Beggar thy Neighbor? The In-State, Out-of-State, and Aggregate Effects of R&D Tax Credits[1]

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Abstract

The proliferation of R&D tax incentives among U.S. states in recent decades raises two questions: (1) Are these tax incentives effective in increasing in-state R&D? (2) How much of any increase is due to R&D being drawn away from other states? This paper answers (1) "yes" and (2) "nearly all." The paper estimates an augmented R&D factor demand model using state panel data from 1981-2002. I estimate that the long-run elasticity of in-state R&D with respect to the in-state user cost is about -2.5, while its elasticity with respect to out-of-state user costs is about +2.5, suggesting a zero-sum game among states.

[Keywords: R&D Tax Credits, R&D Price Elasticity; JEL Codes: H25, H23, O18, O38]

1 Introduction

Over the past two decades, R&D tax credits offered by U.S. states have become wide-spread and increasingly generous. This phenomenon is illustrated in Figure 1, which plots from 1981 to 2006 both the number of states offering R&D tax credits and the average effective credit rate among those states.[1] The process began with Minnesota in 1982, one year after the introduction of the U.S. federal R&D tax credit. As of 2006, 32 states provided a tax credit on general, company-funded R&D, and the average effective credit rate has grown approximately fourfold over this period to equal roughly half the value of the federal effective credit rate.[2][3] In fact, a number of states' R&D credits are considerably more generous than the federal credit.

The proliferation of state R&D credits raises two important questions. First, are these tax incentives effective in achieving their stated objective, to increase private R&D spending within the state? Second, insofar as the incentives do increase R&D within the state, how much of this increase is due to drawing R&D away from other states? This latter question is particularly important given recent U.S. court decisions on the constitutionality of state business credits (discussed further in Section 5).

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[1] The effective credit rate corresponds to the k_{it}^e term defined in Section 2.

[2] The statutory rate for the U.S. federal R&D tax credit is 20%. However, since the credit itself is considered taxable income, the effective credit rate is 20%(1-0.35) = 13%, using 0.35 as the corporate income tax rate.

[3] The sizeable jump in the average credit rate in 1990 was because many states piggyback on the federal definition of the R&D base amount (explained in Section 2 below) and this was changed in 1990 from a moving-average base to a fixed-period base, which increases the effective credit rate.

There has been surprisingly little empirical research on either of these questions. Most work on R&D tax incentives has investigated the effectiveness of the federal R&D credit. Studies in this area generally follow the approach of estimating the elasticity of R&D with respect to its price (user cost), exploiting panel data variation across firms, industries, or countries.[4] These studies, which generally find a statistically significant R&D cost elasticity at or above unity, are frequently cited in debates over the efficacy of state R&D credits.

It is not at all clear, however, that inferences based on existing firm-, industry-, or country-level data, which report only nationwide R&D expenditures for the unit of observation, can be extended to the state level. R&D may be mobile across states so that the cost of R&D in other states can affect how much R&D is performed in any one state. Thus, the "net" or "aggregate" R&D elasticity with respect to the cost of R&D, for a given state, is actually the difference between (the absolute value of) the elasticity with respect to the cost of performing R&D within the state and the elasticity with respect to the cost of performing R&D outside of the state.

This paper addresses the two questions posed above by estimating an augmented version of the standard R&D factor demand model using a two-way fixed effects esti- mator with state panel data from 1981-2004. An appealing aspect of using state-level information to identify the elasticities of R&D with respect to in-state and out-of-state

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[4]See, e.g., Hall [1993], Swenson [1992], and Berger [1993] for firm-level studies; Baily and Lawrence [1995] and Mamuneas and Nadiri [1996] for industry-level studies; and Bloom, Griffith, and Van Reenen [2002] for a country-level study.

costs is that state-level variation in the user cost of R&D is driven entirely by variation in R&D tax credits and corporate income tax rates, both of which are arguably exogenous to firms' contemporaneous R&D decisions.[5]

2 Data

State and federal R&D credits offer corporations credits against income tax liability based on the amount of qualified research done by the corporation within the state or country, respectively. U.S. states generally follow the federal Internal Revenue Code (IRC) definition of qualified research: the wages, materials expenses, and rental costs of certain property and equipment incurred in performing research "undertaken to discover information" that is "technological in nature" for a new or improved business purpose. State-level data on qualified research from tax returns is unavailable, but state data on industrial (company-performed) R&D expenditures by source of funding (company, federal, and other) from 1981-2004 are available from the National Science Foundation (NSF) (*Industrial Research and Development*, various issues). These data are biannual (odd years) from 1981-1996 and annual from 1997-2004.[6] Note the NSF

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[5]This approach of using tax code changes as natural experiments has been employed in the investment literature (see, e.g., Cummins, Hassett, and Hubbard 1994).

[6]Due to disclosure limitations, R&D spending for small states is often missing. The severity of this problem varies from year to year as the sample size of the underlying survey varies, but generally declines over time. Data is available for nearly all states by the end of the sample. In order to be sure that the data underreporting is not systematically related to any of the analysis variables, I have estimated results (1) based on a balanced panel of 11 large states from 1987-2004, and (2) using a

definition of R&D is somewhat broader than that of the IRC, which excludes late-stage product development.

Like most economic studies concerning R&D, this paper treats R&D as an input into a firm's production function. The actual input is the services of R&D capital (knowledge) formed by past and present R&D expenditures net of depreciation (obsolescence). The price for this factor is the implicit rental rate, or user cost, after taxes. The Neoclassical formula for the user cost of capital, derived in the seminal work of Hall and Jorgenson [1967], can be adapted easily to apply to R&D capital services.

Extending the standard Hall-Jorgenson formula to incorporate both state and federal tax considerations yields the following formula for the user cost of R&D capital (per dollar of investment):

$$
\rho_{it} = \frac{1 - s\left(k_{it}^e + k_{ft}^e\right) - z\left(\tau_{it}^e + \tau_{ft}^e\right)}{1 - \left(\tau_{it}^e + \tau_{ft}^e\right)} \left[r_t + \delta\right], \tag{1}
$$

where t indexes time.[7] The subscript i indicates a state-level variable, while the subscript f is used for federal-level variables. r_t is the real interest rate, and δ is the economic depreciation rate of R&D capital. τ_{it}^e and τ_{ft}^e denote the effective corporate income tax rates, while k_{it}^e and k_{ft}^e denote the effective R&D tax credit rates. s is

Heckman two-step estimator to allow for potential data-reporting/selection bias. The results from each of these estimations were quite similar to those reported below.

[7]This formula assumes that either the credit is refundable or the firm is in a sufficiently positive tax liability position that the credit may be exhausted in the current tax year. This assumption is supported by Hall (1993), who finds that during the 1981-91 period, over 80% of firms were in a positive tax position in any given year.

the share of NSF-reported R&D expenditures considered "qualified" R&D in the tax code. According to IRS Statistics on Income data, s is approximately 0.5. z denotes the present discounted value (PDV) of tax depreciation allowances. Given that labor and intermediate expenses are immediately deductible as are qualified R&D capital expenses (for all states and the federal government since 1954), $z = 1$.

The effective credit rate, k_{it}^e or k_{ft}^e, varies over time and states depending on design, statutory credit rate, and whether the credit is "recaptured" (taxed). There are three basic designs for existing R&D tax credits: (1) non-incremental, where all qualified R&D is eligible for the credit; (2) incremental with a fixed-period base, where only R&D above a base level, determined by the company's activity (sales and R&D) in a fixed past period, is eligible; and (3) incremental with a moving-average base, where the base level is determined by the company's recent activity.

For non-incremental credits and incremental credits with a fixed-period base, the effective credit rate on a marginal unit of R&D, assuming current R&D is above the base, is: $k_{it}^e = k_{it}(1 - \omega_{it}\tau_{it}^e)$, where k_{it} is the statutory (legislated) credit rate and ω_{it} is the share of R&D subject to recapture. Similarly, $k_{ft}^e = k_{ft}(1 - \omega_{ft}\tau_{ft}^e)$.[8] For incremental credits with a moving-average base, the base is current sales multiplied by the company's average R&D-sales ratio over n previous years. The marginal effective

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[8]Note the federal R&D tax credit was not recaptured from 1981 to 1988; in 1989, 50% of the credit was recaptured; since 1989, 100% of the credit has been recaptured. Recapturing in the IRC and in state tax codes is achieved by requiring firms to subtract the credit from expenses that would otherwise be deductible (see IRC Section 280(c)(1)).

credit rate is then: $k_{it}^e = k_{it}(1 - \omega_{it}\tau_{it}^e)\left(1 - \frac{1}{n}\sum_{s=1}^n (1 + r_{t-s})^{-s}\right)$, again assuming that current R&D is above the base.[9] As has been pointed out in numerous discussions of R&D tax credits, this moving-average formula drastically reduces the value of the credit, as current R&D spending serves to lower, one-for-one, the amount of R&D that qualifies for the credit in future years.

In the United States, the *effective* federal and state corporate tax rates generally are lower than the *statutory* tax rates, τ_{it} and τ_{ft}, because the taxes a firm pays to states are deductible from its federal tax liability, and often vice-versa. This makes τ_{ft}^e a function of τ_{it}^e: $\tau_{ft}^e = \tau_{ft}(1 - \tau_{it}^e)$; and τ_{it}^e a function of τ_{ft}^e: $\tau_{it}^e = \tau_{it}\left(1 - \lambda_{it}\tau_{ft}^e\right)$, where λ_{it} is the fraction of federal taxes that are deductible from state taxable income. The two equations can be solved in terms of the published statutory tax rates: $\tau_{ft}^e = \frac{\tau_{ft}(1-\tau_{it})}{1-\lambda_{it}\tau_{ft}\tau_{it}}$, and $\tau_{it}^e = \tau_{it}\left[\frac{1-\lambda_{it}\tau_{ft}}{1-\lambda_{it}\tau_{ft}\tau_{it}}\right]$.

The values of k_{it}, ω_{it}, τ_{it}, and λ_{it} for the 50 states plus the District of Columbia over the period 1981-2002 were compiled from a variety of sources (see Wilson [2007] for details), with the principal source being online state corporate tax forms.

3 Empirical Model

In order to analyze the determination of private R&D conducted within a state and, therefore, the impact of R&D tax credits, I begin by modeling the demand for R&D

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[9]The assumption that current R&D is above the base level for incremental credits can be justified by the fact that in the Compustat manufacturing sample analyzed by Hall (1993), the percentage of firms with current R&D above their base was 60-80% depending on year (between 1981-1991).

capital by a representative firm in the economy.

First, consider the case where the firm's output in state i in year t is produced via a production function with a constant elasticity of substitution (γ) between R&D services (R_{it}) and other inputs. The first-order conditions for profit-maximization yield a standard factor demand equation relating R&D services (R_{it}) to its user cost (ρ_{it}) and output (Y_{it}): $R_{it} = \zeta Y_{it} \rho_{it}^{-\gamma}$, where ζ is the CES distribution parameter. Notice that the elasticity of substitution, γ, is also the elasticity of R&D with respect to its user cost (in absolute value). This factor demand equation forms the theoretical basis for the estimation of the R&D cost elasticity in most previous studies in this area.

Now consider the case where the R&D capital input into the firm's state i production function consists of two subcomponents: in-state R&D services (R_{it}^{in}) and out-of-state R&D services (R_{it}^{out}). The factor demand equation then becomes:

$$R_{it}^{in} = \zeta Y_{it} \left(\rho_{it}^{in}\right)^{-\theta} \left(\rho_{it}^{out}\right)^{\phi}, \tag{2}$$

where ρ_{it}^{in} is the in-state R&D user cost (i.e., the user cost faced by the firm if it conducts R&D within state i) and ρ_{it}^{out} is the out-of-state R&D user cost (i.e., the user cost faced by the firm if it conducts R&D outside of state i). $-\theta$ is the elasticity of in-state R&D with respect to the in-state R&D user cost, or simply the "in-state elasticity." ϕ is the elasticity of in-state R&D with respect to the out-of-state R&D user cost, or simply the "out-of-state elasticity." The out-of-state elasticity reflects the degree of interstate mobility of R&D activities. A finding of $\phi > 0$ indicates that firms, or at least their R&D funds, are able to relocate to some extent in response to changes

in relative user costs. The sum of the external and internal R&D elasticities, $\phi - \theta$, is the "aggregate" or "net" R&D elasticity – the elasticity of R&D with respect to an equiproportional change in all R&D user costs.

The factor demand equation (2) can be straightforwardly estimated in its log-linear form via OLS. However, before doing so, one should take two considerations into account. First, there are likely to be unobserved state-specific factors that influence the R&D spending in a state. For example, the level of human capital, the relative cost of labor, the quality of public infrastructure, environmental and labor regulations, natural amenities, and the cost of land are all factors that are fixed at the state level (at least over the sample period) and may influence where firms choose to locate their R&D activities and the intensity with which they conduct R&D in a given location. If these state-specific factors are correlated with the user cost of R&D or any other independent variable in the regression, the estimator of the model's parameters will be inconsistent unless one controls for these fixed effects. Second, state-level R&D likely will be affected by aggregate, macroeconomic factors such as aggregate demand, technological opportunities, patent policy, and federal tax policy. Thus, it is important either to control for these factors explicitly or to control for general year effects.

To allow for the possibility of partial adjustment of R&D capital, e.g., due to adjustment costs, I extend the above static model by including the lagged dependent variable. Incorporating state and year fixed effects and adding an i.i.d. error term, the estimating equation becomes:

$$\log\left(R_{it}^{in}\right) = \lambda \log\left(R_{it-1}^{in}\right) - \theta \log\left(\rho_{it}^{in}\right) + \phi \log\left(\rho_{it}^{out}\right) + \alpha \log\left(Y_{it}\right) + f_i + f_t + \nu_{it}, \quad (3)$$

where Y_{it} is state output. In this specification, $-\theta$ and ϕ identify the *short-run* R&D elasticities with respect to the in-state and out-of-state user costs, respectively. The *long-run* elasticities are given by $-\theta/\left(1-\lambda\right)$ and $\phi/\left(1-\lambda\right)$.

The use of a lagged-dependent-variable model here is complicated by the fact that the NSF state R&D data are biannual for the early part of the sample. Thus, R_{it-1}^{in} is missing for years 1981-1997. Fortunately, the independent variables are observed annually. It can be shown that, under certain reasonable conditions, the model can thus be consistently estimated by simply pooling the biannual and annual samples while allowing the coefficient on the lagged dependent variable to vary across the two periods (see Wilson [2007]).

It should also be noted that, theoretically, the R&D inputs into the production function are R&D capital services, which are unobserved. I assume that the flow of R&D capital services in a year is proportional to R&D investment. As a robustness check, I also obtain results based on an R&D stock constructed using the perpetual inventory method assuming a 15% depreciation rate and filling in even-year investment data via interpolation between adjacent years. The results are qualitatively similar (available in Wilson [2007]).

I employ the standard within-groups estimator, which is simply an OLS regression on mean-differenced data.[10] The OLS estimator is inconsistent if state legislatures

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[10]The within estimator is potentially biased in finite samples when the regressor set includes the

and governors are more likely to enact or increase R&D tax credits when current R&D relative to their state average is particularly low. Note, however, that for such reverse causality to cause bias, the link must be contemporaneous: if current R&D affects tax policy only in future periods (as is likely, given the typical lag between the time when tax changes are passed and when they go into effect), then the inclusion of lagged R&D as a regressor will control for this effect. Moreover, if I replace contemporaneous user costs with lagged user costs, which cannot be affected by current R&D spending, I obtain very similar results, suggesting that any bias is negligible.

4 Results

The main results from estimating the log-linear model discussed above are shown in Table 1. All regressions include year dummies. The dependent variable in all regressions is the log of company-funded industrial R&D spending, deflated by the GDP deflator.

To facilitate comparisons to previous studies of the R&D cost elasticity, I first estimate an R&D cost elasticity omitting the out-of-state R&D user cost, ρ_{it}^{out}. The estimated short-run elasticity of in-state R&D with respect to in-state cost $(-\theta)$ is

lagged dependent variable (Nickell 1981). Fortunately, the bias goes to zero as $T \to \infty$. As a check on the unbiasedness of the estimates in this paper, I additionally estimate the model using the Bias-Corrected Least Squares Dummy Variable (LSDVC) estimator, which is based on adjusting the within estimates using an approximation of the bias term. The results confirm that the original estimates are approximately unbiased (LSDVC results available upon request).

-1.21 with a robust standard error of 0.44 (Column (1)).[11] The long-run elasticity is -2.18 (s.e. $= 0.81$). These elasticities are well within the range of R&D cost elasticities found in previous studies. Evaluated at the mean user cost for the sample, these elasticities imply that a 1 *percentage point* increase in a state's effective R&D credit rate results in an increase in in-state R&D of around 1.7% in the short-run and 3.0% in the long-run.[12] State GDP is found to be positively and significantly associated with R&D, with a coefficient of 0.73 (0.18). I also control for the state's federally funded industrial R&D spending (lagged one period to avoid any spurious correlation from contemporaneous company funding affecting federal funding). The estimated coefficient on federally funded industrial R&D is -0.05 (0.01). This result of federal R&D funding crowding out private R&D funding is consistent with the industry-level results reported by Mamuneas and Nadiri [1996].

Columns (2)-(4) of Table 1 show the results of *explicitly* adding the out-of-state cost to the R&D factor demand regression equation. (Note that, to some extent, the out-of-state cost implicitly was taken account of in the previous regression by year effects.) The regression underlying column (2) uses a weighted average of the R&D user costs of the five states closest to state i. The weight between state i and some nearby state j is simply the inverse of the distance between their population centroids (from

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[11]Standard errors are estimated using a VC matrix allowing for AR(1) errors within-state and panel (state) heteroskedasticity.

[12]The marginal effect is calculated as $-\theta \frac{\partial \ln \rho}{\partial k_{it}^e} = \frac{-\theta}{1 - \left(k_{it}^e + k_{ft}^e\right) - z\left(\tau_{it}^e + \tau_{ft}^e\right)}$. The sample mean of this denominator is 0.72.

U.S. Census Bureau). The second regression uses a similarly constructed proximity-weighted average of the user costs of the 10 closest states; and the third regression uses a proximity-weighted average of all other states' user costs.

Adding the out-of-state cost is found to have only a small effect on the estimated in-state elasticity – consistent with the hypothesis that the year effects picked up much of the effect of out-of-state costs in the previous regression. Depending on which measure of out-of-state cost is used, the estimated in-state elasticity is between -1.26 and -1.43 in the short run, and between -2.29 and -2.58 in the long run (all significant below the 1% level). The out-of-state elasticity, on the other hand, is estimated to be positive and significant for each of the three measures of out-of-state cost. Using the narrowest measure – a weighted-average of R&D costs in the five closest states, the short-run in-state elasticity is 2.06, and statistically significant at the 5% level. The implied long-run in-state elasticity is 3.72. The implied aggregate-cost elasticity – the sum of the in-state and out-of-state elasticities – is relatively small and statistically insignificant.

As one broadens the measure of out-of-state cost by including more outside states in the weighted average, which reduces cross-sectional variation, the out-of-state elasticity estimate becomes increasingly imprecise. Nonetheless, even with the broader out-of-state cost measures used in the regressions underlying columns (3) and (4), the elasticity is found to be positive and significant at below the 5% level, and in no case is the aggregate-cost elasticity found to be significantly different from zero.

Columns (1)-(3) of Table 2 provide estimates based on regressions analogous to

those underlying columns (2)-(4) of Table 1 but replacing the year dummies with a year trend and GDP to capture aggregate macroeconomic shocks to R&D spending.[13] I also separately included $\log(r_t + \delta)$ even though this term is already part of $\log\left(\rho_{it}^{in}\right)$ and $\log\left(\rho_{it}^{out}\right)$ to allow for possible endogeneity of the real interest rate. (Note $\log(r_t + \delta)$ is absorbed by the year effects in the previous regressions.) The estimated elasticities are quite similar to those in Table 1, but are estimated with much greater precision. The in-state elasticity is around -1.5 in the short run while the out-of-state elasticity is around $+1.6$. The long-run elasticities are somewhat higher, at around -2.5 for the in-state elasticity and $+2.8$ for the out-of-state elasticity. In both the short and long run, the aggregate-cost elasticity is essentially zero (and precisely estimated). Moreover, as shown by comparing among columns (1)-(3), the results are quite consistent across all three measures of out-of-state cost.[14]

Alternative weighting schemes for measuring the out-of-state user cost, not based on geographic proximity, yield very similar results. In particular, columns (4) and (5) of Table 2 show the results of weighting other states' user costs by proximity in technology and industry space. Technology proximity is the Euclidean distance between two states' vectors of patent shares across 401 technology classes (from the U.S.

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[13]Unreported regressions including either a quadratic time trend or presidential-term dummies yielded similar results.

[14]Another finding worthly of note is that holding a state's own GDP constant, the national GDP has a negative and significant effect on state R&D spending, suggesting that R&D may relocate out of state not just in response to favorable changes in out-of-state costs, but also in response to comparatively faster out-of-state economic growth.

Patent and Trademark Office), while proximity in industry composition is measured by the Euclidean distance between two states' vectors of employment shares across 3-digit industries (from U.S. Bureau of Labor Statistics).

A number of additional exercises, not shown, confirm the robustness of these regressions (see Wilson [2007]). These robustnesss checks include: verifying that the estimated elasticities are not biased due to the omission of even-year data between 1981-1997; replacing the flow (investment) of R&D as the dependent variable with an imputed measure of the stock of R&D; including additional out-of-state factors (constructed as above) such as out-of-state GDP and population; allowing for potential R&D data-reporting/selection bias via a Heckman two-step estimator; and excluding Alaska and Hawaii from the sample.

5   Policy Implications and Conclusion

Summarizing the results above, I estimate an in-state R&D cost elasticity that is negative and above unity and an out-of-state cost elasticity that is of equal magnitude but opposite sign. Thus, returning to the two questions posed in Section 1, I find state R&D tax credits are indeed effective at increasing R&D within the state. I also find, however, that nearly all of the resulting increase comes at the expense of reduced R&D spending in other states. Specifically, the estimates imply that, on average, a 1 percentage point increase in a state's effective R&D credit rate leads in the long run to a $3-4\%$ increase in R&D spending within the state and a $3-4\%$ decrease in R&D

spending outside of the state, such that R&D nationwide is essentially unchanged.[15]

These findings have important policy implications. First, they imply that a state's R&D fiscal policies impose an externality on R&D activity and its associated benefits in other states. In light of recent U.S. court decisions, this implication raises concerns about the constitutionality of state R&D credits.[16] The Supreme Court has established that a state tax policy potentially violates the Commerce Clause of the Constitution if the policy "will in its practical operation work discrimination against interstate commerce,..., by providing a direct commercial advantage to local business." (*Bacchus Imports v. Dias* [1984]). Cases challenging business tax credits currently are pending in several states. The findings of this paper suggest state R&D tax credits may indeed "work discrimination" both in statute and in practice.

Second, the result that the in-state and out-of-state elasticities are of opposite signs and equal magnitude suggests high long-run geographic mobility in R&D activity. This mobility could reflect either shrinking spending per R&D facility (the intensive margin) or a declining number of facilities (the extensive margin) in high-cost states relative to low-cost states. Unfortunately, adequate data on R&D spending by state broken down into these separate margins is not currently available, but may be a fruitful area for research in the future. The result also implies that the net elasticity

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[15]Note these are the in-state and out-of-state responses of *total* R&D. The responses of credit-eligible R&D, which excludes late-stage development, could well be larger, depending on the degree of complementarity between early- and late-stage R&D.

[16]See Stark and Wilson (2006) for a discussion of this issue.

of R&D – i.e., the effect on national R&D of an equiproportional change in all states' R&D user costs – is quite small, suggesting that the setting of R&D tax credits by states is nearly a zero-sum game.
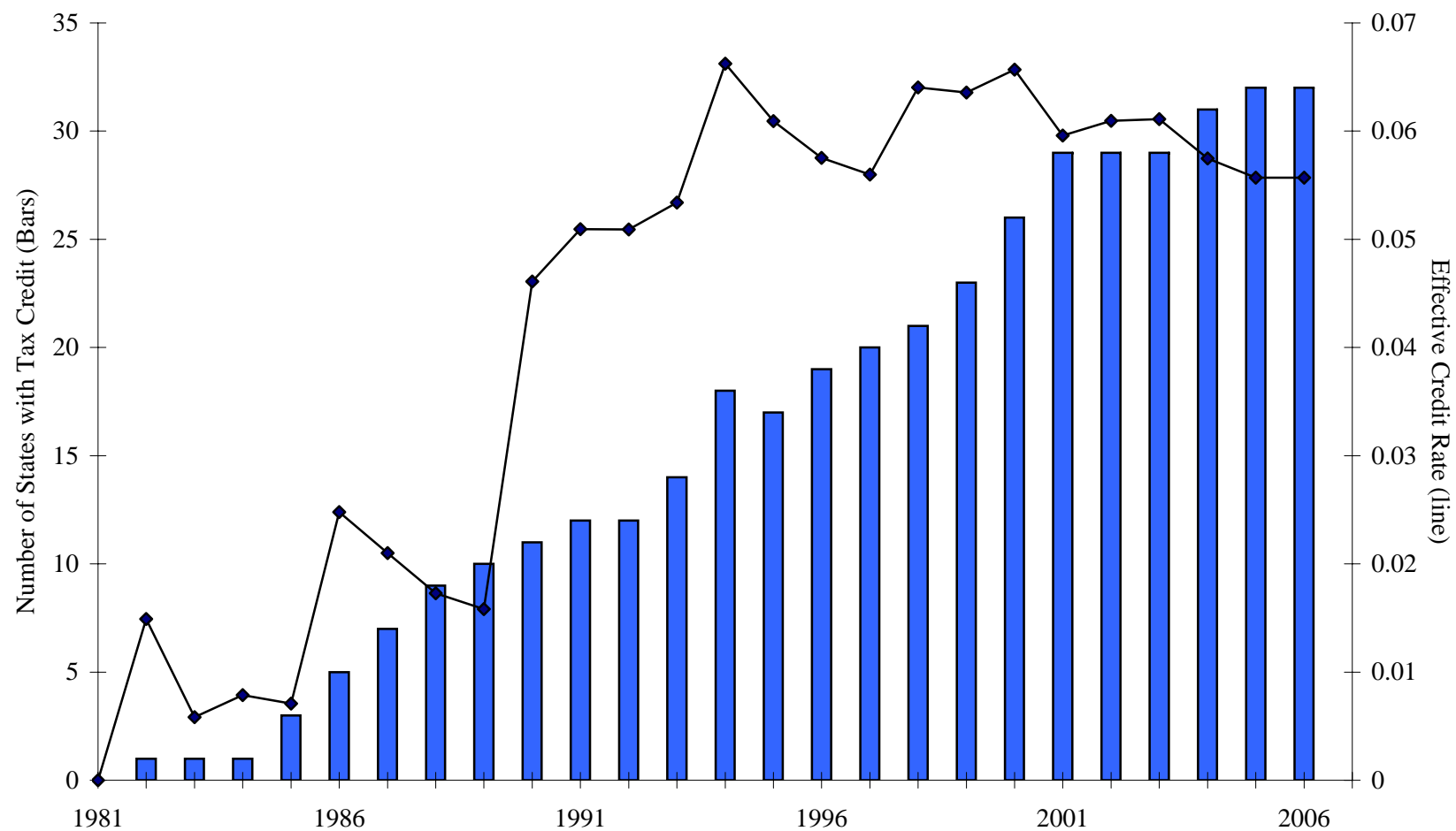
What these findings imply regarding the effectiveness of the U.S. federal R&D tax credit depends on the degree of international mobility of R&D. In the current era of globalization, it seems likely that large foreign and U.S. multinationals, which are responsible for the bulk of U.S. R&D spending, may fairly easily reallocate R&D activity to (from) the U.S. in response to favorable (unfavorable) changes in U.S. policy vis-a-vis foreign policy. Thus, the degree of international R&D mobility remains an important topic for future research.

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Figure 1. Number and Average Value of State R&D Tax Credits in the U.S., 1981-2006

Number of States with Tax Credit (Bars)

Effective Credit Rate (line)

1981   1986   1991   1996   2001   2006

Source: Author's Calculations

TABLE 1.

Within Estimates of R&D Cost Elasticities (with Year Effects)

Dependent Variable: Company R&D

Explanatory Variable	(1)	5 Closest (2)	10 Closest (3)	All (4)
Internal (In-state) R&D cost	-1.21 ***	-1.43 ***	-1.37 ***	-1.26 ***
	(0.44)	(0.45)	(0.45)	(0.44)
External (Out-of-State) R&D cost		2.06 **	2.44 **	4.71 **
		(0.94)	(1.18)	(2.13)
Federal R&D (-1)	-0.05 ***	-0.05 ***	-0.05 ***	-0.05 ***
	(0.01)	(0.01)	(0.01)	(0.01)
Company R&D (-1) [biannual periods]	0.49 ***	0.47 ***	0.47 ***	0.47 ***
	(0.04)	(0.04)	(0.04)	(0.04)
Company R&D (-1) [annual periods]	0.45 ***	0.45 ***	0.45 ***	0.45 ***
	(0.05)	(0.05)	(0.05)	(0.05)
State GDP	0.73 ***	0.63 ***	0.64 ***	0.64 ***
	(0.18)	(0.19)	(0.19)	(0.19)
Implied Estimates (based on coefficients above):				
Short Run Aggregate-Cost Elasticity		0.63	1.07	3.44
		(0.93)	(1.17)	(2.13)
Long-Run Internal-Cost Elasticity	-2.18 ***	-2.58 ***	-2.48 ***	-2.29 ***
	(0.81)	(0.83)	(0.82)	(0.80)
Long-Run External-Cost Elasticity		3.72 **	4.41 **	8.54 **
		(1.72)	(2.18)	(3.94)
Long Run Aggregate-Cost Elasticity		1.14	1.93	6.24
		(1.69)	(2.13)	(3.92)
Year Coverage	1981-2004	1981-2004	1981-2004	1981-2004
Number of state-year obs.	365	365	365	365
Log Likelihood	135.076	138.219	137.978	138.321

Notes: All variables are measured in natural logs. Standard errors are shown in parentheses.
Standard errors are robust to panel (state) heteroskedasticity and AR(1) within-state autocorrelation.
The out-of-state R&D costs are geographical-proximity-weighted averages of R&D user costs in the
five closest states (Column (2)), ten closest states (Column (3)), and all other states (Column (4)).
*** denotes significance at the 99% level
** denotes significance at the 95% level
* denotes significance at the 90% level

TABLE 2.

Within Estimates of R&D Cost Elasticities (without Year Effects)

Dependent Variable: Company R&D

Explanatory Variable	5 closest (1)	10 closest (2)	All (3)	Patents (4)	Employment (5)
In-State R&D cost	-1.50 ***	-1.48 ***	-1.41 ***	-1.23 ***	-1.13 ***
	(0.44)	(0.43)	(0.43)	(0.39)	(0.40)
Out-of-State R&D cost	1.64 ***	1.64 ***	1.62 ***	1.42 ***	1.27 ***
	(0.50)	(0.50)	(0.51)	(0.48)	(0.48)
Fed R&D (-1)	-0.06 ***	-0.06 ***	-0.06 ***	-0.06 ***	-0.06 ***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Year	0.03 ***	0.03 **	0.03 **	0.03 **	0.03 **
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
State GDP	0.70 ***	0.72 ***	0.77 ***	0.82 ***	0.83 ***
	(0.16)	(0.15)	(0.16)	(0.16)	(0.16)
National GDP	-0.92 **	-0.92 **	-0.88 *	-1.01 **	-1.03 **
	(0.46)	(0.46)	(0.49)	(0.49)	(0.48)
Company R&D (-1) [biannual periods]	0.43 ***	0.44 ***	0.45 ***	0.45 ***	0.45 ***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Company R&D (-1) [annual periods]	0.40 ***	0.40 ***	0.40 ***	0.40 ***	0.39 ***
	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)
Real Interest Rate plus Depreciation Rate	0.31 **	0.28 **	0.26 *	0.27 *	0.25 *
	(0.13)	(0.13)	(0.15)	(0.15)	(0.15)
Implied Estimates (based on coefficients above):					
Short Run Aggregate-Cost Elasticity	0.14	0.16	0.20	0.18	0.14
	(0.20)	(0.20)	(0.22)	(0.22)	(0.22)
Long-Run In-State Elasticity	-2.51 ***	-2.47 ***	-2.34 ***	-2.05 ***	-1.86 ***
	(0.74)	(0.74)	(0.72)	(0.67)	(0.68)
Long-Run Out-of-State Elasticity	2.75 ***	2.74 ***	2.68 ***	2.36 ***	2.10 ***
	(0.82)	(0.83)	(0.85)	(0.80)	(0.79)
Long Run Aggregate-Cost Elasticity	0.24	0.27	0.34	0.30	0.24
	(0.32)	(0.33)	(0.36)	(0.37)	(0.35)
Year Coverage	1981-2004	1981-2004	1981-2004	1981-2004	1981-2004
Number of state-year obs.	365	365	365	365	365
Log Likelihood	134.417	134.497	133.662	133.259	132.749

Notes: All variables are measured in natural logs. Standard errors are shown in parentheses. Standard errors are robust to panel (state) heteroskedasticity and AR(1) within-state autocorrelation. The out-of-state R&D costs are as follows: geographical-proximity-weighted averages of R&D user costs in the five closest states (Column (1)), ten closest states (Column (2)), and all other states (Column (3)); weighted average of R&D user costs in all other states, weighting by similarity between own state's and other state's patent composition across technology classes (Column (4)); and weighted average of R&D user costs in all other states, weighting by similarity between own state's and other state's employment composition across 3-digit industries (Column (5)).

*** denotes significance at the 99% level

** denotes significance at the 95% level

* denotes significance at the 90% level