private R&D. Federal support is motivated by both potential spillovers from privately conducted R&D and a notion that R&D affords U.S. firms a competitive advantage in global markets. In an attempt to stanch a decade-long decline in the GDP-share of private R&D, Congress adopted a tax credit for R&D expenditures in 1981. Today, the Research and Experimentation Credit (R&D Credit) awards firms that increase their research spending a tax credit of up to 20% of their expenditures, amounting to more than $8 billion in research credits annually (OTP, 2011). This paper uses new data and an instrumental variables strategy to assess how effectively the R&D tax credit, along with expensing provisions, increases corporate research spending.

Effective R&D tax credit rates have varied over time due to legislative changes and—thanks to the incremental nature of the credit—changes in R&D spending due to cyclical and firm-specific factors. In its earliest incarnation, the credit's design undermined its statutory rate of 25%. Between 1981 and 1984 effective credit rates averaged less than one-tenth of the statutory rate (Altshuler, 1988). Early studies of the credit's effectiveness suggested that the subsidy did little to increase corporate research spending (Eisner et al., 1984) and (Mansfield, 1986), while later studies, most notably Hall (1993b) and Hines (1993) found much higher elasticities—well exceeding unity in both the short- and long-run. Hall and Van Reenen (2000) provide an excellent review of prior work on the U.S. federal credit

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and other national credits. These studies of the credit's effectiveness employ publicly available data.[1]

More recent work examining the impact of state tax credits and international experiences has found more modest elasticities—particularly in the short-run. In the preferred dynamic specification of their cross-country analysis, Bloom et al. (2002) estimate a −0.14 short-run elasticity and a long-run elasticity of −1.09.[2] Wilson (2009) uses variation in state tax preferences for R&D to estimate the impact of a state's R&D policy on both R&D conducted within that state and on R&D conducted in neighboring states.[3] His analysis of state aggregate data yields elasticity estimates of −0.17 in the short-run and −0.68 in the long-run. In both of these studies some countries and states have incremental R&D credit regimes, where high spending firms receive higher credit rates. The authors assume that all R&D subject to incremental R&D tax credits receives the highest statutory rate, abstracting from the simultaneity between R&D spending and R&D user costs because they use aggregate data.

This paper examines the impact of federal tax advantages for R&D between the inception of the R&D tax credit in 1981 and 1991, the last year prior to the credit's first lapse in 1992.[4] The identification strategy hinges on tax policy changes that were common in the credit's early years but absent more recently. As the last change in the major provisions of the credit occurred in 1991, the sample ends in 1991. The empirical analysis presented here makes two main contributions. First, it implements a new instrumental variables (IV) strategy that directly addresses the simultaneity of R&D spending and marginal credit rates. Second, it makes use of new restricted-access IRS Statistics of Income (SOI) corporate return data describing R&D expenditures. During its first decade the R&D credit underwent several substantial revisions that allow for an instrumental variables strategy based on tax changes. As explained in more detail in section two, 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 filings. Using IRS tax data is crucial to accurately measure a firm's marginal research credit rate. I compare tax subsidy measures constructed from previously used public financial filing data to tax subsidy measures constructed using IRS SOI data. The measures differ and the differences vary from year to year, suggesting that the public data could lead to biased elasticity estimates. The IRS SOI data also describe private firms, including small firms not found among the public firms studied in prior research that relied on data compiled from financial filings. The combination of accurately measured marginal R&D tax credit rates and a new IV strategy allows for the unbiased estimation of the impact of the R&D tax credit on R&D expenditures.

Using new IRS SOI data and an IV strategy based on tax law changes to disentangle any potential simultaneity between R&D spending and its user cost, I estimate the user cost elasticity for R&D expenditures. Estimates imply that a 10% reduction in the user cost of R&D leads the average firm to increase its research intensity—the ratio of R&D spending to sales—by roughly 20% in the short-run. Long-run estimates imply that the average firm faces adjustment costs and increases spending over time, though small and young firms show evidence of reversing initial increases. IRS SOI data report the different components of R&D spending separately. Analysis of the components shows that wages and supplies account for the bulk of the increase in research spending. Elasticities of qualified and total (qualified and non-qualified) research intensities from a smaller sample suggest that firms respond to changes in the user cost largely by increasing their qualified spending, meaning that the type of R&D the federal credit deems qualified research is an important margin on which the credit affects firm behavior.

The paper proceeds as follows. Section 2 overviews the key provisions of the R&D tax credit and describes the restricted access IRS SOI data used in this study. The empirical model is laid out and estimation strategy is detailed in Section 3. Section 4 presents the results of the regression analysis. Section 5 assesses the policy implications and concludes.

2. Measuring R&D user costs and R&D expenditures

2.1. Federal tax subsidies and the user cost of R&D

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 of private 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.

The tax credit is incremental in nature; it aims to reward research expenditures in excess of what the firm would have spent in the absence of the credit. As such, the credit defines a firm's base level of R&D spending and awards a tax credit equal to a fraction of spending above that base level. Originally, the credit was equal to 25% of qualified research expenditures (QREs)—which are expenses incurred in research undertaken to discover knowledge that is technological in nature for a new or improved business purpose—above the firm-specific base amount. A firm's base was its average nominal qualified R&D spending in the previous 3 years or 50% of current spending, whichever was greater. Because a firm's base was a moving average of its past spending, increased qualified research spending in the current year raised the firm's base by one-third of the increase in each of the subsequent 3 years. This 'claw-back' muted the credit's incentive effects; some firms were even left with negative marginal credit rates.

The tax credit was extended and its provisions were amended by several legislative acts after its introduction in 1981; they are detailed in Table 1. The credit was revamped in 1989 to address the dynamic disincentives for current qualified R&D spending created by the claw-back provision. The legislative overhaul 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% of current QREs and the product of the firm's average gross

[1] Hall (1993b) employs data from financial filings and using cross-time within-firm variation in a log first-difference specification finds a short-run elasticity of −1.5 and a long-run elasticity of −2.7. Hall addresses the endogeneity of the user cost using lags of the user cost and other right-hand side variables as instruments. Hines (1993) explores the effect of changes in the allocation rules of R&D expensing on the R&D activity of multinational firms, exploiting variation in the fraction of U.S. R&D expenses firms can deduct against U.S. income to estimate the response of R&D spending to its after-tax price. His short-run estimates range from −1.2 to −1.6 and long-run estimates range from −1.3 to −2.0. Although the changes in the allocation rules are conceivably exogenous, This tack hinges on differences between firms with and without foreign tax credits—an experiment that is different from the changes in the main statutory provisions of the R&D tax credit examined here.

[2] 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.

[3] 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.

[4] Limiting the sample to the years before the first (of many) lapses in the credit also limits the sample to years when firms' expectations regarding the credit were similarly stable; the first lapse in 1992 and subsequent lapses likely affected firm expectations of the after-tax user cost of R&D.

Table 1
Legislative history of the Federal Research and Experimentation Tax Credit, 1981–2013.

	Credit rate[a]	Corporate tax rate	Definition of base	Qualified research expenditures	Sec. 174 deduction[b]	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. possessions.	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
Jan 2008 to Dec 2013	Same	Same	Same	Same	Same	Same	Same

Note: Based on Hall (1993b), the Senate Budget Committee's 2006 Tax Expenditures compendium and Thomas legislative summaries.
[a] 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.
[b] 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."

receipts in the previous four tax years and the firm's "fixed-base percentage," a measure of historic research intensity. A firm's fixed-base percentage is its ratio of total qualified R&D expenditures to total gross receipts between 1984 and 1988. Start-ups and other firms lacking gross receipts or QREs for three of 5 years between 1984 and 1988 were assigned a 3% fixed-base percentage.

The incremental nature of the R&D tax credit renders a firm's marginal credit rate a non-monotonic function of its research spending: firms that fail to exceed their bases receive no subsidy, firms that exceed their bases but do not spend more than twice their bases receive the full statutory subsidy rate and firms that exceed twice their bases receive half the statutory credit rate on their marginal spending. This simultaneity complicates the empirical analysis as explained in Section 3.

2.2. R&D expenditures

The empirical analysis makes use of restricted-access IRS SOI data that have not previously been used to estimate the user cost elasticity of R&D. 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 Form 6765. 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. Only IRS SOI data describe qualified spending and provide enough detail to accurately measure the actual credit rates firms face on their marginal dollar of R&D spending. R&D expenses reported in financial filings and publicly available through Compustat conform to a broader definition of R&D 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 of the credit.[5]

If firms respond to changes in subsidies for qualified R&D by changing their qualified and non-qualified spending shares, determining a firm's marginal credit rate using public data describing the sum of qualified and non-qualified 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 marginal 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 user cost. Only SOI data can overcome this measurement issue. In addition, 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 user cost elasticity.[6]

Table 2 details the differences between the true marginal credit rate as determined by the IRS SOI data and the marginal credit rates inferred from the broader measure of R&D reported in financial filing data from Compustat. Because the IRS SOI data include both public and private firms and do not oversample large firms, only a small set of firms appears in both the Compustat and IRS SOI data. There are a total of 686 common firm-year observations between 1981 and 1991. As Table 2 shows, the impact of taxes on the user cost is different in the two data sets and the differences vary from year to year. In 1981 the claw-back provision actually increases the user cost of the average firm in the merged sample from 1 to 1.038 while according to the less accurate Compustat data the average firm enjoyed a subsidy that reduced its user cost to 88.8% of the pre-tax subsidy user cost. This difference is partly due to a substantially larger fraction of firms facing negative marginal credit rates than the Compustat data suggest, 45.6 versus 11.8%.[7] In general, the Compustat data suggest that more firms—from 2.7 to nearly 22 percentage points more, depending on the year—qualify for an R&D tax credit than actually do. In nearly every year between 1982 and 1989 the Compustat data imply higher user costs, that more firms receive credits and that more firms face negative marginal credit rates than the accurate IRS SOI data detail. The IRS SOI data show that the reformulation of the base starting in 1990 coincided with a reduction in the fraction of firms earning an R&D tax credit—a pattern consistent with the Compustat-based findings of (Gupta et al., 2011)—and a modest increase in the user cost not apparent in the Compustat data. The fact that the Compustat data suggest such different effects of the R&D tax credit provisions and the fact that these differences vary so widely from year to year bring into the question the appropriateness of using data from financial filings to determine R&D tax subsidies which depend so crucially on comparisons of spending patterns over time.

But for all the detail and accuracy the IRS SOI data afford, they have limitations as well. First, is the issue of censoring. A firm likely only reports the details of its research spending in years when it applies for the R&D tax credit; in years when 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. 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 should interpret the impact of the R&D tax credit differently than if they increase total research spending. IRS data do not provide any sense of how a firm's non-qualified spending responds to subsidies for qualified spending. Analysis using both the IRS SOI and Compustat data, though in a substantially limited sample, is conducted to assess the importance of this limitation.

[5] 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.

[6] 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 higher priority credits would value currently earned R&D credits less.

[7] The unusually high fraction of firms that had negative credit rates in 1981 may be caused by delays in research spending increases 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.

Table 2
Average user costs, credit receipt 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 subsidy impact)	Fraction receiving R&D tax credit	Fraction with negative marginal credit rates	User cost (tax subsidy impact)	Fraction receiving R&D tax credit	Fraction with negative marginal credit rates
Regime 1: statutory rate of 25% and expensing, clawback	1981	68	0.888	0.779	0.118	1.038	0.706	0.456
	1982	72	0.930	0.736	0.167	0.861	0.639	0.111
	1983	73	0.952	0.712	0.247	0.826	0.685	0.082
	1984	74	0.934	0.689	0.230	0.821	0.581	0.122
	1985	43	0.939	0.651	0.163	0.873	0.465	0.116
Regime 2: statutory rate of 20% and expensing, clawback	1986	66	0.931	0.652	0.061	0.923	0.439	0.106
	1987	61	0.966	0.623	0.230	0.891	0.426	0.098
	1988	60	0.935	0.683	0.133	0.909	0.467	0.100
Regime 3: statutory rate of 20% OR expensing, clawback	1989	57	0.929	0.667	0.140	0.894	0.474	0.053
Regime 4: statutory rate of 20% or expensing, NO clawback	1990	55	0.879	0.636	0.000	0.913	0.418	0.000
	1991	57	0.907	0.526	0.000	0.907	0.368	0.000

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 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 exceed their calculated base amounts. In the IRS sample all firms who report a tentative R&D tax credit are considered credit recipients. 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 3 years when they did qualify for the credit.

3. Empirical model and estimation strategy

3.1. Empirical model

Firms are viewed to dedicate personnel and purchases to R&D to develop new products and services that increase sales. The output Y_{it}, of firm i in time t is generated via a production function with a constant elasticity of substitution (γ) between R&D services and all other inputs. The profit maximization first-order conditions yield a standard factor demand equation for R&D services as a function of its *ex ante* user cost, $R_{it} = \theta Y_{it}\rho_{it}^{-\gamma}$, where θ is the CES distribution parameter and ρ_{it} is the user cost of R&D. Note that γ captures both the elasticity of substitution and the user cost elasticity of R&D. Tax subsidies that reduce the user cost will increase the firm's use of R&D as an input factor. Estimating this response is the focus of this paper.

The standard Hall and Jorgenson (1967) user cost of capital formula can be extended to reflect both the federal tax deduction and tax credit for R&D.[8] 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 R&D tax credit rate is a function of the firm's R&D spending.[9] A nontaxable firm with l_{it} years of tax losses cannot use the R&D expensing provision to offset income until those losses are exhausted. Similarly, a firm with insufficient tax liabilities to fully apply any R&D credit earned this year will carry its credit forward m_{it} years. Firms are assumed to discount the future at a common real interest rate, r_t, and purchase R&D at price p_t^K. Thus, the relevant user cost of R&D capital, ρ_{it}, for firm i at time t is:

$$\rho_{it} = \frac{(r_t + \delta - \pi_t^K)\, p_t^K \left(1 - \tau_{it+l_{it}}(1+r_t)^{-l_{it}} - c_{it}(1+r_t)^{-m_{it}}\right)}{\left(1 - \tau_{it+l_{it}}(1+r_t)^{-l_{it}}\right)} \quad (1)$$

where π_t^K is the time-varying growth rate of R&D input prices.[10] Since wages comprise the bulk of R&D spending, π_t^K should closely track wage growth for scientists and engineers. Note that when firm i is taxable, l_{it} and m_{it} will be zero.

During the 1980s many changes were made to the provisions of the R&D tax credit, including changes in the statutory rate and recapturing provisions. The impact of these changes on the marginal R&D credit rate are detailed in Appendix A. The user cost of R&D capital for each firm in each year is carefully calculated using these provisions and assuming a 3% real interest rate, a 15% depreciation rate and that π_t^K is equal to science and tech wage inflation.

It should be noted that the input into the firm's production function is R&D services flowing from an unobserved stock of R&D capital. Researchers proxy for the unobservable service flow by assuming that R&D services in a given year are proportional to either R&D investment or the R&D capital stock in that year, which they typically calculate using a perpetual inventory method and a constant rate of geometric decay. Papers that compare the flow and stock proxies, such as Hines (1993), Wilson (2009) and Hall (1993b), find very similar results. Given the inherent difficulty in measuring the depreciation rate of a firm's R&D stock—and potential variation in the depreciation rate across industries—and the difficulty posed by the fact that IRS SOI data only provide R&D expenditures in years when the firm applies for a tax credit, I opt to use R&D investment as the proxy, as is commonly done in the literature.

Although log-linearizing the factor demand equation would prescribe a log–log regression model that uses the logarithm of R&D spending as the outcome of interest, this paper assesses how changes in the tax subsidies for research spending affect firm research intensities—the ratio of R&D expenditures to sales. A firm's research intensity is a reasonable outcome of interest for a number of reasons. First, research intensity is a commonly used measure of innovation spending in the academic literature, such as Cohen and Klepper (1992), Jaffe (1988), Berger (1993) and Pakes and Schankerman (1984), industry publications and government agency reports, such

[8] Hall (1993b), Bloom et al. (2002) and Wilson (2009) similarly extend the standard investment user cost of capital to measure the user cost of R&D.

[9] The corporate tax rate is indexed by firm to account for the progressivity of federal corporate taxes. Some small firms subject to a marginal tax rate less than 35% do spend on R&D; their R&D credit rates reflect their lower marginal tax rates.

[10] The credit rate, c_{it}, enters the relation linearly because the depreciation base is not typically reduced by the amount of the credit.

Table 3
Descriptive statistics, IRS SOI data.

	Mean	25th perc.	Median	75th perc.	90th perc.	99th perc.	St dev	Observations
Tax term	0.90	0.86	0.90	0.91	1.00	1.05	0.07	17,876
Qualified R&D	8.88	0.00	0.00	0.46	5.27	160.9	112.5	17,876
Qualified R&D if > 0	28.21	0.63	2.10	7.77	27.1	456.4	199.2	5626
Qualified R&D intensity	0.01	0.00	0.00	0.00	0.03	0.12	0.05	17,876
Qualified R&D intensity if > 0	0.03	0.00	0.01	0.03	0.07	0.18	0.08	5626
Sales	1144	39.8	131	467	1969	17,464	5666	5626
NI tax	72.5	0.4	4.8	25.5	122	1350	422	17,876
NI book	69.9	0.0	2.7	17.8	103.6	1368	494	17,876
Total assets	2101	18.0	81.7	360	2245	41,746	13,538	17,876
Foreign tax credits if > 0	30.5	0.06	0.73	6.70	40.7	559	193	4006

Note: The sample consists of all firm-year observations from the IRS SOI data that report sufficient data to be included in later regression analysis. The sample is trimmed of firms with sales of less than $7 million.

as the National Science Foundation (Board, 2012) and the Congressional Budget Office (Austin, 2006). The fixed-base percentage of the R&D credit itself uses research intensity to formulate a research spending benchmark. Second, any procedure for creating a stock measure for R&D capital involves great uncertainty as to how spending translates into a stock of innovation capital or how this capital depreciates. Examining the effect of tax subsidies on scaled research expenditures has the meaningful advantage of transparency. Third, and perhaps most importantly, the more accurate IRS SOI data contain a number of zeros—both because firms do not report research spending every year and the IRS reports missing data as zeros and because firms report zero spending in some years. Of course, in the cases where the missing data are assumed to be zeros, the mis-measurement could bias the estimates; regressions that use only firms that report in all years, however, confirm the baseline results. Finally, given the assumed CES production technology, the elasticity of research intensity with respect to the user cost is also γ, meaning that the analysis here will give us similar insight into the price-sensitivity of R&D investments.

As firms may have generally different research intensities, the estimation equation is first-differenced to remove any unobservable firm-level differences. Because 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. Thus, the estimation equation is:

$$\left[\frac{R_{it}}{S_{it}} - \frac{R_{it-1}}{S_{it-1}}\right] = \alpha + \gamma[\rho_{it} - \rho_{it-1}] + \chi_t + \epsilon_{it} \qquad (2)$$

Table 3 presents key descriptive statistics for the variables used in the analysis. During the sample period, the average firm's marginal R&D expenditures are subsidized by the tax credit, reducing its user cost of R&D to $0.90 per dollar of R&D. The average belies substantial heterogeneity. Although the R&D tax credit reduces the user cost for firms through the 75th percentile, 3.38% of firms actually face a user cost higher than unity due to the perverse incentives created by the claw-back provisions of the R&D credit prior to the 1990 reformulation. Fig. 1 provides more insight into the dispersion of user cost tax factors over time. The average firm spends nearly $9 million on qualified research, though the distribution is heavily right skewed. The top decile of firms accounts for more than 96% of all R&D expenditures. The top 5% account for more than 91% and the top percentile itself contributes nearly 71% of all qualified research in the sample. While the average firm's R&D-to-sales ratio is 2.86% (conditional on non-zero qualified research), the median firm's research intensity is only 1.28% and the the ratio rises to 7.17% at the 90th percentile; the unconditional distribution shows a similar pattern. It should be noted that the firms conducting much of the R&D are large firms whose research intensities are not in the very top of the distribution—their sales are sufficiently large that the ratio is not extreme. Firms average roughly $.1 billion in sales and $72.5 million and $69.9 million in tax and book profits respectively. The average firm has approximately $2.1 billion in assets, though assets, like research spending, are heavily rightward skewed with the top percentile of firms having more than 500 times the assets of the median firm. While the average firm has more than $30 million in foreign tax credits, only the top 25% of firms have appreciable foreign tax credits.

3.2. Estimation strategy

As explained in Section 2, a firm's R&D tax credit is a non-monotonic function of its R&D spending. A firm's marginal R&D credit rate and its R&D spending level are jointly determined; the user cost of capital, ρ_{it}, is correlated with ϵ_{it}. If, for example, 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 Eq. (2) 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 change in user costs variable, $(\rho_{it} - \rho_{it-1})$, which is a function of contemporaneous research spending, is to compute $\left(\rho_{it}^S - \rho_{it-1}^S\right)$, the "synthetic" change in firm i's marginal user cost unrelated to current research spending. A natural construction of such an instrument is the difference in the firm's synthetic user costs under current law and under the previous year's rules, computed using research spending from two-years

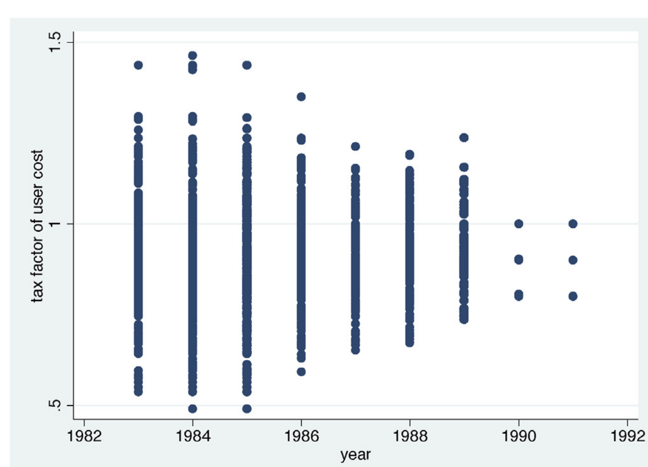

Fig. 1. Factor of user cost of qualified R&D by year.

ago, $\left(\rho^S_{it}(R_{it-2}) - \rho^S_{it-1}(R_{it-2})\right)$. This instrument captures how firm i's incentives for R&D spending would have changed between year t and year $t-1$ due to only changes in the tax rules.

By construction the instrument eliminates the effect of R&D spending changes on the change in tax price. The synthetic change in tax price reflects only the exogenous changes in the provisions of the R&D tax credit—not the tax price change due to changes in R&D spending. It is the exogenous changes in the effective tax price of R&D due to changes in the tax code that are the source of identification of the behavioral response. First-differencing purges firm-specific time-invariant differences in the evolution of qualified research 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. Legislative changes drive identification.

Only observations from years when there was a change in tax policy are used in the analysis.[11] The key exclusion restriction is that the constructed synthetic tax factor—which is constructed from spending prior to the tax change—does not affect R&D spending other than through the actual tax factor, conditional on firm and year fixed effects. In other words, there are no time-varying firm specific factors affecting research spending, besides the credit, that are correlated with the timing of the legislative changes. In later regressions, as explained in Section 4, a spline 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. The significant nonlinearity of the firm-specific credit function strengthens the believability of the exclusion restriction. It is true, however, that the local average treatment effect estimated here arises from firms whose research budgets are influenced by marginal tax subsidies. If these firms are systematically different from the typical firm, the elasticities measured here may be less applicable to policy extrapolations involving all firms.

4. Results

If the tax credit is effective in increasing R&D outlays, we should see research intensities increase in response to higher effective credit rates. Table 4 presents the main results of the empirical analysis. The outcome of interest for all columns is the one-year change in research intensity. The first column reports OLS estimates of Eq. (2) while columns (2)–(8) report IV estimates.[12] The specification reported in column (2) instruments for the endogenous tax variable with the synthetic tax subsidy constructed from two-year lagged R&D spending as described in Section 3.[13] Comparing columns (1) and (2) makes clear that the simultaneity of the tax credit and R&D expenditures leads to substantial under-estimation of the responsiveness of research spending to the tax credit—instrumenting for the tax variable yields an estimate that is statistically dissimilar and three times larger in magnitude. The results of column (2) suggest that research intensities are very responsive to changes in the research subsidy; a 10% increase in the average firm's tax subsidy leads to a nearly 19.8% increase in the firm's research intensity. The average research-to-sales ratio is approximately 4.56% for firms in the baseline IV sample, conditional on engaging in research that year. Translated into value for money terms, this estimate suggests that a 10 percentage point reduction in user costs will lead the average firm to increase its research spending by \$1.95 million. Extending the subsidy will reduce tax liabilities by roughly \$1.08 million per firm on average, including the additional subsidy on infra-marginal and marginal qualified research spending and assuming all credits are used in the same tax year they are earned. This translates into a value for money ratio of 1.8—a dollar of tax credit results in \$1.80 of new R&D spending.

Column (3) adds a five-knot spline in the previous year's R&D spending to better control for underlying changes in the R&D spending distribution that may confound the analysis. Mean reversion, for example, could be particularly problematic in examining the response to an incremental credit. A spline in two-year lagged R&D spending is also added to the instruments. Controlling for any potential mean-reversion or other changes in the distribution has no appreciable impact on the estimated tax price elasticity. Outlier observations are dropped in (4); dropping the 3% most-research intense firms (that report the required information to be in the sample) does not affect the point estimate, though it does increase the estimated elasticity due to the decrease in average R&D-to-Sales ratios in the trimmed sample.

Column (5) adds industry fixed effects. Two-digit SOI industry codes are used. The sample spans 68 industries. The highest R&D-to-sales ratios are found in non-electrical machinery manufacturing (category 35), chemicals and allied product manufacturing (28), business services (73), electrical and electronic equipment manufacturing (36) and instrument manufacturing (38). The addition of industry fixed effects has no substantive impact on the estimated elasticity, meaning that industry-level changes do not account for the increases in R&D spending we see in years when firms have higher effective R&D tax credit rates.

Column (6) tests the validity of using the two-year lag of R&D spending to construct the synthetic tax instrument. Serial correlation in the error term of Eq. (2) will lead to an inconsistent estimated elasticity. Weber (2014) suggests a diagnostic solution: use longer lagged variables to construct the synthetic, or predicted tax change, instrument to assess how problematic serial correlation may be. The potential for a serial correlation issue is reduced here by the use of two-year rather than one-year lags to construct the tax instrument. The specification reported in (6) adds an instrument constructed from the four-year lag in R&D spending. Although the estimated coefficient is slightly larger, −0.117 (0.016), it is statistically and economically indistinguishable from the baseline.[14]

If a firm does not qualify for an R&D tax credit, it likely will not file a Form 6765 and thus does not disclose the details of its research activities (though approximately 10% of firms that include form 6765 in their filing report zero R&D spending). Column (7) assesses the impact of selective reporting by limiting the sample to only those firms that report R&D spending in all years. The

[11] The years used are 1986, 1987, 1988, 1989 and 1990. Without a change in tax policy, there is no instrument since the synthetic and actual tax factor would be identical. Year without tax changes are dropped for identification. For a summary of the changes made to the R&D tax credit in these years, please see Table 1, and for further detail please see the Appendix. The introduction of the credit cannot be used as QRE data is not available in the pre-period

[12] The sample used in Table 3 through 9 exclude firms with very low sales (less than \$7 million or the bottom 10%). The excluded observations collectively account for less than one-tenth of 1% of the total qualified R&D conducted by sample firms. Including these low sales observations still yields significant coefficients and elasticities; for example, estimating the baseline specification of column (2) of Table 4 yields a coefficient of −0.204 (0.057) and a corresponding elasticity of −3.887 (1.076).

[13] In the corresponding first-stage regression, the predicted tax subsidy, that is the synthetic tax instrument, is a very strong predictor of the actual tax subsidy rate, with a first-stage F-stat of 1183.

[14] More directly using the Difference-in-Sargan test to assess the exogeneity of the synthetic tax instrument constructed from the two-year lag (relative to the instrument constructed using the four-year lag of R&D spending), the p-value of the Difference-in-Sargan test is 0.413, meaning that I cannot reject the exogeneity of the two-year lag instrument.

Table 4
User-cost elasticity of firm R&D intensity. [Dependent variable: Δ (qualified R&D / sales)]

	OLS	IV	IV	IV	IV	IV	IV	IV
	Full sample	Full sample	Spline	Trimmed	Industry FE	IV validity	Balanced	Dec. FY
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ User-cost	−0.039	−0.104	−0.109	−0.117	−0.105	−0.117	−0.082	−0.118
	(0.008)	(0.025)	(0.040)	(0.019)	(0.025)	(0.016)	(0.048)	(0.024)
User-cost elasticity	−0.777	−1.980	−2.084	−4.044	−1.998	−2.076	−1.175	−2.248
	(0.157)	(0.473)	(0.767)	(0.330)	(0.356)	(0.290)	(0.695)	(0.462)
Prob > F	–	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Observations	20,883	17,876	17,876	17,433	17,876	16,324	8555	9692
Firms	6338	5715	5715	5619	5715	5391	1711	3160

Notes: All regressions include year fixed effects. All data converted to real dollars using the GDP index. Column (1) presents OLS results while columns (2)–(8) instrument for the endogenous tax tax subsidy using predicted subsidy rates. Column (2) is the baseline IV estimate. Column (3) adds a 5-knot spline in the two-year lag of R&D spending. Column (4) drops the 3% most research intense firms. Column (5) adds industry fixed effects. Column (6) adds a synthetic tax instrument constructed from the four-year lag in R&D spending. Column (7) includes only firms that report in all years while column (8) restricts the sample to firms with December fiscal year ends. Standard errors clustered at the two-digit industry level according to SOI industry codes; these data span 68 industries.

sample of 8555 observations describing 1711 firms is substantially smaller, but the estimated elasticity, −1.175 (0.695) is statistically similar.

Firms end their fiscal years in all months of the year. Tax policy is largely tied to the calendar year, but it is possible that firms may choose to allocate research spending into different tax years to show certain increases or decreases in research spending in their financial reports. Column (8) reports results from an estimation that uses only firms with December fiscal year ends. Although the sample is roughly half the size of the baseline sample, the estimated elasticity, −2.248 (0.368), is statistically indistinguishable from the baseline and is economically similar.

Firms claiming an R&D tax credit must categorize their research expenditures into one of five categories of spending. Table 5 reports the impact of tax subsidies on the different types of qualified research spending.[15] All regressions are of the same specification as Eq. (2) but replace the ratio of total qualified R&D spending-to-sales on the left-hand side with the ratio of each category of spending to firm-wide sales. Wages comprise nearly two-thirds (66.5%) of all qualified research expenditures. Supplies make up the next largest share (19.0%). Contracted research, where a third party performs a qualified research service and is paid by the taxpayer firm regardless of the success, follows, accounting for 11.9% of total research spending. For tax credit purposes contract research payments are included at 65% of the actual expense. Payments to universities and other eligible nonprofit organizations for the conduct of basic research comprise roughly 3.8% of research expenditures in the single year they are reported. Rent comprises less than 1% of research spending.

Qualified spending broken down by category was unavailable for 1990, so the number of observations in Table 5 is only 13,759. Column (1) reports the effect of the tax subsidy on the ratio of total QREs to sales for this smaller sample. The coefficient estimate is very similar to those of Table 4, though the elasticity is somewhat larger due to lower average research intensities in this sample. As column (2) shows, spending on wages and salaries, which accounts for the majority of research spending, is very responsive to the tax subsidy. A 10% tax subsidy leads to a 35% increase in the wages-to-sales ratio, which averages 2.1% in the sample. Spending on supplies, which comprises less than 20% of R&D spending, responds similarly with an estimated elasticity of -2.91 (0.87) and is reported in column (3). Spending on R&D-related rent, which is a trivial component of qualified research expenditure, does not show a measurable response to the tax subsidy as shown by column (4). Though they account for much less spending, contracted research and university or non-profit based spending (columns (5)–(6)) both show similar, high, tax price responsiveness like wages and supplies .[16] Incentives to increase research spending, it appears, boost expenditures in proportion to existing spending ratios, other than the lack of response in the trivial rent component. Marginal research expenditures do not appear to have a markedly different mix of inputs than existing research. The research credit in effect mostly accrues to the wages and salaries of R&D employees.

The above analyses all examine the short-run impact of how changes in the user cost of R&D affect research spending. If there are adjustment costs or frictions associated with adjusting R&D spending, as has been shown by (Bernstein and Nadiri, 1986), (Hall et al., 1986) and (Hall, 1993a), there may be meaningful costs associated with changes in a firm's R&D spending. Such adjustment costs would lead firms to only partially adjust their R&D intensities in response to tax-driven changes in the user cost. To allow for partial R&D adjustment, I extend the static model of Eq. (2) by including the lagged dependent and independent variables:

$$\left[\frac{R_{it}}{S_{it}} - \frac{R_{it-1}}{S_{it-1}}\right] = \alpha + \gamma\left[\rho_{it} - \rho_{it-1}\right] + \lambda\left[\frac{R_{it-1}}{S_{it-1}} - \frac{R_{it-2}}{S_{it-2}}\right] + \eta\left[\rho_{it-1} - \rho_{it-2}\right] + \chi_t + \epsilon_{it} \quad (3)$$

The addition of the lagged variables to assess the dynamics of firm responses to research subsidies does, however, raise its own estimation issues. First, the lagged user cost is itself endogenous. Second, as demonstrated by Nickell (1981), because the lagged dependent variable is correlated with the unobserved firm fixed effect, in the first difference framework used here, the resulting "Nickell bias" will generally lead to a downward biased coefficient on the lagged dependent variable and inconsistent coefficient estimates. The general method of moments (GMM) difference estimator proposed by Arellano and Bond (1991) is used to address these issues with all available lags of the regressors beginning in $t-2$ and lags of the "synthetic" tax term serving as instruments. Robust standard errors are reported with the finite-sample correction proposed by Windmeijer (2005).

The long-run user cost elasticity is given by $(\gamma+\eta)/(1-\lambda)$. Table 6 presents estimates of Eq. (3) for the all firms, column (1), and subsamples of interest, columns (2)–(9). The additional data required for this specification reduces the sample to 14,595 observations. For this

[15] Beginning with Table 5 the results of the first-stage, that is Prob > F is no longer reported in the tables as in Table 4, all first-stage F-statistics are sufficiently large that Prob > F is nearly 0.

[16] 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.

Table 5
User-cost elasticity of qualified research components. [Dependent variable: Δ (component / sales)]

	Baseline	Wages & salaries	Supplies	Rent	Contracted	University
	(1)	(2)	(3)	(4)	(5)	(6)
Δ User-cost	−0.113	−0.084	−0.018	2.39E-04	−0.009	−0.001
	(0.019)	(0.015)	(0.005)	(1.44E−03)	(0.002)	(0.000)
User-cost elasticity	−3.387	−3.530	−2.911	1.000	−3.541	−2.605
	(0.555)	(0.611)	(0.867)	(6.041)	(0.737)	(0.989)
Observations	13,759	13,759	13,759	13,759	13,759	2777
Firms	5357	5357	5357	5357	5357	2777

Notes: All regressions include year fixed effects. All data converted to real dollars using the GDP index. Component data are not available for 1990; research conducted by universities and non-profits is only available until 1986. Standard errors clustered at the two-digit industry level according to SOI industry codes; these data span 68 industries.

sample, estimating the static model of Eq. (2) yields a slightly larger coefficient of −0.125 (0.021) that is not statistically dissimilar from the baseline estimate of column (2) of Table 3, −0.104 (0.025). In the dynamic model, the short-run coefficient is somewhat smaller than than the static model, −0.104 (0.008) rather than −0.125 (0.021), though the difference is not statistically significant. The coefficients on both lagged variables are statistically significant and suggest the firms only partially adjust their R&D spending in the short-run and make the full adjustment over time. The long-run elasticity, −1.937, is slightly smaller than the short-run elasticity, but is not meaningfully or statistically different than the short-run elasticity estimated in the static model.

Columns (2) and (3) compare the results for domestic and multi-national firms. Although domestic and multi-national firms respond similarly in the short-run, domestic firms continue to increase their R&D spending in long-run in reaction to the tax subsidy while multi-national firms do not exhibit a statistically discernible long-run response. Small and large firms, in terms of real total assets, are compared in columns (4) and (5). Small firms show a stronger short run response to the tax subsidy than large firms, but as the lagged coefficient, 0.047 (0.013), is positive, small firms appear to reverse their immediate increase in research spending in the longer run. Large firms, on the other hand, have a weaker immediate response but do not significantly add to or retreat in their R&D spending over time. The strong immediate response of smaller firms and their subsequent reversal suggests that the credit serves as an impetus, perhaps by providing much needed cash, for a burst of research spending that is not sustained over time. Taxable and non-taxable firms are compared in columns (6) and (7). Estimates from the dynamic model suggest that both taxable and non-taxable firms respond strongly in the short-run but taxable firms go on to ramp up their research spending in the future while nontaxable firms show no significant long-run response. This may be because non-taxable firms are generally more liquidity constrained and the tax credits may provide much needed financing for immediate R&D. Columns (8) and (9) describe young and older firms, respectively. Young firms are responsive immediately but pull-back on—in fact nearly wholly reverse—their increase in research spending in the long-run, offsetting initial research spending increases with subsequent matching spending reductions. Older firms, that is firms that have been incorporated for at least 10 years, have a larger contemporaneous coefficient than younger firms and do not go on to reduce their research spending in future years like younger firms do. Young and old firms likely differ along a host of margins. Liquidity constraints are more common for start-ups and other young firms and may be one of the drivers here, too. Young firms may also rely on external financing to a greater extent than older firms which may have enough cash on hand to finance R&D investments; if this is the case, then using a common interest rate in the user cost equation may not be appropriate.

Taken together the evidence on the long-run impact of the R&D tax credit suggests that while the average firm increases its research spending both immediately and in the longer run in response to the tax subsidy, some firms only react significantly in the short-run and others—low asset firms and young firms—actually reverse their initial increases with reduced future research spending. That is, while the average firm may face adjustment frictions in altering its research spending, for young and small firms that later reverse subsidy-related spending increases, the credit may particularly affect the timing of spending.

The final table draws on the combination of Compustat and IRS SOI data to both understand the added-value of the restricted-access IRS data and assess whether qualified R&D, captured by the IRS SOI data, responds differently than total R&D spending, which is described by the Compustat data. Only a small subset of firms are found in both the Compustat and IRS SOI data and report enough data to construct the synthetic tax price instrument used in the estimation procedure. The merged sample is small because the IRS dataset is a panel sample that describes mostly private firms, meaning only

Table 6
Long-run user-cost elasticity of firm R&D intensity. [Dependent variable: Δ (qualified R&D / sales)]

	Baseline	Domestic	Multi-nat.	1st quint	5th quint.	Taxable	Non-tax.	<10 years	≥10 years
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Δ User-cost	−0.104	−0.094	−0.089	−0.124	−0.057	−0.128	−0.101	−0.053	−0.104
	(0.008)	(0.012)	(0.009)	(0.015)	(0.009)	(0.044)	(0.032)	(0.032)	(0.018)
Δ User-cost$_{t-1}$	−0.031	−0.025	0.004	0.047	0.009	−0.057	0.020	0.051	−0.046
	(0.006)	(0.009)	(0.008)	(0.013)	(0.006)	(0.035)	(0.016)	(0.023)	(0.029)
Δ (Qualified R&D / sales)$_{t-1}$	−0.491	−0.491	−0.215	0.015	−1.18E−04	−0.498	−0.118	−0.127	−0.497
	(0.009)	(0.008)	(0.067)	(0.052)	8.35E−05	(0.001)	(0.015)	(0.027)	(0.001)
Observations	14,595	11,269	3326	2904	2861	9575	5020	2606	11,989
Firms	4969	4170	1389	1160	1148	3708	2416	1204	4095

Notes: All regressions include year fixed effects. The GMM difference estimator proposed by Arellano and Bond (1991) using all available lags starting with $t-2$ is used to correct the bias related to inclusion of the lagged dependent variable in addition to the tax change-based instrument used in previous static regressions. All data are converted to real dollars using the GDP index. The results above come from estimating Eq. (3), which includes the lagged dependent and independent variables. The estimation uses the full sample in column (1) and notable sub-samples in columns (2)–(9). The robust standard errors reported in parentheses are calculated with the finite-sample correction of Windmeijer (2005).

a limited number of the public firms tracked by Compustat data are found in the IRS SOI sample. This small subset of firms, however, accounts for nearly a third of the aggregate qualified R&D conducted by firms in the IRS sample.

Because the R&D tax credit is based on how a firm's qualified spending evolves over time, mis-measurement of a firm's qualified research spending can lead to substantial mis-measurement of the marginal subsidy. As the previously discussed Table 2 details, the IRS and Compustat data yield very different values for the subsidy rate firms face on their marginal R&D spending with even the share of firms facing negative marginal credit rates prior to 1990 differing substantially. Columns (1) through (4) of Table 7 examine whether relying on the Compustat-based measure of the tax component of the user cost has a meaningful impact on the the estimated elasticity; that is, columns (1) through (4) assess the importance of the restricted-access IRS data in estimating the tax price elasticity of R&D expenditures. Columns (1) and (2) use the ratio of qualified R&D from the IRS data to sales as the dependent variable while columns (3) and (4) employ the ratio of total R&D from the Compustat data to sales on the left-hand side of the regression equation. User costs are constructed using the Compustat data in columns (1) and (3); in columns (2) and (4) the user cost is constructed using the more accurate IRS data instead. All specifications use the synthetic tax variable to instrument for the endogenous tax subsidy. Column (1) shows that the using the Compustat data to construct the user cost creates enough measurement error that the relationship between changes in the subsidy and changes in qualified R&D spending is not statistically discernible. In column (2) on the other hand, where the user cost is constructed using the IRS data, we see a strong impact of the subsidy on qualified research spending; the estimated response is statistically similar to the main results of Table 4. Column (3) shows that using the Compustat data to measure research intensities and the user cost also yields statistically insignificant results. On the other hand, column (4) shows that changes in the accurately measured user cost are negatively related changes in total research intensity, though the coefficient and elasticity are substantively smaller than the results of column (2) which examines the impact on qualified R&D. Taken together columns (1) through (4) show that using Compustat data to measure the subsidy rate of the R&D tax credit leads to enough mis-measurement that the resulting estimates are not statistically meaningful. They suggest that the qualified share of total R&D is not stable enough that comparing current total R&D spending to each firm's base amount, calculated using total rather than qualified research spending, yields an unreliable measure of the firm's marginal subsidy rate.

The estimates of columns (1) and (3) do not match the results of prior studies using the Compustat data, many of which estimate statistically significant negative coefficients. The discrepancy is likely due first to the use here of a new, arguably more exogenous instrument based on tax changes (as opposed to simply lagged user costs); and second due to the much smaller sample of firms. Though these firms undertake a significant fraction of aggregate R&D, they only comprise 203 observations.

This small merged sample also affords us the opportunity to assess how the qualified share of total research spending—the ratio of the IRS measure of R&D to the Compustat measure of R&D—responds to the tax subsidy. The Compustat total R&D spending variable encompasses research that qualifies for the R&D tax credit as well as research spending that does not qualify because it fails to meet the experimental and technological criteria of the credit or because it is conducted abroad. Qualified spending comprises roughly 37% of total research spending. The last three columns of Table 7 examine how the qualified share of total R&D spending responds to tax-driven reductions in the user cost (measured with the accurate IRS data). The estimation equation mirrors Eq. (2) with the dependent variable replaced by the ratio of qualified to total research spending. If firms simply increase in their research budgets but do not change their mixes of qualified and non-qualified research activities, the increases in qualified spending seen in Table 4 through Table 6 should be mirrored by proportional increases in non-qualified spending such that the qualified to total R&D ratio stays unchanged. Column (1) shows that in fact qualified research share is very sensitive to the tax subsidy; increases in the R&D tax credit's marginal subsidy rate strongly shift research spending towards activities that qualify for the federal tax credit.

Part of the research spending that does not qualify for the credit is R&D conducted outside of the U.S. Columns (6) and (7) investigate whether the elasticity seen in column (5) is driven by the actions of multinational corporations, which are more likely to have research facilities abroad from which they can shift research spending to the United States and vice versa. If multinational firms are driving the elasticity seen in column (5) we would expect that only multinational firms would show this type of elasticity. The results of columns (6) and (7) show that while both domestic and multinational firms increase their qualified shares when the research subsidy increases, it is domestic firms that are the more sensitive group. In other words, there is no evidence that the shift towards qualified spending that follows increases in the R&D tax credit is driven by firms with operations abroad either physically repatriating or re-labelling foreign R&D.

Table 7
User cost elasticity of qualified and total research spending, merged sample of Compustat and IRS SOI data. [Dependent variables: Δ(qualified R&D / sales), Δ(total R&D / sales) and qualified share]

	Qualified		Total		Qualified share		
	All	All	All	All	All	Domestic	MNC
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Δ User-cost (Compustat)	−0.397		0.220				
	(1.507)		(0.746)				
Δ User-cost (IRS)		−0.172		−0.025	−4.844	−5.323	−2.261
		(0.064)		(0.008)	(1.284)	(1.350)	(0.526)
User-cost elasticity	−10.849	−4.549	5.015	−0.552	−11.728	−14.691	−4.757
	(41.157)	1.687	(17.014)	0.170	(3.109)	(3.727)	(1.106)
Observations	203	203	203	203	227	123	104
Firms	66	66	66	66	76	50	36

Notes: All regressions include a constant and year fixed effects. All data converted to real dollars using the GDP index. 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 construct the instrument. The user costs for columns 2, 4 and 5 thorugh 7 are constructed using the accurate IRS SOI data. The user costs for columns 1 and 3 were constructed using Compustat data. For columns 1 and 2 the research intensity variable is constructed from IRS SOI data that only describe qualified research spending. For Columns 3 and 4 the research intensity variable is constructed using Compustat data from financial filings that describe total R&D, that is qualified and non-qualified R&D. For Columns 5 through 7 the dependent variable is the ratio of qualified (IRS SOI) R&D to total (Compustat) R&D. Standard errors are clustered at the two-digit industry level according to SOI industry codes; these data span 68 industries.

The difference between the elasticities estimated in columns (2) and (4) as well as the responsiveness of the qualified share of R&D spending shows that qualified research is more responsive to the tax subsidy than total R&D. In a sense these results suggest that when the federal government decides what types of research to subsidize, it gets just that. The credit drives spending in qualified categories, suggesting that how the government defines 'qualified spending' may be an important margin on which policy affects firm behavior. It is important to note that the merged sample is small; because the merged sample is so small, the pattern of these estimates is better taken as suggestive rather than definitive. The pattern does show, however, that firms appear to respond to tax subsidies for R&D by increasing their spending that qualifies for the credit much more than R&D spending overall.

5. Conclusions and policy implications

This paper uses new restricted-access data from corporate 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 a firm's research intensity—the ratio of R&D expenditures to sales—responds to changes in the user cost of R&D. Estimates imply that a 10% reduction in the user cost of R&D leads the average firm to increase its research intensity—the ratio of R&D spending to sales—by 19.8% in the short-run. Analysis of subsamples suggests that these results are broadly robust. Long-run estimates imply that while the average firm faces adjustment costs and adds to its initial response with further increases in spending over the longer-run, estimates do not suggest that long-run responses exceed estimates from static regressions.

Analysis of the components of qualified research shows that wages and supplies account for the bulk of the increase in research spending. Evidence from dynamic panel estimates suggests that while the average firm reacts initially to the tax incentive and continues to increase research spending in the future, small and young firms may actually reverse their initial increases in R&D spending over time. Analysis drawing on both the restricted-access IRS SOI data,which tracks research expenditures that qualify for the federal R&D tax credit and is used in the bulk of the empirical estimates, and public Compustat data, which reports total research expenditures, shows that the IRS qualified research data are crucial for accurately measuring marginal subsidy rates and key to identifying the impact of the R&D tax credit on research spending. Elasticities of qualified and total (qualified and non-qualified) research intensities from a smaller sample suggest that firms respond to changes in the user cost largely by increasing their qualified spending, meaning that what R&D the federal credit deems qualified research is an important margin on which the credit affects firm behavior.

As the research credit until recently has only ever been temporarily extended, its provisions have been frequently considered by policymakers. In 2015, legislation made permanent both the traditional credit as well as the Alternative Simplified Credit (ASC), a research tax credit firms can permanently opt for in lieu of the traditional research credit assessed here, at budgetary cost of $113.245 billion over the 2016–2025 window (Joint Commitee on Taxation, 2015). The ASC was introduced in 2007 for firms that struggle to qualify for the tradition R&D tax credit despite the traditional credit's start-up provisions. These firms either cannot adequately substantiate historical QREs for the traditional calculation methods, or generate fixed-base-percentages that significantly limit the credit. Currently the ASC provides a credit equal to 14% of current year qualified research expenses that exceed 50% of the average qualified research expenses for the three preceding taxable years. Both executive branch and Congressional proposals have suggested raising the ASC credit rate, for example to as high as 18%, while eliminating the traditional credit. The credit calculations presented here suggest that enhancing the ASC would leave more firms with negative credit rates in some years as the claw-back provision would mute incentives for marginal R&D spending. Furthermore, recent analysis by the Government Accountability Office (Office, 2009) found that the ASC provides windfalls to some firms but reduces incentives for new research. Given the high and robust user cost elasticities estimated here, any policy shift that would lead to lower credit rates could substantially reduce corporate research spending. Redirecting tax expenditures away from the traditional credit and toward the ASC should be considered carefully.

The empirical findings reported here suggest that research intensities are elastic in both the short- and long-run but there are important considerations regarding broader interpretations. First, the analysis here uses changes in the provisions of the research credit during the 1980s to identify the user cost elasticity; research patterns from up to 35 years ago may not represent current R&D patterns in terms of shares of spending by firms in different industries, of different sizes, of different domiciles, etc. Second, throughout the analysis firms' expectations of the future R&D tax credit are ignored. During its first decade the research credit was always renewed before it expired. Later the credit was allowed to lapse several times, most of the time being put into place retroactively, but on one occasion in 1995 the credit was simply allowed to expire for a year. Even though the credit has now been made permanent, any differences in uncertainty regarding the future marginal credit rate or the types of expenses deemed qualified between today and the 1980s render the estimates reported here less applicable. Future research that assesses how policy certainty affects research credit responses would be useful to policymakers as they decide whether their longer-term commitment to the research credit was worth the budgetary cost.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jpubeco.2016.05.003.

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