Tax Policy Endogeneity: Evidence from R&D Tax Credits

Andrew C. Chang*

September 3, 2017

Abstract

This paper estimates the causal effect of research and development (R&D) tax incentives on R&D expenditures using new data on U.S. states. Identifying tax variation comes from changes in federal corporate tax laws that heterogeneously and, due to the simultaneity of state and federal corporate taxes, automatically affect state-level tax laws. Instrumental variables (IV) regressions indicate that a 1% increase in R&D tax incentives causes a statistically significant 2.8-3.8% increase in R&D. Alternatively, ordinary least squares (OLS) regressions of R&D expenditures on R&D tax incentives, which do not correct for the policy endogeneity of R&D tax incentives, indicate that a 1% increase in R&D tax incentives causes a statistically insignificant 0.4-0.7% increase in R&D. One possible explanation for these results is that tax policies are implemented before an economic downturn.

Keywords: Corporate Tax; Fiscal Policy; R&D Price Elasticity; Tax Credits; Policy Endogeneity

JEL Codes: H20; H25; H32; H71; K34; O38

*Senior Economist, Division of Research and Statistics, Board of Governors of the Federal Reserve System. 20th St. NW and Constitution Ave., Washington DC 20551 USA. +1 (657) 464-3286. a.christopher.chang@gmail.com. https://sites.google.com/site/andrewchristopherchang/. This research was supported by a grant from the Department of Economics at the University of California - Irvine. However, the views expressed in this paper are mine and are not necessarily those of the university or the Board of Governors of the Federal Reserve System. I thank anonymous referees, Ryan Baranowski, Marianne P. Bitler, David Brownstone, Christopher S. Carpenter, Linda R. Cohen, Kenneth A. Couch, Theodore F. Figinski, Christopher Karlsten, Bree J. Lang, Sarah B. Lawsky, David Licata, David Neumark, George C. Saicoc, Manisha Shah, and seminar participants at the All California Labor Conference, APPAM, Bates White, Cal Poly - SLO, CFPB, CLEA, DOJ, FDIC, FRB, Georgia Tech, HKU, NTAs, NTU, Oregon State, RAND, RPI, UB, UBC, UC - Irvine, and WEAI for valuable comments. I also thank Amanda G. Bauer and Anthony Marcozzi for valuable research assistance, Ellen Augustiniak and Jenny Chang for aid in interpreting tax laws, Jonah B. Gelbach and Jennifer Graves for assistance with bootstrapping, Daniel J. Wilson for information on tax data, and Nirmala Kannankutty and Raymond Wolfe for support with National Science Foundation data. I am responsible for any errors.
1 Introduction

A standard fiscal incentive to promote innovation is a research and development (R&D) tax incentive. These tax incentives are justified by a market failures argument. R&D is a public good with positive spillovers where firms cannot appropriate all of the benefits for R&D, so there is room for the government to intervene to improve on the free market outcome (Arrow, 1962; Griliches, 1992). However, a necessary condition to evaluate whether the tax incentives are an efficient use of resources is to see whether they actually boost R&D.

This paper estimates the causal effect of R&D tax incentives on R&D expenditures. I use the setting of U.S. states and their R&D tax incentives because of a plausibly exogenous source of variation in state-level R&D tax incentives: variation caused by changes in federal corporate tax laws. The rationale for using this variation is that state policymakers give special attention to their own state’s economic conditions when tailoring their state-level tax policies, which makes changes in state tax policies endogenous to state-level economic conditions. However, the federal government both: (1) pays less attention to individual state-level conditions when it forms uniform federal tax policies, and (2) causes automatic, heterogeneous between-state changes in state-level tax laws without state policymaker intervention, due to the linking of state and federal tax law. To mitigate policy endogeneity concerns and generate consistent estimates, this paper uses the key identification assumption that changes in state-level R&D tax incentives caused by changes in federal corporate tax laws are uncorrelated with state-level factors that would otherwise affect state-level corporate tax policy and R&D.

I use instrumental variables (IV) regressions of state-level R&D expenditures on state-level R&D tax incentives and instrument the tax incentives using the portion of state-level tax variation caused by changes in federal tax laws. My preferred estimates assert that a 1% increase R&D tax incentives causes a statistically significant 2.8-3.8% increase in R&D.

My IV estimates are large relative to most of the previous literature on R&D tax incentives. For example, Hall and Van Reenen (2000), Table 2, reviews studies of U.S. data and suggests that existing research finds an average elasticity of 1.0, although one subsequent study on U.S. data by
Rao (2016) finds larger effects.¹

To be comparable with previous studies, this paper also estimates ordinary least squares (OLS) regressions of state-level R&D expenditures on state-level R&D tax incentives. These OLS models should give inconsistent estimates because states choose their tax incentives, which makes the uninstrumented state-level R&D tax incentive regressor endogenous. My OLS models give estimates in the range of [0.4, 0.7], which are estimates that are both consistent with most of the previous literature and are statistically significantly different from my IV models. A comparison of my IV vs. OLS estimates suggests serious bias toward finding that tax incentives are ineffective when ignoring the endogenous determination of tax policies.

Why are my IV estimates greater than my OLS estimates? One possible economic explanation for the attenuation of the OLS estimates, although not the only possible explanation, is that tax incentives offset future economic downturns either because policymakers have foresight about downturns or because of fortunate timing of the taxes.

For example, suppose that tax incentives affect the economy and that, in terms of timing, tax incentives change just prior to when a downturn would occur without the tax incentives. This timing of tax incentives could be with or without government foresight of the impending downturn. Such a downturn could be a general economic downturn caused by business cycle fluctuations or a large firm that is planning on halting operations to relocate to a different geographic region. If lawmakers offer tax incentives just prior to when a downturn would occur and the true effect was that the tax incentives prevented the downturn, then econometricians would observe no effect of the tax incentives when the true effect was positive. In this case, the bias in an OLS regression model would be toward finding no effect.²

This paper has two main contributions to the tax and innovation economics literatures.

¹For non-U.S. data, work by Bloom, Griffith, and Van Reenen (2002); Falk (2006); Lokshin and Mohnen (2012); Crespi, Giuliodori, Giuliodori, and Rodriguez (2016) and Thomson (Forthcoming), among others, also find relatively inelastic estimates, while several studies on U.K. data by Fowkes, Sousa, and Duncan (2015); Guceri and Liu (2015); Dechezleprêtre, Einiö, Martin, Nguyen, and Van Reenen (2016) find larger effects. See also Cerulli (2010); Zúñiga-Vicente, Alonso-Borrego, Forcadell, and Galán (2014) for a more recent reviews.

²An example of this type of preemptive tax incentive behavior is from December 2016, when then U.S. President-elect Trump and then U.S. Vice President-elect Pence offered Carrier tax incentives to prevent Carrier from moving some of its operations from the U.S. to Mexico.
The first contribution is a new, hand-collected dataset on state-level corporate tax structures and R&D tax incentives. I estimate effective state-level R&D tax incentives directly from the text of the state tax laws themselves - a primary data source. My dataset has two advantages over existing corporate tax datasets used in economics: (1) the tax laws, as a primary source, provide a more reliable record than any secondary source, such as CCH’s State Tax Handbook, and (2) the tax laws document structural tax parameters often omitted in secondary sources, such as the ability for firms to deduct federal income taxes paid from their state taxes. Because of these two features, my dataset could be useful in other studies of state-level corporate tax systems.3

The second contribution of this paper is a clean estimate of the causal effect of R&D tax incentives on R&D expenditures. This estimate will help inform future policy discussions on taxes and incentives to increase innovation. Evaluating whether these tax policies boost R&D is a necessary, although not sufficient, condition to determine whether these tax policies are an efficient use of government resources.

2 Data and Estimation

To quantify the effect of R&D tax incentives on R&D expenditures, I estimate the following model:

\[
\ln(RD_{it}) = \pi \ln(RD_{it-1}) + \phi_i + \lambda_t + \gamma \ln(RDTaxIncentiveRate_{it}) + \ln(X'_{it}) \beta + \epsilon_{it}
\]  

(1)

where subscript \(i\) represents a state, subscript \(t\) is time, \(\ln()\) is the natural log operator, state fixed-effects are \(\phi\), time dummies are \(\lambda\), and \(X\) is a matrix of controls. The key regressor, \(RDTaxIncentiveRate\), is the proportion of R&D that the government pays for through tax incentives.4

The main source of data for constructing state-level R&D tax incentive rates is the volumes

---

3To maximize the public benefit of these data, I will make my data and code freely available upon publication acceptance of this article, whether or not the journal that accepts this paper requires authors to share their data and code, following the recommendations of Chang and Li (2015, 2017). My data and code will also allow other researchers to verify my results, which will boost this paper’s scientific integrity and contribution.

4This model is analogous to the panel data models of Bloom, Griffith, and Van Reenen (2002); Wilson (2009).
of laws that each state legislature passes in a given year, called state session laws. Session laws are printed individually by each state and are accessible digitally through HeinOnline, a paid-subscription service. The political science literature has used state session laws as a source of data, but to my knowledge this paper is the first in economics to use session laws.

Session laws are a primary data source, not a secondary data source, so the session laws offer a complete, unadulterated record of a state’s tax laws. I hand-code key tax parameters from state session laws and use a model that captures the simultaneity of state and federal taxes, described in Appendix A, to calculate effective state-level R&D tax incentive rates. To mitigate potential hand-coding errors, when available I cross-check the session laws against Lexis Nexus’s annotated state statutes, which are also a primary source, and against a variety of secondary sources: Commerce Clearing House’s (CCH’s) U.S. Master Multistate Corporate Tax Guide (various years), CCH’s IntelliConnect, CCH’s State Tax Handbook (various years), state-level corporate tax forms, and data from Wilson (2009). Because of the detailed nature of the session law data, I am able to construct a more accurate measure of \( RDTaxIncentiveRate \) than used by existing studies.

The dependent variable, \( RD \), is state-year company-financed R&D expenditures from 1981-2006. This variable excludes federally-financed R&D, income taxes, and interest on tax. These data come from the Survey of Industrial Research and Development (SIRD), sponsored by the National Science Foundation (NSF). These data are biennial (odd year) observations of company-financed R&D up to 1997 and annual observations from 1997-2006. I focus on spending for three reasons: 1) a tax incentive’s first-order effect is on spending, 2) other measures of innovative output are noisy, and 3) identification of the causal effect of tax incentives on innovative output is even more problematic given the lags in innovation.

The NSF censors observations when the disclosure of a state’s R&D in a particular year would

\( ^5 \)R&D data are available since 1963, but I focus on the period since the introduction of the federal R&D tax credit, following previous studies of state R&D tax incentives (Paff, 2005; Wu, 2005; Wilson, 2009). The introduction of the federal R&D tax credit in 1981 created strong incentives for firms to relabel expenditures as R&D and creates a potential measurement break between the pre-credit era and the post-credit era (Eisner, Albert, and Sullivan, 1986; Hall and Van Reenen, 2000). While subsequent revisions to the tax code that increased the generosity of the federal R&D tax credit could have strengthened the relabeling incentive, starting in 1981 firms already had the incentive to relabel their expenditures as R&D.
reveal information about an individual firm’s R&D. This censoring tends to eliminate observations from low-R&D states and states where R&D is concentrated among a few firms. Therefore, I analyze the 21 high-R&D states where I observe R&D expenditures consistently in the 1980s and 1990s. Observing states in the 1980s and 1990s is necessary because federal R&D tax incentive laws were passed in the 1980s and 1990s.6

Because I observe states on a yearly basis, the controls capture state-level factors that could affect R&D. As R&D is procyclical, the model incorporates gross state product (GSP) from the Bureau of Economic Analysis (BEA) and the unemployment rate from the Bureau of Labor Statistics as proxies for business cycle effects.7 Federal funding for R&D can either complement or substitute for company-financed R&D. For example, if a firm receives a federal R&D contract, then it may undertake complementary R&D investments to help fulfill the contract. Conversely, firms may simply substitute the acquired public funds for private funds.8 I control for federal funding with federally-financed R&D expenditures from the NSF’s SIRD and data on federal obligations for R&D from the NSF’s WebCASPAR database.9 To control for other unobserved factors that could influence innovative activity, the model uses state expenditures on academic R&D. Data on academic R&D expenditures come from the NSF’s WebCASPAR database. I convert all variables from nominal to real values with the BEA’s gross domestic product deflator.10

I estimate specifications both with and without the lagged dependent variable. To incorporate this lag, I impose a biennial structure over the entire sample period and use the first available lag

6For the period from 2000-2006 the NSF provides imputed observations of R&D for states that are not in the data for the 1980s and 1990s. For this paper, I cannot use the states that appear in the sample after 2000 because the variation I use for identification is in the 1980s and 1990s. The 21 states in my sample are: Alabama, Arizona, California, Colorado, Connecticut, Florida, Illinois, Indiana, Maryland, Massachusetts, Michigan, Minnesota, New Jersey, New York, North Carolina, Ohio, Oregon, Pennsylvania, Texas, Virginia, and Wisconsin. This sample of high-R&D states makes up 80-90% of R&D after 2000.

7See Barlevy (2007), Ouyang (2011), or Chang (2013) for research into macroeconomic determinants of R&D.

8There is a large literature debating whether public funds complement or substitute for private funds. See David, Hall, and Toole (2000) for a review.

9See the review in Brown, Plewes, and Gerstein (2005) for details on the differences between these two sources of data. The results report estimates using obligation data to maximize the sample size. The results are insensitive to both measurements of federal R&D expenditures.

10The raw data for most of the variables are non-stationary. However, the time dummies and state fixed effects detrend all of the variables (Cameron and Trivedi, 2005). Panel unit root tests (Said and Dickey, 1984; Levin, Lin, and Chu, 2002) on the detrended variables support stationarity for all variables except GSP, and GSP has no effect on the main results.
of R&D \((t - 2)\). Imposing a biennial structure on the data drops observations when R&D data are available on an annual basis, but it has no effect on the results.

The OLS estimator applied to equation (1), assuming exogeneity in \(RDTaxIncentiveRate\) and the controls \(X\), is consistent for a large time dimension. However, for a small time dimension the coefficient on the lagged dependent variable estimated by OLS is biased downward (Nickell, 1981). For the panel in this paper, I have data with a time dimension similar to Bloom, Griffith, and Van Reenen (2002); Wilson (2009) of between 12-19 observations, which should reduce the Nickell (1981) bias.\(^{11}\)

### 3 R&D Tax Incentive Rates

This section describes the calculation of state-level R&D tax incentive rates and shows pre-treatment plots that support this paper’s identification strategy.

Because of the deductibility of R&D expenditures and R&D tax credits, a firm’s marginal dollar of R&D reduces the firm’s tax liability.\(^{12}\) The decrease in tax liability from a marginal dollar of R&D is the government’s R&D tax incentive rate.

Let \(FT\) denote federal taxes, \(ST\) denote state taxes, \(RD_{\text{tot}}\) be total R&D expenditures, and \(r\) be the discount rate. I model the R&D tax incentive rate for the representative firm, \(^{13}\) \(RDTaxIncentiveRate\), as:

\[
RDTaxIncentiveRate_{it} = -\left(\frac{\partial (ST_{it} + FT_{it})}{\partial RD_{ \text{tot}it}^{\text{tot}}} + \sum_{m=1}^{M} \frac{1}{\prod_{s=1}^{m} (1 + r_{t+s-1})} \frac{\partial (ST_{it+m} + FT_{it+m})}{\partial RD_{\text{tot}it}^{\text{tot}}}\right) \tag{2}
\]

\(^{11}\)As a robustness check, I also attempt to correct for potential Nickell bias with both the one-step and two-step Blundell and Bond (1998) generalized method of moments (GMM) estimators, transforming the instrumenting equation using the orthogonal deviations transformation (Arellano and Bover, 1995) to maximize the sample size, and I also perform the three bias-corrections of the bias-corrected least squares (LSDVC) estimators of Bruno (2005a,b). Unfortunately, both the Blundell and Bond (1998) and Bruno (2005a,b) LSDVC estimators generate imprecise estimates.

\(^{12}\)Firms above their minimum taxable income amount can reduce their tax liability by increasing R&D because R&D is fully deductible.

\(^{13}\)I model the representative firm because the NSF’s R&D data are at the state level.
which is the reduction in taxes at time $t$ for state $i$ due to R&D at time $t$, plus the discounted changes in taxes for future periods.\footnote{Taking into account the discounted sum of future changes in taxes is necessary because R&D tax credits are occasionally calculated as a credit amount over an $M$-year moving-average base of previous R&D expenditures. This calculation implies that taking R&D tax credits in period $t$ can affect the ability of a firm to take a credit in future periods. The model takes into account future changes in taxes only when they would be affected by a moving-average base, which is at most four years into the future.} I set the discount rate as the dividend-to-price ratio of the S&P 500 plus its long-term growth rate of 2.4%, following Chirinko, Fazzari, and Meyer (1999);\footnote{The theoretical rationale behind discounting future periods with the S&P 500 is the opportunity cost of a firm’s funds. A firm deciding to undertake R&D could instead fund some outside investment, with the S&P being a representative indicator of the available market rate of return.} Wilson (2009) with data from Shiller (2005).\footnote{Equation (2) discounts changes in the tax liability of future periods using the actual realized interest rate. The assumption behind this formulation is firms correctly anticipate the interest rate with certainty and follows Wilson (2009). As a robustness check, I also discount future periods by assuming that firms in period $t$ use the interest rate from period $t-1$ to form future expectations of the interest rate. This alternative formulation gives similar results.}A key feature of \textit{RDTaxIncentiveRate} is that I use only assumptions that are either the same as or weaker than existing studies. Appendix A describes the computation and the assumptions in detail.

Equation (2) incorporates tax variation from both state and federal tax laws.\footnote{At the end of my sample in 2006, the average effective state R&D tax incentive is worth about one-half of the federal R&D tax incentive. Therefore, firms have a strong incentive to take into account state-level R&D tax incentives.} The variation in equation (2) from state tax laws is likely endogenous to R&D expenditures at the state level, as states set their R&D tax incentives as a function of unobserved state economic or political conditions. For example, if a firm threatens the state legislature that it will close down its operations and move to a different state, then the threat of relocation by the firm may cause the legislature to pass a tax incentive policy that benefits the firm.

A large body of research from economists and political scientists finds that observed state characteristics influence tax policy changes: tax policies are not randomly changed. These state characteristics range from business cycle measures, such as the unemployment rate, to political variables, such as balanced budget rules.\footnote{Examples of studies that research how state characteristics affect taxes include Berry and Berry (1992, 1994) for electoral cycles, Stratmann (1992, 1995) for strategic coalitions among politicians, Poterba (1994) for balanced budget rules, Crain and Muris (1995); Gilligan and Matsusaka (2001) for legislative structure, Swank and Steinmo (2002) for unemployment and capital mobility, and Aidt and Jensen (2009) for fiscal spending pressure and tax collection costs.}
Specific to R&D tax incentives, Miller and Richard (2010) find, using Cox hazard models, that a state’s initial adoption of a R&D tax credit is correlated with its observed unemployment rate. In addition, Kim (2010) argues the generosity of state-level R&D tax incentives may be affected by politicians’ concerns over revenue loss.

Of course, if observable characteristics were all that drive tax policy changes, then a model could control for these observables. The concern is that unobservable variables influence tax policies. A direct test for unobservable characteristics that affect tax policies is impossible.\textsuperscript{20} However, an abundance of anecdotal evidence documents that state lawmakers respond to state economic conditions when formulating tax policies. Many of these conditions are probably unobservable to econometricians. For example, Arizona Senator Barbara Leff, one of the sponsors of a bill to increase Arizona’s R&D tax credit, wrote, “We should be the leader in manufacturing, research and development and headquarters but we are not. These jobs are going elsewhere because Arizona does not have specific incentives in place to attract these companies” (Leff, 2009). Similarly, when California was plagued with high unemployment in 1993, California Governor Pete Wilson made job creation the center of his political platform. In the governor’s 1993 State of the State address, he asserted, “If we are to create jobs, we have to cut taxes... I ask this new legislature to create new jobs. To put Californians back to work by enacting tax incentives and other changes to create jobs... I ask you to invest in the jobs of the future by enhancing the tax credit for research and development of new technologies, and I ask you to make it permanent.”

In addition to explicit economic conditions, passing bills through informal political coalitions is another unobserved variable that affects the passage of tax policies.\textsuperscript{21} For example, a lawmaker may vote to pass a R&D tax credit tax bill for high-tech companies with the sole purpose of securing another vote for a bill on highway construction. To the extent that firms take into account the state’s provision of public goods when making their R&D decisions, this unobserved coalition would be correlated with both R&D expenditures and R&D tax policies, biasing regression\textsuperscript{20}\textsuperscript{21}

\textsuperscript{20}By extension, trying to infer policy endogeneity based on correlations between observable variables and the policy is not a meaningful exercise.
\textsuperscript{21}This practice is also called logrolling.
estimates. Furthermore, these coalitions between politicians are commonplace (Tullock, 1959).

To get a measure of $RDTaxIncentiveRate$ that is free from the bias that arises because states choose their own R&D tax incentives, I isolate the variation in equation $RDTaxIncentiveRate$ from only federal laws. Table 1 lists the laws this paper uses for federally-driven variation in state-level R&D tax incentive rates. This variation should be exogenous to unobserved state-level conditions that affect state-level R&D and state-level policies. State governments can tailor tax policies to respond to their own idiosyncratic state economic conditions. However, the federal government sets uniform national R&D tax policies and is less attentive to idiosyncratic state conditions.

Let $\Delta RDTaxIncentiveRate^{fed}$ be changes in the R&D tax incentive rate driven by federal laws. The expression for $\Delta RDTaxIncentiveRate^{fed}$ is as follows:

$$\Delta RDTaxIncentiveRate^{fed}_{it} = RDTaxIncentiveRate(ST_{it-1}, FT_{it}) - RDTaxIncentiveRate(ST_{it-1}, FT_{it-1})$$

(3)

which is the change in the R&D tax incentive rate from a given change in federal tax laws holding state tax laws fixed. This strategy of isolating only the exogenous variation in R&D tax incentives is analogous to the Gruber and Saez (2002) method of constructing exogenous personal income tax rates.\footnote{Gruber and Saez (2002) isolate exogenous changes in personal income tax rates arising from variation in tax laws at time $t$ by conditioning on the previous period’s income. Their exogenous changes in personal income tax rates reflect policy decisions at a higher level (federal government) than the unit of observation (individual). I take the analogous approach and create exogenous R&D tax incentives from variation in federal tax laws at time $t$ by conditioning on the previous period’s state tax laws. My exogenous changes also reflect law changes at a higher level (country) than the unit of observation (state). The general identification strategy of using federal laws for policy variation across states has been used in other ways, such as analyzing minimum wages (Card, 1992).} The R&D tax incentive rate at time $t$ from only federal laws is the sum of all previous changes in R&D tax incentives caused by federal tax laws:

$$RDTaxIncentiveRate^{fed}_{it} = \sum_{n=1}^{t} \Delta RDTaxIncentiveRate^{fed}_{in} + RDTaxIncentiveRate^{fed}_{i0}$$

(4)

There are several paths through which changes in federal tax law cause automatic changes in
state-level R&D tax incentives. For example, states offer R&D tax credits computed with the same method as the federal R&D tax credit and have this computation method linked directly to the federal R&D tax credit. This linking feature is known as piggybacking.

For example, Oregon Revised Statues § 317.152, which authorizes a R&D tax credit for Oregon research expenses, states “A credit against taxes otherwise due under this chapter shall be allowed to eligible taxpayers for increases in qualified research expenses... the credit shall be determined in accordance with section 41 of the Internal Revenue Code.” This feature implies any change in section 41 of the Internal Revenue Code, which is the federal R&D tax credit, automatically updates how Oregon and other piggybacking states calculate their R&D tax credits: changes in federal tax law cause changes in effective state tax law and state policymakers do not dictate these changes. Therefore, these changes in federal tax law cause plausibly exogenous changes to state-level tax law. Appendix C gives an extensive conversation of other routes through which changes in federal tax law cause changes in state tax law.

A researcher may be concerned that IV regression models that use $RDTaxIncentiveRate_{f fed}$ might still be biased because state tax policies may respond endogenously to federal corporate tax policies. Another worry is that if state laws change contemporaneously with federal laws, then an estimated coefficient on $RDTaxIncentiveRate_{f fed}$ may actually be picking up the effects of contemporaneous state and federal tax law changes instead of the variation in only exogenous federal tax laws. To mitigate these concerns, as a robustness check I drop the two states (Illinois and Massachusetts) that enacted R&D tax credits within one year after a change in the federal R&D tax credit. Dropping these states gives similar results.23

Additional evidence against the hypothesis that states are responding endogenously to changes in federal tax laws comes from the session law data. The R&D tax credit laws for some states contain a preamble that describes the rationale behind why the law was passed. The preambles champion goals such as job creation, business expansion, and leadership in innovation. None of

23Section 5.2 also presents Difference-in-Sargan overidentification validity tests following a format similar to that in Weber (2014). With these overidentification tests, I am unable to reject the validity of my instrument.
the preambles mention changes in federal tax laws as motivation.\textsuperscript{24}

Figure 1 plots summary statistics of per-dollar state-level R&D tax incentive rates, calculated with both state and federal laws causing the variation (equation 2). Figure 1’s vertical lines denote the effective dates for the federal tax laws.

Federal laws cause large shifts in state-level R&D tax incentive rates. For example, the phase-in of the federal R&D tax credit caused the large increase in rates from 1981 to 1982. Similarly, a reworking of the federal R&D tax credit caused the second large increase in rates from 1989 to 1990. Over the last 30 years, the average state-level R&D tax incentive rate was about 0.5. In addition, the introduction of state R&D tax incentives (the first state R&D tax credit was introduced in 1981 and became effective in 1982) increased the cross-state variation in state-level R&D tax incentive rates over time.\textsuperscript{25}

Figure 2 plots R&D tax incentive rates for a few individual states. Aside from 1999, between zero and two states in my sample pass a R&D tax credit bill that affects the state’s R&D tax incentive rate in each year, whereas in 1999 four states passed such a bill.

Figure 3 plots summary statistics of per-dollar state-level R&D tax incentive rates with only federal laws causing the variation (equation 4). Figure 4 plots the same variable for four individual states. Again, vertical lines show the effective dates for the federal tax laws. The removal of the endogenous variation from state laws decreases the range. However, because of the heterogeneous effects of federal laws on state-level R&D tax incentive rates, the cross-state variation in rates continues to increase over time.

\textsuperscript{24}Examples of these preambles are available on my website.

\textsuperscript{25}With state fixed effects and time dummies, identifying variation comes from mean deviations in R&D tax incentive rates, not from large shifts that affect all states equally. The robustness checks appendix confirms that the main results are not sensitive to the large increase in rates from the introduction of the federal R&D tax credit in 1981.
4 Results

4.1 Main Specifications

Table 2 presents instrumental variables estimates with $RDTaxIncentiveRate^{fed}$ instrumenting the statutory tax incentive rate $RDTaxIncentiveRate$. The table reports coefficients as elasticities.

All specifications in Table 2 indicate an elastic response of R&D to tax incentives of at least 2.0. Columns (1) and (2) present results from static specifications that omit the lagged dependent variable. Column (1), a specification that includes only the R&D tax incentive rate with state fixed effects and time dummies, indicates an elasticity (standard error) of 4.51 (1.59). Column (2) adds lagged federal R&D, academic R&D, and the unemployment rate as controls. The elasticity (standard error) of R&D with respect to tax incentives remains large at 5.06 (2.03). Among the control variables, only federal R&D is statistically significant. The positive coefficient on federal R&D suggests complementarity between federal R&D and company-financed R&D.

If the lagged dependent variable belongs in the model, then omitting it leads to inconsistent estimates. I prefer to include the lagged dependent variable because of R&D’s high adjustment costs. Dynamic specifications also allow me to back out an implied long-run elasticity, $\gamma/(1 - \pi)$, where $\gamma$ is the coefficient of the key regressor and $\pi$ is the coefficient on the lagged dependent variable. Columns (3) - (5) represent my preferred estimates that include the lagged dependent variable.

The lagged dependent variable attenuates the elasticity estimate of R&D to tax incentives, but improves the precision.26 Furthermore, the results continue to indicate that a 1% increase in R&D tax incentives leads to at least a 2% increase in R&D. The estimates are also statistically significant at standard levels. Column (3) of Table 2, which uses only the instrumented tax rate, the lagged dependent variable, and fixed effects implies an elasticity estimate (standard error) of 2.90 (1.14). This estimate comes without any other macroeconomic controls. The coefficient (standard error) on the lagged dependent variable is 0.46 (0.10), confirming the presence of adjustment costs for

---

26 Attenuated estimates with improved precision when including the lagged dependent variable are consistent with Bloom, Griffith, and Van Reenen (2002)’s cross-country study of R&D tax credits.
R&D and implying a long-run elasticity (standard error) of 5.38 (1.75).

Column (4) of Table 2 includes a full set of control variables. The coefficient (standard error) of the instrumented $ln(RDTaxIncentiveRate)$ is still large at 3.70 (1.59). GSP enters the model as positive and large, consistent with the procyclicality of R&D. The coefficients on the other control variables have a similar interpretation to the static specification in column (2), although the coefficient on academic R&D is now negative. Column (5) removes GSP so that the model includes only stationary variables. This specification gives similar results to column (4) and continues to indicate an elastic response of R&D to tax incentives. Academic R&D in column (5) is once again insignificant.

Table 3 presents results from equation (1) with the key regressor as the potentially endogenous R&D tax incentive rate (state and federal laws driving the tax variation) estimated with OLS. The lack of an instrument makes Table 3’s specifications analogous to specifications from some of the existing literature on R&D tax incentives. The estimates from Table 3 should be biased due to states choosing their R&D tax policies.

The key takeaway from Table 3 is that the OLS estimates indicate a statistically insignificant response of R&D to tax incentives, regardless of the set of control variables.

### 4.2 Statistical Significance of IV vs. OLS

The point estimates from all IV specifications in Table 2 are statistically different from zero, while the point estimates from all OLS specifications in Table 3 are not statistically different from zero. In addition, as shown at the bottom of Table 3, the difference between the tax incentive rate terms from IV and OLS in my preferred dynamic specifications in Tables 2 and 3 is also statistically significant. Cluster-robust Hausman (1978) tests reject the null hypothesis of equality of coefficients from IV and OLS at the 5% level or lower for each of these dynamic specifications (Cameron and Trivedi, 2005, pg. 276).
5 Instrument Validity

5.1 Pre-treatment Plots

Separating the effect of R&D tax incentives on R&D from other macroeconomic shocks relies on heterogeneous effects of federal tax laws on state-level R&D tax incentives. One concern with this strategy is that the effects of federal tax laws on state-level R&D tax incentives are non-randomly assigned. If states receive disproportionate tax incentives from federal laws because of unobserved state-level factors that also affect R&D, then even federal variation in taxes would give inconsistent estimates.

To check for instrument validity, I perform a standard check and plot the levels and trends of R&D for each state prior to the introduction of the federal R&D tax credit in 1981 (the first federal R&D tax incentive law). If the levels and the trends of R&D for the treatment and control states appear similar prior to the introduction of the federal R&D tax credit, then these plots bolster the case for instrument validity.

A slight complication with constructing pre-treatment plots is that the tax variation that I use is a series of laws that each affects all states — not just a single law that affects some states but not other states. Federal tax laws affect some states more than others, but each federal tax law affects every state. To make results comparable to a standard pre-treatment plot, I divide states into two groups — one group with above median R&D tax incentive rates and another group with below median R&D tax incentive rates — and plot the average R&D for each of the two groups.

Figure 5 divides states into the two groups based on variation in R&D tax incentives rates caused by both state and federal laws (the statutory rates in equation 2). The dashed line represents average nominal R&D for the set of states with an above median average value of R&D tax incentives from 1981-2007.27 The solid line is the set of states with a below median average value of incentives over the same time period. From 1963-1971, the trends in R&D look parallel, although the level of R&D for states with above median tax incentives is higher in each year. From 1971-

27This group consists of: Arizona, California, Connecticut, Indiana, Massachusetts, Minnesota, New Jersey, New York, Pennsylvania, and Wisconsin.
1979, a gap in the R&D trend emerges between these two groups of states, with R&D growing faster for states that implement more generous tax incentives from 1981-2007. This gap in the R&D trend suggests the endogenous selection of higher R&D tax incentive rates by states that do more R&D.

Figure 6 instead divides states into the two groups with the tax incentive rates calculated from only federal tax law variation (my instrument in equation 4). Again, the dashed line represents states above the median.\textsuperscript{28} From 1963-1977, the trends and levels of R&D for the two groups are close. A small gap in R&D opens up in 1979, with the above-median group showing higher R&D. However, the pre-treatment R&D lines match much more closely in both levels and trends of R&D when I group states according to tax incentive rates calculated from my instrument. The closer pre-treatment lines suggest that my instrument is valid.

5.2 Difference-in-Sargan Overidentification Tests

As an additional check of instrument validity, I estimate specifications with an overidentified first-stage and run Difference-in-Sargan tests. Table 4 runs Difference-in-Sargan overidentification tests following a format similar to that in Weber (2014), Table 2, using the 2SLS estimator. I construct variations of my baseline instrument by conditioning on different lags of state tax policy:

\[ \Delta \text{RDTaxIncentiveRate}_{it}^{\text{fed},l} = R\text{DTaxIncentiveRate}(ST_{it-l}, FT_{it}) - R\text{DTaxIncentiveRate}(ST_{it-l}, FT_{it-1}) \]  

for \( l = 1, 2, 3, 4 \). I then test the validity of my instrument by running the Difference-in-Sargan test by excluding the instrument constructed by conditioning on the shortest lag length of state tax policy, which presumably would be most susceptible to endogeneity bias. Column (1) displays the baseline IV specification using one instrument constructed by conditioning on \( l = 1 \), as shown in the baseline Table 2. Columns (2) - (5) display results using an overidentified first stage and corresponding Difference-in-Sargan overidentification test p-values, with the null hypothesis that

\textsuperscript{28}This group consists of: California, Colorado, Connecticut, Indiana, Minnesota, New York, North Carolina, Pennsylvania, Oregon, and Wisconsin.
the excluded instrument is valid. For all overidentified specifications, I am unable to reject the
validity of the excluded instrument at standard significance levels. The elasticity estimates of the
tax incentive rate using multiple instruments are a bit smaller than when using a single instrument
but are still in excess of 2.5.

6 Robustness Check: Piggybacking States and Public Law 101-239

In this section, I present results from two robustness checks. Appendix B presents a variety of
additional robustness checks, which show that this paper’s results are insensitive to various model,
estimator, and data specifications.

One of the main paths that changes in federal tax law heterogeneously affect state tax laws is
whether or not states piggyback their state R&D tax credit to the federal R&D tax credit. To
check for different elasticities of R&D with respect to tax incentives between the piggybacking
and nonpiggybacking states, Table 5, columns (1) and (2) show specifications that interact
\( RDTaxIncentiveRate \) with a dummies for piggybacking states and nonpiggybacking states. The
estimated elasticities between these two groups are very similar.

Table 5, column (3) calculates the instrument using only the single law that generates the
largest source of variation across states: PL 101-239, which was passed on December 19, 1989 and
became effective in 1990. The table denotes this instrument as \( \ln(RDTaxIncentiveRate^{PL101−239}) \).
Instrumenting \( RDTaxIncentiveRate \) with \( \ln(RDTaxIncentiveRate^{PL101−239}) \) makes the model anal-
ogous to a binary treatment and control setup in which the treatment law is PL 101-239 and the
pre-treatment period is before 1990. The cost of this setup is removing potentially exogenous vari-
ation and increasing measurement error in the key right-hand side variable. A benefit is that this
formulation uses only variation from R&D tax credits and not variation from more general income
tax deductions. Income tax deductions are applicable to other types of investments available to a
firm. Changes in income tax deductions might elicit complementary or substitutable investments
for R&D and would imply that the response of R&D to changes in these more general tax deductions might be different than the response of R&D to R&D-specific changes in the tax incentive rate (for example, R&D tax credits). However, calculating R&D tax incentive rates with only variation from PL 101-239 continues to suggest an elastic response of R&D to tax incentives (standard error) of 3.14 (1.39).\textsuperscript{29}

7 Conclusion

This paper contributes to the literature on taxes and innovation economics in two ways: (1) it creates a new, detailed dataset on state-level R&D tax incentives, and (2) it provides a clean estimate of the elasticity of R&D with respect to R&D tax incentives. I use IV and identifying tax variation in state-level R&D tax incentives caused by changes in federal corporate tax laws. The rationale for using this identifying tax variation is that the federal government sets uniform national tax policies and is less attentive than state governments to idiosyncratic state-level economic conditions, so using this variation reduces concerns over inconsistent estimates.

This paper finds that R&D is sensitive to tax incentives, with my preferred IV estimates indicating that a 1% increase in R&D tax incentives would lead to a statistically significant 2.8-3.8% increase in R&D expenditures. In contrast, OLS regressions of R&D on R&D tax incentives, which should give biased estimates of the effect of R&D tax incentives on R&D because states choose their tax policies, indicate a statistically insignificant response of R&D to R&D tax incentives. The difference between my preferred IV and OLS estimates is also statistically significant and could be explained by tax incentives that offset future economic downturns, although there could be other

\textsuperscript{29}Researchers may be concerned that firms anticipated PL 101-239. However, anticipation of PL 101-239 would bias the elasticity estimates toward zero. In 1989 the federal R&D tax credit was a credit amount for R&D over a three-year moving-average base of R&D. The moving average base created a disincentive for firms to claim the R&D tax credit as taking a credit in a given year would reduce the allowable credit for the next three years. PL 101-239 removed the moving-average base amount and the opportunity cost of claiming the R&D tax credit. If firms anticipated this policy change in 1989, then more firms would have claimed the R&D tax credit in 1989, perhaps at the expense of R&D they would have claimed in 1990, which would bias the estimate of the effect of PL 101-239 in 1990 toward zero.
explanations, such as capture of state legislatures.\textsuperscript{30}

Could policymakers be purposely designing offsetting tax incentives? If so, then policymakers may see a downturn is beginning, or predict one will happen, and change policies to offset the upcoming downturn. Another story is that policymakers could simply be adopting tax incentives when funds are available, which may be just before a downturn starts.

Like most studies that use cross-regional variation to estimate the elasticity of R&D with respect to tax incentives, this paper has little to say about the mechanisms that contribute to the estimated elastic response of R&D to tax incentives. The models identify coefficients based on deviations from mean levels of R&D and R&D tax incentives. Increases in R&D for states that implement incentives and decreases in R&D for states that do not implement incentives would both contribute to the magnitude of the estimates.

A large elasticity could be due to low adjustment costs of R&D across state borders. There may be low adjustment costs because firms may relocate R&D between their establishments to maximize tax incentives. The presence of mobile R&D could be an incentive for states to compete strategically with tax incentives. Depending on the slope of state reaction functions, strategic competition can lead to either states with too generous tax incentives, relative to the efficient level, or some states with generous incentives and others with minimal incentives (Brueckner and Saavedra, 2001; Brueckner, 2003; Decker and Wohar, 2007; Chirinko and Wilson, 2008, 2011).

My elasticity estimates could also be explained by firms raising their total R&D in response to being offered tax incentives. This explanation seems plausible when the firm’s general investments have strong complementarities or even when just the firm’s R&D-specific projects have strong complementarities. For example, suppose that R&D and non-R&D investment, such as production machinery or in-house labor training courses, are complements. In this case, if a tax incentive lowers the price of R&D, then the firm will respond by undertaking additional non-R&D investments.

\textsuperscript{30}These results are also consistent with the growth theoretical results of Yang (2005) and the empirical results on US GDP by Romer and Romer (2010). Yang (2005) is a theory paper that simulates growth models. The paper shows that calibrated models that omit preemptive tax policies are misspecified. Romer and Romer (2010) use narrative information on federal taxes to separate endogenously determined taxes from exogenously determined taxes to identify the effect of tax changes on gross domestic product (GDP). With vector autoregressions, Romer and Romer (2010) find the endogenous tax variation leads to underestimates of the effect of taxes on GDP.
investment. However, this additional non-R&D investment will also incentivize the firm to take on additional R&D and potentially leads to a large response of R&D to tax incentives.

References


### Appendix: R&D Tax Incentive Rate Model

This appendix provides details on computing the R&D tax incentive rate in equation (2).

Let $FTI$ denote federal taxable income, $I$ indicate income, $k$ be the R&D credit rate for established firms, subscript $i$ indicate a state-level variable, subscript $f$ indicate a federal-level variable, subscript $t$ be time, $\chi$ be the proportion of the federal R&D credit the Internal Revenue Code (IRC) disallows as a deduction, $RD_{fedCR}$ symbolize the amount of R&D claimed for the federal R&D credit, and $RD_{tot}$ be total R&D expenditures. Because the federal government allows both state corporate income taxes and R&D expenditures as deductions from $FTI$, $^{31}$ the expression for $FTI$ follows (6):

$$FTI_{it} = I_{it} - ST_{it} - RD_{it}^{tot} + \chi_{ft} k_{ft} RD_{it}^{fedCR}$$  \hspace{1cm} (6)

Federal taxes, $FT$, are simply the corporate income tax rate $\tau$ times $FTI$, less the federal R&D credit. The expression for $FT$ is as follows:

$$FT_{it} = FTI_{it} \tau_{ft} - k_{ft} RD_{it}^{fedCR}$$  \hspace{1cm} (7)

After a transitional period from 1981-1982, the federal R&D credit was a percentage of qualified research expenditures (QREs) over the greater of 50% of a firm’s QREs or a three-year moving

---

$^{31}$The federal government has allowed these deductions since prior to the beginning of the R&D data from the National Science Foundation.
average of QREs. Assuming firms are not constrained by the base,\(^{32}\) the three-year moving average makes \(RD_{it}^{\text{fedCR}} = RD_{it}^{\text{tot}} - \frac{1}{3} \sum_{m=1}^{3} RD_{it-m}^{\text{tot}}\) and makes the expression for \(FT\) as follows:

\[
FT_{it} = FTI_{it} \tau_{ft} - k_{ft} (RD_{it}^{\text{tot}} - \frac{1}{3} \sum_{m=1}^{3} RD_{it-m}^{\text{tot}})
\]  \(8\)

Since 1990 the federal R&D credit is a percentage of QREs above a fixed-percentage base instead of a three-year moving average base. Assuming that QREs are unconstrained by this fixed-percentage base, \(RD_{it}^{\text{fedCR}} = RD_{it}^{\text{tot}}\) and:

\[
FT_{it} = FTI_{it} \tau_{ft} - k_{ft} RD_{it}^{\text{tot}}
\]  \(9\)

Comparing equations (8) and (9), the three-year moving average formulation directly increases federal taxes paid by \(k_{ft} \frac{1}{3} \sum_{m=1}^{3} RD_{it-m}^{\text{tot}}\). There are also indirect effects on the federal tax burden because federal taxes depend on state taxes and vice versa.

In computing state taxable income \(STI\), states generally start with federal taxable income or income from all sources and then add state-specific modifications to form state taxable income. Let \(\xi\) be the proportion of state \(i\)'s income taxes required to be added back to federal taxable income, \(\phi\) be the proportion of state \(i\)'s federal taxes that is deductible from state taxable income, \(\omega\) indicate the proportion of state \(i\)'s R&D credit recaptured, \(\alpha\) represent the proportion of federal recaptured credit allowed as a state deduction, and \(RD_{it}^{\text{stateCR}}\) be the amount of R&D claimed for state \(i\)'s R&D credit. The expression for \(STI\) is as follows:

\[
STI_{it} = FTI_{it} + \xi_{it} ST_{it} - \phi_{it} F TI_{it} + \omega_{it} k_{it} RD_{it}^{\text{stateCR}} - \alpha_{it} \chi_{ft} k_{ft} RD_{it}^{\text{fedCR}}
\]  \(10\)

which gives way to a state tax burden \(ST\) of:

\[
ST_{it} = STI_{it} \tau_{it} - k_{it} RD_{it}^{\text{stateCR}}
\]  \(11\)

\(^{32}\)Hall (1993) notes that the majority of R&D firms have R&D levels above their base amounts. Mamuneas and Nadiri (1996) and Wilson (2009) also employ the assumption of R&D levels over the base amounts.
For the corporate income tax rate $\tau$ I follow Shea (1993) and Wilson (2009) and use the top-tier corporate rates without alternative minimum tax. For states with only a tax on gross income or stated capital instead of net income, I set $\tau_{it}$ as the rate on gross income or stated capital. I account for temporary taxes and surcharges in $\tau_{it}$. In the R&D sample, two-thirds of the states have a single corporate income tax rate for the entire sample period. The remaining one-third of the states levy the highest-tier corporate income tax at very low levels of taxable income. For example, among states with graduated rates, in 2000 the average highest tier was only $146,000 of taxable income.

I model firms as filing based on the calendar year to keep the timing consistent with the other annual variables. If states change a law midway through the year and specify an explicit proration for a calendar year, then I prorate accordingly. For example, if a state has $\tau = 0.1$ for six months of 1990 and then implements an increase to $\tau = 0.2$ for 1990, I code 1990 as $\tau = 0.2$ if no proration clause exists and as $\tau = 0.15$ if a proration clause does exist.

States generally compute their R&D credits in one of three ways: 1) a non-incremental credit, in which the credit is calculated as a percentage of QREs, 2) a credit for QREs above a fixed-percentage base (following the federal credit formula in place since 1990), or 3) a credit for QREs above a $M$-year moving average of QREs. With QREs above the fixed-percentage base or for the non-incremental credit case, $RD_{it}^{stateCR} = RD_{it}^{tot}$. For the years a state employed a $M$-year moving average base, $RD_{it}^{stateCR} = RD_{it}^{tot} - \frac{1}{M} \sum_{m=1}^{M} RD_{it}^{tot} - m$. Following Wilson (2009), I do not consider state R&D tax credits specific to a given industry, for a given area within a state, or for a specific firm size because the NSF R&D data are at the state level.

The federal R&D credit and approximately two-thirds of states use a single R&D credit rate $k$ for all applicable R&D expenditures (i.e., no credit tiers). The remaining one-third of states

---

33In the R&D sample, Connecticut and Maryland are exceptions. Connecticut has had two R&D credits since 1993: a 20% credit for QREs over a one-year moving average (Connecticut General Statutes § 12-217j) and a level credit for QREs below the moving average (Connecticut General Statutes § 12-217n). The level credit is tiered at 1%, 2%, 4%, and 6% based on the firm’s level of QREs. In addition, the firm may take only one-third of the level credit in the tax year that it incurs the R&D expenditures. The remainder must be deferred until the next tax period. Transitional provisions were in place from 1993-1994. Like Connecticut, Maryland has two R&D credits that work in tandem and have been in place since 2000 (Maryland Tax-General Code § 10-721). The first component is a 10% credit for QREs above a four-year moving average of QREs. The second component is a 3% credit for QREs that do not qualify for the 10% credit component. I model both of these alternative mechanisms.
have tiered credit amounts and are divided between offering higher credit amounts for higher tiers of R&D expenditures and offering lower credit amounts for higher tiers of R&D expenditures. I report results using the highest tier of R&D expenditures as large corporations, which constitute the bulk of R&D spending, are likely to be in the top tier.\textsuperscript{34} I also check the results with the median tier, which gives similar results.

These formulations can accompany both states that base $STI$ on $FTI$ and those that start with income from all sources in calculating $STI$. To see this point, substituting the expression for $FTI$ in equation (6) into equation (10) and setting $\alpha_{it} = 1$ (since states that base $STI$ on income from all sources do not consider the recapture provisions of the federal R&D credit) yields the following:

\begin{align*}
STI_{it} &= I_{it} - ST_{it} - RD_{it}^{tot} + \chi_{ft}k_{ft}RD_{it}^{fedCR} + \xi_{it}ST_{it} - \phi_{it}FT_{it} \\
&\quad + \omega_{it}k_{it}RD_{it}^{stateCR} - \alpha_{it}\chi_{ft}k_{ft}RD_{it}^{fedCR} \\
&= I_{it} + ST_{it}(\xi_{it} - 1) - RD_{it}^{tot} + \chi_{ft}k_{ft}RD_{it}^{fedCR}(1 - \alpha_{it}) - \phi_{it}FT_{it} + \omega_{it}k_{it}RD_{it}^{stateCR} \\
&= I_{it} + ST_{it}(\xi_{it} - 1) - RD_{it}^{tot} - \phi_{it}FT_{it} + \omega_{it}k_{it}RD_{it}^{stateCR}
\end{align*}

which is a sufficiently generic expression for $STI$ for states that use income from all sources as a starting point in their $STI$ computation. Solving the system of equations depicting $FTI$, $FT$, $STI$, $ST$, and differentiating with respect to total R&D expenditures, $RD_{it}^{tot}$ (the choice variable), yields the expression for the R&D tax incentive rate in equation (2).\textsuperscript{35} The system of equations for $FTI$, $FT$, $STI$, and $ST$ takes into account a broader range of deductions than is found in the previous literature and models the simultaneity of state and federal taxes, allowing this paper to compute

\textsuperscript{34}Some states impose a maximum credit amount a firm can claim that is not dependent on the firm’s taxable income, a statewide limit on the amount of R&D tax credit that can be claimed by all firms in the state each year, or both a firm-specific maximum and a statewide maximum. The firm-specific limit on R&D tax credits is equivalent to a marginal rate of zero for the top tier. I assume that the statewide limit provision is not binding, following Wu (2005); Wilson (2009).

\textsuperscript{35}Equation (2) assumes firms have sufficient taxable income to claim R&D tax incentives, consistent with previous studies of R&D tax incentives. A dummy variable for whether a state has a refundable R&D tax credit (tax credits that can be claimed for any level of taxable income) or allows firms to sell tax credits to other firms has no effect on the results.
state-level R&D tax incentive rates with weaker assumptions than in previous studies (Paff, 2005; Wu, 2005; Wilson, 2009). In addition, because of the large number of tax parameters captured by the model and because the effective R&D tax incentive rate is a continuous variable, each state in my sample has a different effective R&D tax incentive rate.

Computing the discounted changes in taxes for all future periods requires assumptions about how firms form expectations about future tax law. Because the tax data are available at a higher frequency (annually) than the R&D data are (biennially), minor changes to the timing of forming expectations in the tax data give the same results. Following the assumptions of Romer and Romer (2010) and consistent with evidence in Chang (2017), I treat simple extensions of R&D credits as anticipated. I also treat state IRC conformity updates as anticipated. Extensions to R&D credits, which are almost universally enacted on a temporary basis with built-in expiration dates (sunset provisions), are extremely common. In the R&D sample, only one state (Illinois) allowed its R&D credit to lapse for a year before reactivating its R&D credit. Similarly, most state legislatures tend to enact IRC conformity updates during each legislative session.

For other tax laws, I assume firms in year $t$ have access to laws in effect through November of year $t$, form expectations based on these laws, and take into account the laws that will change taxes in future periods. To my knowledge, no hard data exist on the precise timing of firms’ expectations of future taxes. However, large corporations with dedicated accounting resources should be anticipating future tax changes that will occur because of laws on the books. I confirmed this assumption through correspondence with a tax lawyer who worked for a large corporation. The session law data allow me to pinpoint how laws will change taxes in future periods, which allows this paper to calculate $RDTaxIncentiveRate$ with a weaker assumption than in previous studies.
B Appendix: Robustness Checks

B.1 Additional Controls and Sample Restrictions

A researcher may be concerned that the control variables in Tables 2 and 3 are insufficiently rich. Therefore, I experiment with a more saturated specification of controls that uses contemporaneous, one lag, and two lags of all control variables. The R&D tax incentive rate driven only by federal laws generates an elasticity estimate (standard error) of 4.60 (1.82). This estimate continues to indicate a large response of R&D to tax incentives consistent with the more simple specifications of Table 2. This more saturated specification gives an elasticity estimate (standard error) of 0.53 (0.77) for the endogenous R&D tax incentive rate driven by both state and federal laws, which is in line with the parsimonious specifications in Table 3.\(^{36}\)

Table 6 considers models subject to various sample modifications. Starting with the specification in column (5) of Table 2, in column (1) of Table 6 I trim the 2% of observations with the largest residuals, removing 1% of the sample from each tail.\(^{38}\) I conduct this robustness check to see if the results are driven by only a few observations that the model does not explain well. Column (2) estimates the model with data starting in 1985 to remove the effect of the introduction of the federal R&D tax credit, which causes the large increase in R&D tax incentive rates from 1981-1982 in Figures 1 and 3. In column (3), I estimate the model only with data up to 1999 because the variation in R&D tax incentive rates driven by federal laws comes exclusively from the 1980s and 1990s. In column (4), I use all of the available R&D data by abandoning the biennial structure used so far. This strategy changes the model from biennial to annual observations from 1997-2006 and addresses concerns over potential loss of precision from dropping observations in the latter part of the sample.\(^{39}\)

The models subject to these sample modifications continue to suggest an elastic response of

\(^{36}\)The results are also robust to adding state-specific linear time trends, the rate of growth of GSP, and the first lag of the rate of growth of GSP as controls.

\(^{37}\)The endogenous R&D tax incentive rate driven by both state and federal laws gives inelastic to approximately unit elastic point estimates for all robustness checks.

\(^{38}\)A 5% sample trim (2.5% from each tail) yields similar estimates.

\(^{39}\)Weighting states by average GSP from 1981-2006 also gives similar results.
R&D to tax incentives. The smallest estimate comes from removing outliers in column (1), which indicates that if governments were to increase R&D tax incentives by 1%, then R&D would increase by 3.2%.

Estimating the model with data starting in 1985 yields an estimate similar to the main result in Table 2. Therefore, the main result is not driven by the phase-in of the federal R&D tax credit that causes the large increase in R&D tax incentive rates from 1981 to 1982 shown by Figures 1 and 3.

Dropping observations after 1999 in column (3) imposes the largest sample reduction and also has the largest effect on the estimates. The estimate of the price elasticity (standard error) is now much more elastic at 6.29 (1.75). This large increase in magnitude is likely due to the increased downward bias on the lagged dependent variable from the within estimator. The coefficient on the lagged dependent variable is down to 0.09 from 0.39 in Table 2, column (5). This bias on the lagged dependent variable renders the other coefficients inconsistent, so the estimates from column (3) should be taken with a dose of suspicion.

The final sample modification in column (4), using annual observations from 1997-2006 instead of biennial observations, gives a similar estimate to the main results of Table 2. For all specifications subject to sample modifications, federal R&D complements company-financed R&D. Academic R&D and the unemployment rate are insignificant.\textsuperscript{40,41}

Another selection concern is that certain geographic regions might choose to implement certain policies. However, estimating models with separate policy variables by census region (West,\textsuperscript{40} the clustered standard errors imply rejection at the 5% level or lower for the key coefficient in the preferred models. I also check the rejection rates, following the recommendation of Cameron, Gelbach, and Miller (2008), by bootstrapping the t-statistic using the wild cluster bootstrap-t procedure (Brownstone and Valletta, 2001). I use Rademacher weights with 1000 replications for each test and impose the null hypothesis that the tax policy variable is zero, as advocated by Davidson and MacKinnon (1999); Cameron, Gelbach, and Miller (2008). The bootstrap blocks are states. The hypothesis test of $H_0: \gamma = 0$ vs. $H_A: \gamma > 0$ yields p-values between 0.03 and 0.09 for the preferred model’s key regressors.

\textsuperscript{41}One control I do not consider is some type of geographically-weighted or proximity measure of an out-of-state subsidy rate. For example, adding the weighted R&D tax credit subsidies of Arizona, Nevada, and Oregon as a control observation for California. Geographically-weighted measures most likely ignore or mis-attribute R&D reallocation, particularly within firms situated in multiple states, which would lead to measurement error in a right-hand side variable. For example, the aircraft producer Boeing has manufacturing plants in Washington state and South Carolina. These states are on opposite sides of the U.S., but for purposes of R&D allocation Boeing may want to conduct R&D between these states due to existing infrastructure and human capital while also taking into account R&D tax incentives. However, geographic proximity measures will miss this link. My future work will consider modeling R&D mobility across states. This paper focuses on the within-state response.
South, Midwest, and Northeast) also gives similar results. The coefficients (standard errors) on $\ln(RDTaxIncentiveRate_{fed})$ for the specification in column (5) of Table 2, are 3.73 (1.77) for West, 3.74 (1.82) for South, 3.02 (1.92) for Midwest, and 3.28 (2.04) for Northeast.\footnote{Estimating separate policy variables and separate controls for each census region gives imprecise estimates.}

### B.2 Instrument Relevance

From examining the first-stage F-statistics of Table 2, which are below the Staiger and Stock (1997) rule of thumb of 10, a researcher may be concerned that my large IV tax elasticity estimates are inconsistent. Following Angrist and Pischke (2008), I highlight four reasons why these concerns should be tempered.

First, the estimates of Table 2 are just-identified, and just-identified IV is approximately median unbiased.

Second, with weak instruments IV estimates are mean-biased towards OLS estimates. Therefore, if the IV estimates of Table 2 are mean biased, then the true tax parameter of interest is greater than the Table 2 IV estimates suggest, which would imply that the Table 2 IV estimates would actually understate the bias of OLS.

Third, I estimate over-identified specifications, using an additional lag of the federal tax variable as an instrument (equation 5 with \( l = 1, 2 \)), with the limited information maximum likelihood (LIML) estimator. The LIML estimator in over-identified specifications exhibits approximately median-unbiased behavior even with weak instruments. The LIML specifications, shown in Table 7, give similar results to the baseline just-identified 2SLS models in Table 2.

Fourth, I run the reduced form regressions of R&D on the federal tax instrument using the same pattern of controls as in Table 2. Assuming the instrument is valid, the reduced form results are mean-unbiased. The reduced form results, shown in Table 8, all show large effects of the instrument on R&D, with point estimates always in excess of 2.5, and are statistically significant at standard levels.

To summarize, the results in Tables 2 and 3 suggest that ignoring the endogeneity of tax policies
leads to attenuated estimates of the response of R&D to tax incentives. Because the IV estimates of the response of R&D to tax incentives show a statistically significant effect, and the OLS estimates are statistically insignificant, the results are consistent with policymakers implementing R&D tax incentives to offset the future loss of R&D expenditures. For example, if firms plan to relocate R&D activity to another region, then lawmakers may offer the firm tax incentives to keep the firm’s R&D activity from changing location. This preemptive offering of R&D tax incentives would cause researchers to observe no effect of the endogenously determined tax policies when their true effect was to prevent a drop in R&D.

B.3 User Cost of Capital

In this subsection, I present results from a robustness check involving the user cost of capital. Following Chirinko and Wilson (2008) and Wilson (2009), I form the user cost of R&D capital, \( \text{RDU} \text{serCost} \), as an extension of Hall and Jorgenson (1967). The user cost is the ratio of the R&D tax incentive rate, \( RDTaxIncentiveRate_{it}^{fed} \), to the tax incentive rate of output, \( OutputTaxIncentiveRate_{it} \), where output is a fully deductible expense that does not have an associated tax credit,\(^{43}\) adjusted for depreciation \( \delta \) of R&D and the discount rate \( r \):

\[
RDUserCost_{it} = \frac{RDTaxIncentiveRate_{it}^{fed}}{OutputTaxIncentiveRate_{it}} [r_t + \delta_t]
\]

(13)

Equation (13) captures the fact that the opportunity cost of investment in R&D is an investment in some other good, such as output. Rewriting equation (1) with the natural logarithm of the user cost as the key regressor yields the following:

\[
\ln(RD_{it}) = \pi \ln(RD_{it-1}) + \phi_i + \lambda_t + \kappa \ln(r_t + \delta_t) + \gamma \ln(RDTaxIncentiveRate_{it}^{fed}) - \upsilon \ln(OutputTaxIncentiveRate_{it}) + \ln(X_{it}') \tilde{\beta} + \epsilon_{it}
\]

(14)

\(^{43}\)Specifically, I compute \( OutputTaxIncentiveRate \) with the model in Appendix A without the terms for R&D-specific tax incentives.
Under depreciation and discount rates that are uniform across states, the time dummies absorb $ln(r_t + \delta_t)$ so that equation (14) amounts to the original model with a new term for the tax incentive rate of output, $ln(OutputTaxIncentiveRate_{it})$. Including $ln(OutputTaxIncentiveRate_{it})$ in the model continues to indicate an elastic response of R&D to R&D tax incentives. For example, the specification in column (5) of Table 2 yields a R&D tax incentive rate estimate (standard error) of 3.68 (1.74). The control variables have similar point estimates and the tax incentive rate of output is insignificant at standard levels.\textsuperscript{44}

\section*{C Institutional Details of the Interactions Between Federal and State Tax Law}

The computations of federal and state corporate taxes are interdependent. A firm’s federal tax liability depends on its state tax liability and vice versa. The simultaneity between federal and state corporate taxes contributes to differential effects of federal laws on state-level R&D tax incentive rates across states. I model the heterogeneous changes in R&D tax incentive rates from federal laws by taking into account two broad classes of incentives: 1) incentives relating to deductions for corporate income taxes paid and 2) incentives relating to R&D tax credits.\textsuperscript{45}

The federal government allowed a deduction for state corporate income taxes starting in 1954. At the same time, some states allow deductions for federal corporate income taxes, state corporate income taxes, or both. Other states allow neither type of deduction. This between-state variation in tax policies implies that any change in federal tax law that affects a firm’s federal income tax liability will have differential effects on total tax liability across states.

For example, changes in the federal corporate income tax rate directly affects total taxes for all states. For states that allow federal corporate income taxes paid as a deduction, changes in

\textsuperscript{44}Calculating $OutputTaxIncentiveRate$ by isolating only state-level tax variation from federal tax laws in the cost of output with the analogous definition from equation (3) also gives similar results.

\textsuperscript{45}These two classes are themselves interdependent, but I separate them for the sake of exposition. See the model in Appendix A.
the federal corporate income tax rate are damped. The value of this deduction is proportional to the state corporate income tax rate. Suppose that the federal government increases the federal corporate income tax rate from 0.4 to 0.5 and that there are no R&D tax credits or state deductions for state corporate income taxes.\footnote{The presence of R&D tax credits and state deductions for state corporate income taxes complicates the intuition, but the main point is the same.} If a state does not allow a deduction for federal corporate income taxes paid, then the increase in taxes for firms would be ten cents per dollar of taxable income. If a state with a five percent corporate income tax allows a deduction for federal corporate income taxes paid, then the increase in taxes for firms would be 9.5 cents per dollar of taxable income. For every dollar of additional federal corporate income tax, firms can take an additional dollar of deduction on their state taxes. With a five percent state corporate income tax rate, each dollar of deduction from state taxable income is worth five cents. Therefore, changes in the federal corporate income tax rate have heterogeneous effects on the value of deductions, and hence R&D tax incentive rates due to the deductibility of R&D expenditures, as a function of state corporate income tax rates and what proportion of federal corporate taxes states allow as a deduction.

Variation in the federal R&D tax credit also contributes to differential effects of federal laws on state-level R&D tax incentives. The largest source of variation comes from the passage of Public Law (PL) 101-239 on December 19, 1989. Public Law 101-239 increased the effective federal R&D tax credit and reduced allowable deductions for R&D expenditures starting on January 1, 1990. In 1989, the federal R&D tax credit was 20\% of qualified research expenditures (QREs) above a three-year moving-average base amount of QREs.\footnote{See Guenther (2006) for a review of the federal R&D tax credit.} In addition, in 1989 firms could deduct 50\% of their QREs claimed for computing the federal R&D tax credit from their federal taxable income. PL 101-239 changed the base amount to a fixed-percentage base and disallowed the deduction for QREs used to calculate the credit.\footnote{Treating tax credits as taxable income is called credit recapture.}

Changing the base amount from a three-year moving-average base to a fixed-percentage base dramatically increased the effective R&D credit rate (Hall, 1993; Wilson, 2009). Under the three-year moving-average base, for each dollar of credit claimed a firm had to lower its future claimed
credit by one-third of a dollar for each of the next three years. With the fixed-percentage base, PL 101-239 eliminated this opportunity cost. At the same time, the disallowance of the 50% QRE deduction decreased the effective credit rate because firms could no longer take both a deduction and a credit for the same QREs. The heterogeneous effects on state-level R&D tax incentive rates from PL 101-239 came from two factors: 1) how states structured their R&D tax credits and 2) how states computed state taxable income (basis for state taxable income).

Two common features of state tax policy are: 1) offering a state R&D tax credit computed with the same method as the federal R&D tax credit and 2) having this computation method linked directly to the Internal Revenue Code (IRC), the document that governs U.S. federal tax law. These two combined features of state tax policy are called piggybacking. For example, Oregon Revised Statues § 317.152, which authorizes a R&D tax credit for Oregon QREs, states that “A credit against taxes otherwise due under this chapter shall be allowed to eligible taxpayers for increases in qualified research expenses... the credit shall be determined in accordance with section 41 of the Internal Revenue Code.”

Piggybacking implies that any change in the computation of the federal R&D tax credit automatically updates how piggybacking states calculate their R&D tax credits: changes in federal tax law cause changes in effective state tax law and state policymakers do not dictate these changes. In 1989, California, Indiana, Iowa, Minnesota, North Dakota, Oregon, and Wisconsin piggybacked on the federal R&D tax credit. All else being equal, for these seven states PL 101-239 increased both the effective federal R&D tax credit and the effective state R&D tax credit. Therefore, for these states PL 101-239 caused a disproportionally large increase in R&D tax incentive rates relative to states without piggybacked R&D tax credits. For states without piggybacked R&D tax credits, PL 101-239 caused an increase in R&D tax incentive rates of between nine and thirteen cents per dollar of R&D. The increase in rates for states with piggybacked R&D tax credits was approximately 50% greater than the increase in rates for states without piggybacked R&D tax credits.

The basis for state taxable income also helped foster heterogeneous effects of PL 101-239 on state-level R&D tax incentive rates. In general, states use either income from all sources (gross
receipts) or federal taxable income as a starting point for computing state taxable income. States that incorporate federal taxable income as a starting point automatically apply federal-specific deductions and exemptions to form state taxable income. For these states, changes in the IRC cause automatic updates in state tax codes. However, states that form state taxable income by starting with income from all sources do not incorporate federal-specific deductions and exemptions, so alterations to the IRC have no effect on their state tax codes. Public Law 101-239 disallowed the 50% QRE deduction allowed prior to 1990 when taking the federal R&D tax credit (IRC § 280C(c)). For states with federal taxable income as a base, PL 101-239 caused an automatic increase in the state income base (that is, a decrease in the effective federal R&D tax credit) and had no effect for states that used income from all sources as a base. This feature of state tax codes also contributes to differential effects of federal laws on state-level R&D tax incentive rates.49

49In the interest of brevity I simplified this discussion slightly. Some states have specific provisions that override what the base would predict. See Appendix A for details. A detailed example of how a federal tax law passes through to state tax law is available on my website.
This figure plots summary statistics of state-level R&D tax incentive rates, calculated using variation from both state and federal laws, over time. Vertical lines indicate the dates that federal tax laws were effective. Sources: State session laws, Internal Revenue Code.
This figure plots state-level R&D tax incentive rates, calculated using variation from both state and federal laws, for Arizona (solid line), California (dashed dotted line), Indiana (long dashed line), and Texas (short dashed line). Vertical lines indicate the dates that federal tax laws were effective. Sources: State session laws, Internal Revenue Code.
This figure plots summary statistics of state-level R&D tax incentive rates, calculated using variation from only federal laws, over time. Vertical lines indicate the dates that federal tax laws were effective. Sources: State session laws, Internal Revenue Code.
This figure plots state-level R&D tax incentive rates, calculated using variation from only federal laws, for Arizona (solid line), California (dashed dotted line), Indiana (long dashed line), and Texas (short dashed line). Vertical lines indicate the dates that federal tax laws were effective. Sources: State session laws, Internal Revenue Code.
This figure divides states into two groups - one with above median average R&D tax incentives from 1981-2007 and another with below-median incentives - using variation from both state and federal laws in state-level R&D tax incentives. The dashed line represents average nominal R&D for states with higher than the median average value of R&D tax incentives. The solid line is for states with lower than median average value of R&D tax incentives. Sources: National Science Foundation’s Survey of Industrial Research and Development; State session laws.
This figure divides states into two groups - one group with above median average R&D tax incentives from 1981-2007 and another group with below-median incentives - using tax variation from only federal laws. The dashed line represents average nominal R&D for states with higher than the median average value of incentives from federal tax laws. The solid line is for states with lower than the median average value of incentives from federal tax laws. Sources: National Science Foundation’s Survey of Industrial Research and Development; State session laws.
Table 1: Federal Laws Affecting R&D Tax Incentive Rates

<table>
<thead>
<tr>
<th>Public Law</th>
<th>Tax Code Change</th>
<th>Effective Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>97-34</td>
<td>R&amp;D Credit Implemented at 25%</td>
<td>1981</td>
</tr>
<tr>
<td>99-514</td>
<td>R&amp;D Credit Reduced to 20%</td>
<td>1986</td>
</tr>
<tr>
<td></td>
<td>Corporate Income Tax Reduced to 34%</td>
<td>1987-1988</td>
</tr>
<tr>
<td>100-647</td>
<td>R&amp;D Credit Recapture Increased to 50%</td>
<td>1989</td>
</tr>
<tr>
<td>101-239</td>
<td>R&amp;D Credit Recapture Increased to 100%</td>
<td>1990</td>
</tr>
<tr>
<td></td>
<td>R&amp;D Credit Base Computation Changed</td>
<td>1990</td>
</tr>
<tr>
<td>103-66</td>
<td>Corporate Income Tax Increased to 35%</td>
<td>1993</td>
</tr>
<tr>
<td>104-188</td>
<td>R&amp;D Credit Renewed After Expiration</td>
<td>1996</td>
</tr>
</tbody>
</table>

Source: Internal Revenue Code (Lexis annotations).
Table 2: Instrumental Variables Estimates Indicate Elastic Response of R&D to Tax Credits

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\ln(RDTaxIncentiveRate_{it}^{fed})$</td>
<td>4.51***</td>
<td>5.06**</td>
<td>2.90**</td>
<td>3.70**</td>
<td>3.79**</td>
</tr>
<tr>
<td></td>
<td>(1.59)</td>
<td>(2.03)</td>
<td>(1.14)</td>
<td>(1.59)</td>
<td>(1.69)</td>
</tr>
<tr>
<td>$\ln(RD_{it-2})$</td>
<td></td>
<td></td>
<td>0.46***</td>
<td>0.38***</td>
<td>0.39***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.10)</td>
<td>(0.10)</td>
<td>(0.11)</td>
</tr>
<tr>
<td>$\ln(GSP_{it})$</td>
<td></td>
<td></td>
<td></td>
<td>0.58*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.32)</td>
<td></td>
</tr>
<tr>
<td>$\ln(Federal\ RD_{it-2})$</td>
<td>0.39***</td>
<td>0.20***</td>
<td>0.22***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.12)</td>
<td>(0.07)</td>
<td>(0.07)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\ln(Academic\ RD_{it})$</td>
<td>0.07</td>
<td>-0.32</td>
<td>-0.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.29)</td>
<td>(0.25)</td>
<td>(0.21)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Unemployment\ Rate_{it}$</td>
<td>-0.70</td>
<td>-1.27</td>
<td>-1.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3.27)</td>
<td>(2.68)</td>
<td>(2.69)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$N$</td>
<td>226</td>
<td>226</td>
<td>206</td>
<td>206</td>
<td>206</td>
</tr>
<tr>
<td>Implied Long-Run</td>
<td></td>
<td></td>
<td></td>
<td>5.38***</td>
<td>6.01***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(1.75)</td>
<td>(2.00)</td>
</tr>
<tr>
<td>First-Stage F-stat</td>
<td>6.35</td>
<td>7.69</td>
<td>5.79</td>
<td>4.05</td>
<td>4.28</td>
</tr>
</tbody>
</table>

The dependent variable is the natural log of R&D expenditures. The key regressor $\ln(RDTaxIncentiveRate_{it})$ is instrumented with $RDTaxIncentiveRate_{it}^{fed}$. The estimator is two-stage least squares. First-stage F-statistic is for the excluded instrument. This table reports coefficients as elasticities except for the unemployment rate, which is a semielasticity. All columns include state fixed effects and time dummies. Clustered standard errors by state in parentheses. The implied long-run elasticity is the coefficient of the tax rate divided by one minus the coefficient on the lagged dependent variable with the standard errors calculated with the delta method. *, **, ***: significant at 10%, 5%, 1%.
Table 3: Ordinary Least Squares Indicates Inelastic Response of R&D to Tax Incentives that is Statistically Different from Instrumental Variables

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\ln(RDTaxIncentiveRate_{it})$</td>
<td>1.66</td>
<td>1.75</td>
<td>0.58</td>
<td>0.37</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td>(1.05)</td>
<td>(1.11)</td>
<td>(0.73)</td>
<td>(0.73)</td>
<td>(0.76)</td>
</tr>
<tr>
<td>$\ln(RD_{it-2})$</td>
<td></td>
<td></td>
<td>0.52***</td>
<td>0.49***</td>
<td>0.49***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.11)</td>
<td>(0.09)</td>
<td>(0.11)</td>
</tr>
<tr>
<td>$\ln(GSP_{it})$</td>
<td></td>
<td></td>
<td></td>
<td>0.89***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.20)</td>
<td></td>
</tr>
<tr>
<td>$\ln(Federal\ RD_{it-2})$</td>
<td>0.37***</td>
<td></td>
<td>0.13*</td>
<td>0.17**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.11)</td>
<td></td>
<td>(0.07)</td>
<td>(0.06)</td>
<td></td>
</tr>
<tr>
<td>$\ln(Academic\ RD_{it})$</td>
<td>0.10</td>
<td>-0.44*</td>
<td>-0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.30)</td>
<td>(0.22)</td>
<td>(0.20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unemployment Rate_{it}</td>
<td>1.84</td>
<td>0.86</td>
<td>0.95</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.89)</td>
<td>(1.84)</td>
<td>(1.79)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>226</td>
<td>226</td>
<td>206</td>
<td>206</td>
<td>206</td>
</tr>
<tr>
<td>Implied Long-Run Tax Incentive Elasticity</td>
<td>1.22</td>
<td>0.71</td>
<td>1.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.41)</td>
<td>(1.37)</td>
<td>(1.38)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-Value of IV minus OLS Estimates</td>
<td>0.23</td>
<td>0.22</td>
<td>0.05</td>
<td>0.01</td>
<td>0.02</td>
</tr>
</tbody>
</table>

The dependent variable is the natural log of R&D expenditures. The key regressor $\ln(RDTaxIncentiveRate)$ is the R&D tax incentive rate calculated using changes in both state and federal tax laws (the statutory rate). The estimator is ordinary least squares. This table reports coefficients as elasticities except for the unemployment rate, which is a semielasticity. All columns include state fixed effects and time dummies. Clustered standard errors by state in parentheses. The implied long-run elasticity is the coefficient of the tax rate divided by one minus the coefficient on the lagged dependent variable with the standard errors calculated with the delta method. For each column, the p-value of IV-OLS estimates row uses cluster-robust Hausman (1978) tests for the difference between the IV estimate of $\ln(RDTaxIncentiveRate_{it})^{fed}$ in Table 2 and the OLS estimate of $\ln(RDTaxIncentiveRate_{it})$ from this Table, with the null hypothesis of no difference. *, **, ***: significant at 10%, 5%, 1%. 

49
Table 4: Difference-in-Sargan Tests Are Unable To Reject Instrument Validity

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\ln(RDTaxIncentiveRate_{it}^{fed})$</td>
<td>3.79***</td>
<td>3.14**</td>
<td>3.55***</td>
<td>2.59***</td>
<td>2.56***</td>
</tr>
<tr>
<td></td>
<td>(1.69)</td>
<td>(1.44)</td>
<td>(1.70)</td>
<td>(0.84)</td>
<td>(0.85)</td>
</tr>
<tr>
<td>$\ln(RD_{it-2})$</td>
<td>0.39***</td>
<td>0.41***</td>
<td>0.40***</td>
<td>0.43***</td>
<td>0.43***</td>
</tr>
<tr>
<td></td>
<td>(0.11)</td>
<td>(0.11)</td>
<td>(0.11)</td>
<td>(0.10)</td>
<td>(0.10)</td>
</tr>
<tr>
<td>$\ln(Federal\ RD_{it-2})$</td>
<td>0.22***</td>
<td>0.21***</td>
<td>0.22***</td>
<td>0.20***</td>
<td>0.20***</td>
</tr>
<tr>
<td></td>
<td>(0.07)</td>
<td>(0.06)</td>
<td>(0.07)</td>
<td>(0.05)</td>
<td>(0.05)</td>
</tr>
<tr>
<td>$\ln(Academic\ RD_{it})$</td>
<td>-0.15</td>
<td>-0.16</td>
<td>-0.15</td>
<td>-0.16</td>
<td>-0.16</td>
</tr>
<tr>
<td></td>
<td>(0.21)</td>
<td>(0.20)</td>
<td>(0.21)</td>
<td>(0.19)</td>
<td>(0.19)</td>
</tr>
<tr>
<td>Unemployment Rate$_{it}$</td>
<td>-1.15</td>
<td>-0.71</td>
<td>-0.99</td>
<td>-0.35</td>
<td>-0.33</td>
</tr>
<tr>
<td></td>
<td>(2.69)</td>
<td>(2.43)</td>
<td>(2.74)</td>
<td>(2.04)</td>
<td>(2.00)</td>
</tr>
<tr>
<td>N</td>
<td>206</td>
<td>206</td>
<td>206</td>
<td>206</td>
<td>206</td>
</tr>
<tr>
<td>Implied Long-Run</td>
<td>6.24***</td>
<td>5.35***</td>
<td>5.93***</td>
<td>4.55***</td>
<td>4.50***</td>
</tr>
<tr>
<td>Tax Incentive Elasticity</td>
<td>(2.10)</td>
<td>(1.76)</td>
<td>(2.14)</td>
<td>(0.95)</td>
<td>(0.99)</td>
</tr>
<tr>
<td>Instrument Lags</td>
<td>1</td>
<td>1.2</td>
<td>1.2,4</td>
<td>1.3,4</td>
<td>3,4</td>
</tr>
<tr>
<td>Difference-in-Sargan p-value</td>
<td>0.26</td>
<td>0.23</td>
<td>0.54</td>
<td>0.19</td>
<td>0.19</td>
</tr>
<tr>
<td>First-Stage F-stat</td>
<td>4.28</td>
<td>2.12</td>
<td>3.50</td>
<td>12.95</td>
<td>19.15</td>
</tr>
</tbody>
</table>

The dependent variable is the natural log of R&D expenditures. Each column estimated with two-stage least squares. First-stage F-statistic tests the excluded instruments. All columns include state fixed effects and time dummies. Clustered standard errors by state in parentheses. “Instrument Lags” refers to instruments constructed with the referenced lags of state tax policy. For example, in column (2) I instrument the endogenous $RDTaxIncentiveRate$ with $RDTaxIncentiveRate_{it}^{fed}$, which I construct by conditioning on the first lag of state tax policy, and $RDTaxIncentiveRate_{it}^{fed}$ which I create by conditioning on the second lag of state tax policy. The table calculates the Difference-in-Sargan test by excluding the instrument computed with the shortest listed lag length with the null hypothesis that the excluded instrument is valid. The implied long-run elasticity is the coefficient of the tax incentive rate divided by one minus the coefficient on the lagged dependent variable with the standard errors calculated with the delta method. *, **, ***: significant at 10%, 5%, 1%.
Table 5: Alternative Forms of the Instrument Also Show Large Effects

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \ln(\text{RDTaxIncentiveRate}_{it}^{\text{fed}}) \times \text{piggybacked} )</td>
<td>4.16**</td>
<td>3.97***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.08)</td>
<td>(1.96)</td>
<td></td>
</tr>
<tr>
<td>( \ln(\text{RDTaxIncentiveRate}_{it}^{\text{fed}}) \times \text{nonpiggybacked} )</td>
<td>4.35*</td>
<td>4.11*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.24)</td>
<td>(2.14)</td>
<td></td>
</tr>
<tr>
<td>( \ln(\text{RDTaxIncentiveRate}_{it}^{\text{PL101-239}}) )</td>
<td>3.14**</td>
<td></td>
<td>(1.39)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \ln(\text{RD}_{it-2}) )</td>
<td>0.38***</td>
<td>0.38***</td>
<td>0.41***</td>
</tr>
<tr>
<td></td>
<td>(0.12)</td>
<td>(0.11)</td>
<td>(0.11)</td>
</tr>
<tr>
<td>( \ln(\text{GSP}_{it}) )</td>
<td>0.54</td>
<td></td>
<td>(0.35)</td>
</tr>
<tr>
<td>( \ln(\text{Federal RD}_{it-2}) )</td>
<td>0.23***</td>
<td>0.21***</td>
<td>0.21***</td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.08)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>( \ln(\text{Academic RD}_{it}) )</td>
<td>-0.15</td>
<td>-0.30</td>
<td>-0.16</td>
</tr>
<tr>
<td></td>
<td>(0.22)</td>
<td>(0.26)</td>
<td>(0.20)</td>
</tr>
<tr>
<td>( \text{Unemployment Rate}_{it} )</td>
<td>-1.45</td>
<td>-1.48</td>
<td>-0.72</td>
</tr>
<tr>
<td></td>
<td>(3.04)</td>
<td>(2.98)</td>
<td>(2.41)</td>
</tr>
<tr>
<td>( N )</td>
<td>206</td>
<td>206</td>
<td>206</td>
</tr>
<tr>
<td>( \text{Implied Long-Run} )</td>
<td>6.69***</td>
<td>6.36***</td>
<td></td>
</tr>
<tr>
<td>( \text{Tax Incentive Elasticity (Piggybacked)} )</td>
<td>(2.52)</td>
<td>(2.42)</td>
<td></td>
</tr>
<tr>
<td>( \text{Implied Long-Run} )</td>
<td>7.01**</td>
<td>6.59**</td>
<td></td>
</tr>
<tr>
<td>( \text{Tax Incentive Elasticity (Non-Piggybacked)} )</td>
<td>(2.74)</td>
<td>(2.67)</td>
<td></td>
</tr>
<tr>
<td>( \text{Implied Long-Run} )</td>
<td></td>
<td></td>
<td>5.36***</td>
</tr>
<tr>
<td>( \text{Tax Incentive Elasticity (PL101-239)} )</td>
<td></td>
<td></td>
<td>(1.83)</td>
</tr>
</tbody>
</table>

The dependent variable is the natural log of R&D expenditures. Columns (1) and (2) use separate policy variables for states that piggybacked and states that did not piggyback to the federal R&D tax credit in 1990. Column (3) calculates the instrument using only variation from PL101-239. The estimator is two-stage least squares. This table reports coefficients as elasticities except for the unemployment rate, which is a semielasticity. All columns include state fixed effects and time dummies. Clustered standard errors by state in parentheses. The implied long-run elasticity is the coefficient of the tax rate divided by one minus the coefficient on the lagged dependent variable with the standard errors calculated with the delta method. *, **, ***: significant at 10%, 5%, 1%.
Table 6: Sample Modifications of the Baseline Instrumental Variables Models Also Show Large Effects

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\ln(RDTaxIncentiveRate_{it})$</td>
<td>3.21**</td>
<td>3.22*</td>
<td>6.29***</td>
<td>3.41***</td>
</tr>
<tr>
<td></td>
<td>(1.30)</td>
<td>(1.82)</td>
<td>(1.75)</td>
<td>(1.66)</td>
</tr>
<tr>
<td>$\ln(RD_{it-2})$</td>
<td>0.45***</td>
<td>0.32**</td>
<td>0.09</td>
<td>0.44***</td>
</tr>
<tr>
<td></td>
<td>(0.10)</td>
<td>(0.16)</td>
<td>(0.10)</td>
<td>(0.11)</td>
</tr>
<tr>
<td>$\ln(Federal\ RD_{it-2})$</td>
<td>0.23***</td>
<td>0.24***</td>
<td>0.37***</td>
<td>0.20***</td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.07)</td>
<td>(0.13)</td>
<td>(0.07)</td>
</tr>
<tr>
<td>$\ln(Academic\ RD_{it})$</td>
<td>-0.22</td>
<td>-0.25</td>
<td>0.16</td>
<td>-0.20</td>
</tr>
<tr>
<td></td>
<td>(0.18)</td>
<td>(0.20)</td>
<td>(0.27)</td>
<td>(0.20)</td>
</tr>
<tr>
<td>$Unemployment\ Rate_{it}$</td>
<td>-2.15</td>
<td>1.59</td>
<td>-5.19*</td>
<td>-0.62</td>
</tr>
<tr>
<td></td>
<td>(2.61)</td>
<td>(2.86)</td>
<td>(3.00)</td>
<td>(2.46)</td>
</tr>
<tr>
<td>$N$</td>
<td>202</td>
<td>199</td>
<td>143</td>
<td>287</td>
</tr>
<tr>
<td>$Implied\ Long-Run$</td>
<td>5.80***</td>
<td>4.71**</td>
<td>6.88***</td>
<td>6.15***</td>
</tr>
<tr>
<td>$Tax\ Incentive\ Elasticity$</td>
<td>(1.72)</td>
<td>(1.98)</td>
<td>(1.45)</td>
<td>(2.29)</td>
</tr>
</tbody>
</table>

The dependent variable is the natural log of R&D expenditures. The key regressor $\ln(RDTaxIncentiveRate_{it})$ is instrumented with $RDTaxIncentiveRate_{it}^{fed}$. The estimator is two-stage least squares. First-stage F-statistic is for the excluded instrument. This table reports coefficients as elasticities except for the unemployment rate, which is a semielasticity. All columns include state fixed effects and time dummies. Clustered standard errors by state in parentheses. The implied long-run elasticity is the coefficient of the tax rate divided by one minus the coefficient on the lagged dependent variable with the standard errors calculated with the delta method. *, **, ***: significant at 10%, 5%, 1%.
<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(RDTaxIncentiveRate_{it}^{fed})</td>
<td>4.71***</td>
<td>4.99**</td>
<td>2.73**</td>
<td>3.32**</td>
<td>3.41**</td>
</tr>
<tr>
<td></td>
<td>(1.59)</td>
<td>(2.05)</td>
<td>(1.17)</td>
<td>(1.60)</td>
<td>(1.68)</td>
</tr>
<tr>
<td>ln(RD_{it-2})</td>
<td></td>
<td>0.47***</td>
<td>0.40***</td>
<td>0.40***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.11)</td>
<td>(0.11)</td>
<td>(0.12)</td>
<td></td>
</tr>
<tr>
<td>ln(GSP_{it})</td>
<td></td>
<td></td>
<td>0.62**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.32)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ln(Federal RD_{it-2})</td>
<td>0.39***</td>
<td>0.19***</td>
<td>0.22***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.12)</td>
<td>(0.07)</td>
<td>(0.06)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ln(Academic RD_{it})</td>
<td>0.07</td>
<td>-0.33</td>
<td>-0.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.29)</td>
<td>(0.24)</td>
<td>(0.21)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unemployment Rate_{it}</td>
<td>-0.64</td>
<td>-1.03</td>
<td>-0.90</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3.23)</td>
<td>(2.58)</td>
<td>(2.60)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>226</td>
<td>226</td>
<td>206</td>
<td>206</td>
<td>206</td>
</tr>
<tr>
<td>Implied Long-Run</td>
<td></td>
<td>5.12***</td>
<td>5.49***</td>
<td>5.73***</td>
<td></td>
</tr>
<tr>
<td>Tax Incentive Elasticity</td>
<td>(1.70)</td>
<td>(2.02)</td>
<td>(2.04)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First-Stage F-stat</td>
<td>3.07</td>
<td>3.61</td>
<td>2.81</td>
<td>2.04</td>
<td>2.12</td>
</tr>
</tbody>
</table>

The dependent variable is the natural log of R&D expenditures. Each column estimated with limited information maximum likelihood. First-stage F-statistic tests the excluded instruments. All columns include state fixed effects and time dummies. Clustered standard errors by state in parentheses. All columns use an over-identified first-stage using RDTaxIncentiveRate_{it}^{fed}, which I construct by conditioning on the first lag of state tax policy (the baseline instrument), and RDTaxIncentiveRate_{it}^{fed} which I create by conditioning on the second lag of state tax policy. The implied long-run elasticity is the coefficient of the tax incentive rate divided by one minus the coefficient on the lagged dependent variable with the standard errors calculated with the delta method. *, **, ***: significant at 10%, 5%, 1%.
Table 8: Reduced Form Regressions of R&D on the Instrument Also Show Large Effects

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\ln(\text{RDTaxIncentiveRate}^{fed}_{it})$</td>
<td>4.07*</td>
<td>4.38</td>
<td>2.64**</td>
<td>2.85**</td>
<td>2.96**</td>
</tr>
<tr>
<td></td>
<td>(2.34)</td>
<td>(2.67)</td>
<td>(1.00)</td>
<td>(1.02)</td>
<td>(1.11)</td>
</tr>
<tr>
<td>$\ln(\text{RD}_{it-2})$</td>
<td></td>
<td></td>
<td>0.52***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.11)</td>
<td></td>
<td>(0.08)</td>
</tr>
<tr>
<td>$\ln(\text{GSP}_{it})$</td>
<td></td>
<td></td>
<td></td>
<td>0.92***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.18)</td>
<td></td>
</tr>
<tr>
<td>$\ln(\text{Federal RD}_{it-2})$</td>
<td>0.36***</td>
<td></td>
<td>0.14**</td>
<td>0.18***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.11)</td>
<td></td>
<td>(0.06)</td>
<td>(0.06)</td>
<td></td>
</tr>
<tr>
<td>$\ln(\text{Academic RD}_{it})$</td>
<td>0.16</td>
<td>-0.39*</td>
<td>-0.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.32)</td>
<td>(0.22)</td>
<td>(0.21)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\text{Unemployment Rate}_{it}$</td>
<td>2.84</td>
<td>0.62</td>
<td>0.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.69)</td>
<td>(1.81)</td>
<td>(1.74)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$N$</td>
<td>226</td>
<td>226</td>
<td>206</td>
<td>206</td>
<td>206</td>
</tr>
</tbody>
</table>

The dependent variable is the natural log of R&D expenditures. The table reports reduced form regressions of R&D on the instrument, $\ln(\text{RDSubsidyRate}^{fed}_{it})$, which is the R&D tax incentive rate calculated using only changes from federal tax laws. This table reports coefficients as elasticities except for the unemployment rate, which is a semielasticity. All columns include state fixed effects and time dummies. Clustered standard errors by state in parentheses. *, **, ***: significant at 10%, 5%, 1%.