Economic Development Quarterly
Volume 22 Number 2
May 2008 136-148

10.1177/0891242408316728
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State R&D Tax Credits and High-Technology Establishments

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This empirical research examines the effects of state research and development (R&D) tax credits on the size of the high-technology business sector. In addition to a description of federal and state R&D tax credit programs, this article estimates a model that relates each of the two alternate measures of high-technology establishments in each state to state R&D tax credit, controlling for other factors. The results show that the initiation of a state R&D tax credit has significant and positive effects on the number of the state's high-technology establishments relative to its population or total business establishments. This research provides empirical evidence about the role of state R&D tax incentives in technology-based economic development.

Keywords: *R&D tax credit; economic development; high technology; business establishment*

There has been increasing interest in both the policy and research communities about the role of science and technology policy in state economic development. The policy instruments in state and local economic development have been shifting from general tax abatements and public services to specific incentives and services for certain business activities with high economic returns. With the increasing consensus that technology and innovation are important drivers of economic development, state governments have launched a variety of programs to facilitate technology-based economic development in their jurisdictions.[1]

As one important policy instrument to stimulate industrial innovation, the R&D tax credit has become increasingly popular at the state level since the early 1980s.[2] Although R&D tax credits are incentives to encourage industrial R&D expenditure, state governments often expect that they will achieve better performance in economic development as a result of enhanced innovative capacity and industrial competitiveness through additional induced industrial R&D efforts within their boundaries.

As the primary recipients of R&D tax credits, high-technology industries are the primary target of R&D tax incentives because they are more research intensive than other segments of the private sector. The growth of the high-technology sector is an important and necessary step toward better economic prospects, given its contribution to market expansion, productivity enhancement, and industrial competitiveness. Therefore, the effects of state R&D tax credits on economic development depend on the response of the high-technology sector to this incentive program.

This article is an empirical exploration of the effects of state R&D tax credits on the size of the high-technology sector in states measured by two alternate indicators: the number of high-technology establishments per 1,000 of population or the share of high-technology business establishments. Based on a panel of 49 states in the period from 1994 to 2002, the statistical results indicate that R&D tax credits do have significant and positive impacts on the growth of high-technology sector in the states. Given the great importance of high-technology industries to economic development, this article provides empirical evidence to state-level policy making in the arena of technology-based economic development.

Overview of State R&D Tax Credits

The R&D tax credit was first launched at the federal level under the Economic Recovery Tax Act of 1981. Companies were allowed to claim a credit against their federal income tax liability for qualified spending on research and experimentation above a base amount. The value of the credit equals the excess of research expenses

Author's Note: The author is grateful for the comments of three anonymous reviewers on earlier versions of this work.

Table 1
Overview of State R&D Tax Credit

Period (Year)	Number of States with R&D Credit at End of the Period (Year)	Number of Initiator States in the Period (Year)	Initiator States
1982	1	1	Minnesota
1983-1987	7	6	Arkansas, California, Indiana, Iowa, West Virginia, Wisconsin
1988-1992	13	6	Colorado, Illinois, Kansas, Massachusetts, North Dakota, Oregon
1993-1997	22	9	Arizona, Connecticut, Maine, Missouri, New Jersey, North Carolina, Pennsylvania, Rhode Island, Washington
1998-2002	32	10	Delaware, Georgia, Hawaii, Idaho, Maryland, Montana, New Mexico, South Carolina, Texas, Utah
2004	34	2	Louisiana, Ohio

from a defined base multiplied by the credit rate. Therefore, the base definition and the credit rate are two important elements that determine the magnitude of this tax incentive for individual companies.

As a temporary provision of the Internal Revenue Code, this tax credit has been extended many times with substantive changes over the years.[3] For instance, the credit rate was set at 25% in 1981 and then changed to 20% in 1989. In the period from1981 to 1989, the base was the average of qualified research expenses of the previous 3 years. In 1990, the federal government adopted a “fixed-base percentage” method, and the base amount was determined by multiplying a company’s average gross income in the previous 4 years by its fixed-base percentage.[4]

Two provisions were established to address the concerns of new start-up companies or companies that had no income or qualified research expenses for the computation of the fixed-base percentage. First, a constant 3% is assigned as the fixed-base percentage to these firms. Second, because the start-up firms often incur a substantial amount of R&D expenses but have little tax liability to materialize the credit, the federal government allows them to save their credit for future use. The unused tax credit could be carried forward up to 15 years, increased to 20 years since 1998.

The federal R&D tax credit program has diffused gradually to the state level, with the basic structure being copied by an increasing number of state governments. One year after the federal R&D tax credit, the state of Minnesota passed the first state R&D tax credit program. Realizing the importance and mobility of industrial R&D activities, more and more states initiated their own R&D tax credit to encourage private R&D within their boundaries.[5] The pace of initiation has been accelerated across 5-year intervals since 1983, from 6 initiator states in the period from 1983 to 1987 and from 1988 to 1992, to 9 in the period from 1993 to 1997, and to 10 in the period from 1998 to 2002. By the end of 2004, 34 states offered R&D tax credit (see Table 1 for details).

The state R&D credit is offered to companies against their state corporate income tax liability for qualified expenses of research conducted in the state. Although states generally follow the basic design of the federal R&D credit program, there are some differences. Although the majority of states apply the credit rate to the excess of qualified research expenses over a defined base, some states use the total qualified research expenses to calculate the credit.[6] The state credit rate on incremental expenses ranges from 2.5% (Minnesota after 1986) to 20% (Arizona before 2001 and Connecticut after 1993). The base amount is determined by either the fixed-base percentage or the moving average of research expenses of some preceding years. The unused tax credits can be carried forward to the next 15 years in most of the states.

As the direct target of state R&D tax credits, the industrial dollars spent in R&D are monetary inputs that are expected to generate desirable economic results to the states. The relationship between R&D inputs and economic results that governments expect is by no means linear or straightforward, given the substantial amount of uncertainty in industrial technology development, application, and commercialization. Realizing the complex nature of technology-driven economic development, state governments intend to maximize the economic benefits by establishing multiple objectives when authorizing state R&D tax credit programs. For instance, in the state of Washington, the legislature set up multiple criteria to measure the effectiveness of its R&D tax credit program (Washington Department of Revenue, 2003):

- Job creation
- The number of jobs created for Washington residents

- Company growth
- Diversification of the state's economy
- Growth in R&D investment
- Introduction of new products
- Movement of firms or the consolidation of firms into the state

This long list illustrates the state's intent to achieve technology-driven economic development through additional industrial R&D efforts. This single incentive program is expected to result in not only the growth of R&D investment and inward movement of high-technology companies but also other, longer term economic results, such as market expansion, company growth, job creation, and diversification of the state's economy.

To have a growing high-technology industrial sector is the key to better economic prospects. High-technology industries are important to economic development for several reasons. First, high-technology companies innovate and tend to gain market share, create new product markets, and use resources more productively (National Research Council, Hamburg Institute for Economic Research, & Kiel Institute for World Economics, 1996; Tassey, 2000). The R&D performed by high-technology industries helps to expand business and create high-wage jobs, and high-technology companies are often successful in foreign markets (National Science Board, 1998). There is also empirical evidence to support the importance of high-technology industries in economic growth.[7] Therefore, the growth of the high-technology sector plays an essential role in linking the R&D tax credit program and its expected ultimate goals—better economic results for the states.

Review of Literature

The economic justification for government incentives for industrial R&D is derived from the market failure in the conduct of research and development. The knowledge created from R&D is a nonrival and partially excludable good (Romer, 1990). This "public good" nature demonstrates the social desirability of technological knowledge but presents a major disincentive for private investment because of the spillover of benefits to others without full compensation to the investors. The R&D spillovers and the intrinsic risks associated with innovations call for public assistance from governments. According to microeconomic theory, governments can stimulate private R&D investment by either reducing the marginal cost of capital or raising the marginal rate of return on private R&D investment.

R&D tax credit is one major government policy that directly targets private R&D. A body of empirical literature demonstrates the impact of government tax credit for R&D. In a recent review, Hall and Van Reenen (2000) observed that a dollar of tax credit for R&D stimulates a dollar of additional private R&D investment. Whereas the majority of the empirical studies were conducted at the firm or industry level, a few of the country-level studies also confirmed the positive impact of R&D tax incentives on business R&D investment (Bloom, Griffith, & Van Reenen, 2000; Guellec & Van Pottelsberghe de la Potterie, 2003).

Most of the empirical studies employ "user cost of R&D" as the measure of R&D incentives. Hall and Van Reenen (2000) argue that the estimation based on the user-cost-of-R&D model is preferable because it is grounded in economic theory and the price response of R&D investment can be estimated directly. Wilson (2007) estimated the elasticity of private R&D with respect to both within-state (internal) and out-of-state (external) user cost of R&D. He reported a significant negative elasticity of internal user cost and a significant but positive elasticity of external user cost. In another recent study, Wu (2005) used an alternative set of measures for state R&D tax credit—a dummy variable and the deviation of effective credit rate. Wu's statistical results suggest that the establishment of state R&D credit programs is effective in stimulating more industrial R&D expenditure.

Several caveats emerge from this body of literature. First, little empirical assessment has been done at the state level even though a number of U.S. states have been offering R&D tax credits since the early 1980s. The unavailability and incomparability of industrial R&D data are obvious hurdles for any empirical research at the state level.[8] The more important caveat lies in the relatively tenuous relationship of the reported R&D investment with real economic development. R&D spending may not be a good indicator of industrial R&D efforts because of possible manipulation of R&D-related expenses. For instance, companies may recategorize some business expenses to conform to the tax definition of qualified R&D expenses.[9]

In this empirical research, I focus on the development of high-technology industries rather than industrial R&D expenditures. The use of the high-technology establishment measure helps to overcome some of the data issues and enhances the relevance of state R&D policy to economic development. The growth of the high-technology sector is more relevant to the pursuit of technology-based economic development, given its recognized contribution to various economic indictors. This study will extend the literature by examining the effectiveness of state R&D tax credits in augmenting the high-technology sector relative to state population or the whole private sector.

Model and Method

Economic theory suggests that the offer of R&D tax credit could stimulate the growth of the high-technology sector because of its positive effect on industrial R&D investment. The empirical literature on R&D fiscal incentives confirms the effectiveness of R&D credits in stimulating more industrial R&D expenditures, most of which are concentrated in the research-intensive high-technology sector.[10] To examine the effects of state R&D tax credits on states' high-technology establishments, I constructed the following econometric model based on the economic theory and prior empirical studies:

$$HT_{i,t} = \beta_0 + \delta_t + \gamma_i + \beta_1 HC_{i,t-1} + \beta_2 PRDG_{i,t-1} + \beta_3 ARD_{i,t-1} + \beta_4 GRD_{i,t-2} + \beta_5 CTR_{i,t} + \beta_6 STC_{i,t-1} + \varepsilon_{i,t}$$

In this model, the dependent variable *HT* refers to the relative size of the high-technology sector in state *i* in year *t*. Among the explanatory variables, *HC* represents the human capital of a particular state. *PRDG* is the industry-performed R&D financed by government. *ARD* and *GRD* represent R&D conducted in the academic and government sector, respectively. *CTR* refers to the state's corporate income tax rate. *STC* represents state R&D tax credit; δ_t and γ_i refer to time- and state-specific effects, respectively.

I hypothesize that the high-technology sector could grow as additional industrial resources are induced by the offer of R&D tax credits. This hypothesis is based on economic theory and empirical evidence of R&D tax incentives on private R&D expenditure, as discussed in the prior section. DeVol (1999) indicated that government tax incentives may have helped lure high-technology firms and industry to the locality. The size of a state's technology sector is likely to grow as more research-intensive business establishments may set up there. State economies with relatively more business establishments in high-technology industries are likely to be well positioned to take advantage of new technological developments.

The key explanatory variable is state R&D tax credit in the model. As discussed in the prior section, Wilson (2007) and Wu (2005) used two alternate measures of state R&D tax credit. The user cost of R&D is a theoretically sound measure, particularly in assessing the effects of R&D tax incentives on private R&D investment. However, unlike the case of R&D investment, there is no analogous, straightforward, first-order condition for the number of high-technology establishments.[11] Following Wu's approach, this study employs a dummy variable to show the presence of R&D tax credit and the deviation of effective credit rate to capture the relative generosity of the R&D tax incentive in a specific state. An additional benefit of using the R&D credit dummy is that it allows direct calculation of the foregone revenues per induced job based on the tax expenditures of state R&D tax credit programs.

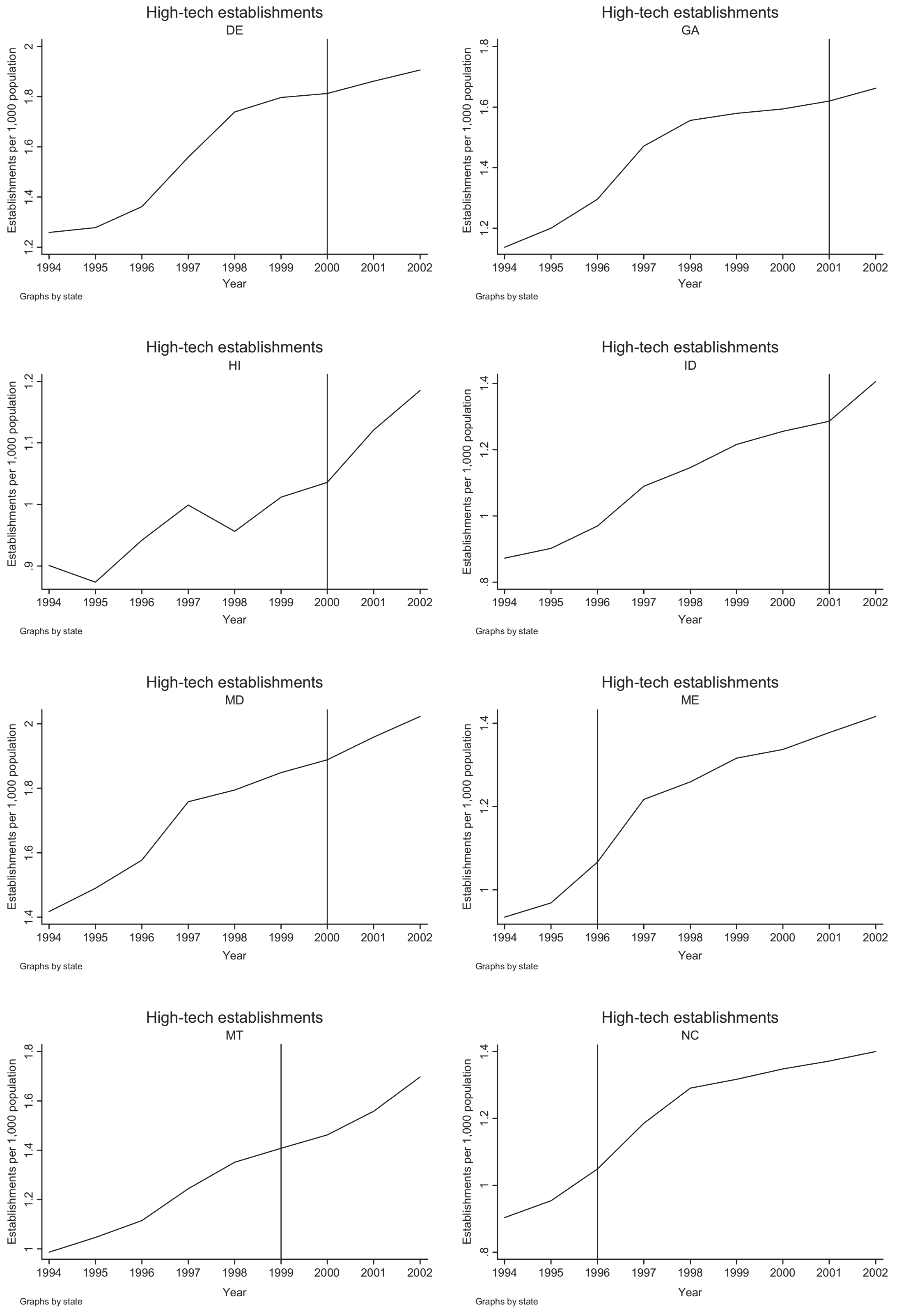
The structure of state R&D credit is fairly homogenous because most of the states offering R&D tax credits follow the basic design of federal research and experimentation tax credit.[12] Among the major components of state R&D tax credit, the most significant variance lies in the statutory tax credit rate that ranges from 2.5% to 20%. I choose effective instead of statutory credit rate because of the taxability of R&D credit in the federal and state corporate income tax. The effective R&D tax credit rate is the statutory credit rate lowered by the product of the statutory credit rate and the federal and state corporate income tax rate if the amount of R&D credit is counted as additional income and thus taxable.[13]

The industry-performed R&D financed by government (either R&D contracts or R&D grants) is another major way governments provide financial support to private R&D activities. Government R&D contracts and grants may induce additional private R&D investment in existing or new research establishments by providing learning and training opportunities for R&D personnel, sponsoring R&D infrastructure construction, signaling future public (and sometimes private) sector product demand, or relieving some joint costs of R&D activities.[14]

Other factors important to high-technology firms' location decisions include access to a well-educated workforce and close proximity to universities and research institutions (Audretsch & Feldman, 1996; DeVol, 1999). Research-intensive high-technology industries are to a large extent dependent on the quantity and quality of human capital in the state because they often demand a large number of qualified R&D personnel. The relevance of state human capital is weakened by the fact that many high-technology companies hire workers from other states. The model includes the educational attainment of each state's population as the measure of its human capital. In addition, high-technology companies may benefit from R&D spillovers and technology transfers from various sources, such as research projects performed in universities and other research institutions. The academic entrepreneurship and spin-off firms from academic or government R&D are examples of this kind. I include the R&D conducted in the academic and government sectors to account for the effects of potential R&D spillovers and technology transfers.

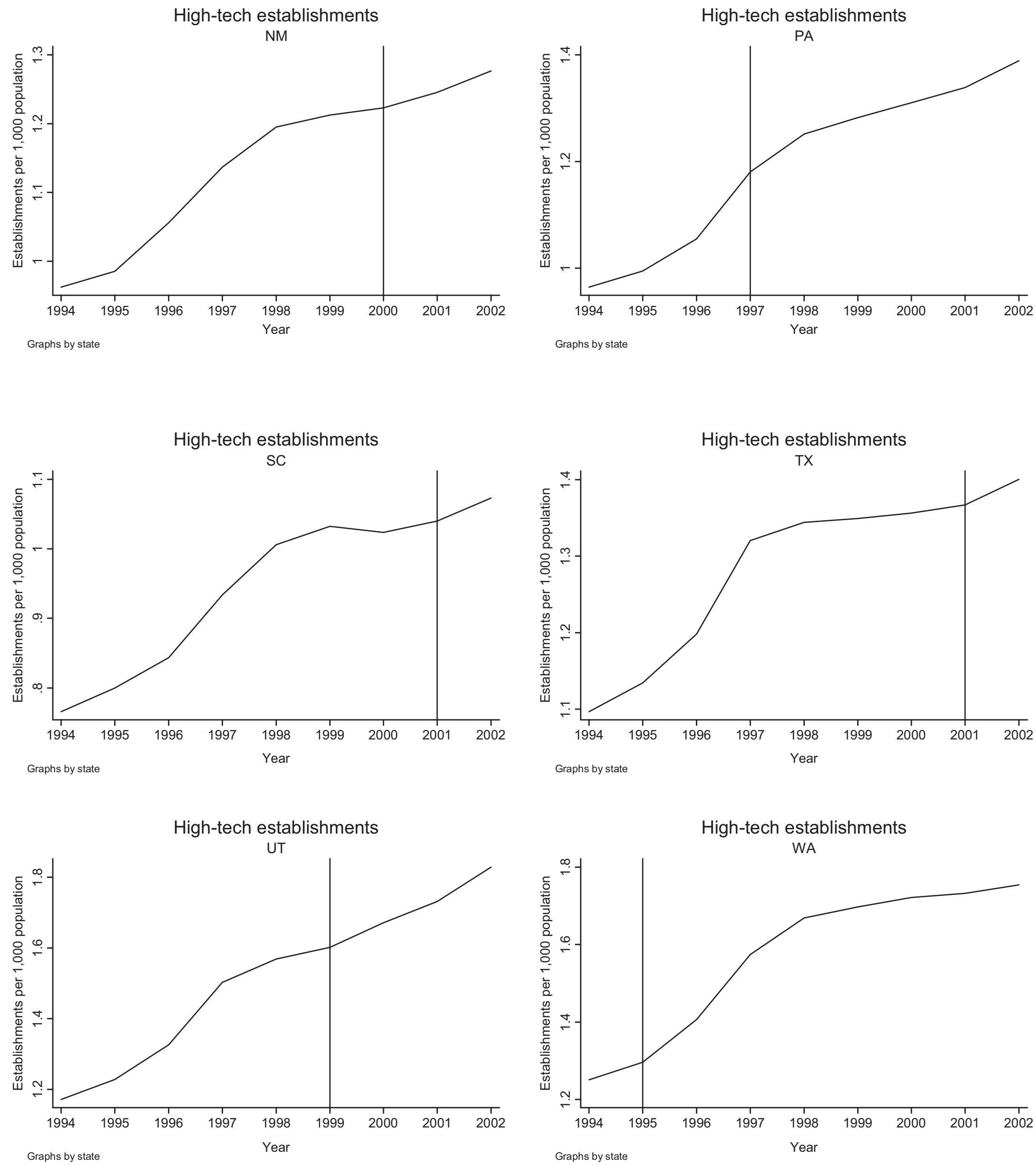
In addition to the variables discussed above, some state-specific and nationwide factors may affect high-technology establishments as well. It is likely that the growth of high-technology sectors may result from some

Figure 1
Graphs of High-Technology Establishments per 1,000 of Population



(continued)

Figure 1 (continued)



Note: The vertical line in each graph shows the year when the state R&D tax credit was initiated.

common national trends that may have significant impact on high-technology industries. For instance, some federal high-technology policies and overall economic factors are likely to affect high-technology businesses no matter where they are located. To better estimate the effects of state R&D tax credit, I include both state-specific variables and year dummies to control for these factors not included in the model.

The explanatory variables are 1-year lagged, except the R&D conducted in government and the state corporate income tax rate. It may take some time for the business sector to set up new establishments as a response to a relatively new incentive program such as state R&D tax credit in new initiator states. The 1-year lag structure of state R&D credit is supported by the graphs of the dependent variable—the count of high-technology establishments per 1,000 of state population (see Figure 1 for details). Most of the initiator states experienced faster growth of high-technology establishments 1 year after the launch of their R&D tax credits. For the same reason as lagged effects, the variables of industry-performed R&D financed by government, R&D performed in the academic sector, and human capital are also lagged by 1 year. The R&D conducted in government is lagged by 2 years because government R&D projects are often mission driven, and it may take longer for spillovers and transfers than in the academic sector. The state corporate income tax rate is not lagged because it is very common to businesses.

Measurement and Data

This section describes the measurement of variables and data collection for implementing the model discussed in the previous section. Two alternate measures are chosen for the dependent variable *HT*: the count of high-technology establishments per 1,000 of population (*HTESPK*) and the share of high-technology business establishments (*HTESHR*).[15] The data on high-technology and business establishments are from the Census Bureau's *County Business Patterns* (U.S. Census Bureau, 1994-2002). The annual population data are from the Regional Accounts Data at the Bureau of Economic Analysis. The collection of high-technology establishment data is based on a list of high-technology industries in which the number of R&D workers and technology-oriented occupations accounts for a proportion of employment that is at least twice the average for all industries.[16] The list of high-technology North American Industry Classification System (NAICS) codes includes 39 categories, of which 30 are manufacturing industries and 9 are service industries (see Table 2). The pre-1998 observations are added to the panel based on the mappings from the Standard Industrial Classification to the NAICS.[17]

I use both a dummy variable (*DSTC*) and the deviation of effective credit rate (*DSTCER*) as the measures of state R&D tax credit. There are no ready-for-use data for this important variable. The State Science and Technology Institute (SSTI) conducted a survey titled State Research and Development Tax Incentives in 1997. However, the SSTI report provides only a snapshot of the R&D tax incentives at state level at the time, which is not sufficient for this cross-state, time-series analysis. The data for this key policy variable were developed by collecting information on the historical evolution of R&D tax credits from the state statutes, tax forms and instructions, and other official documents for R&D tax credit.

The measure for the industry-performed R&D financed by government is the R&D obligations from all federal sources to U.S. industrial firms (*PRDG*). I use the R&D obligations from all federal sources to federal intramural research for the total R&D conducted in the government sector (*GRD*), and I use the total academic R&D expenditures for the R&D performed by the academic sector (*ARD*). The three measures are all converted into constant dollars per capita. The R&D data are from the National Science Foundation's Survey of Federal Funds for Research and Development and Survey of R&D Expenditures at Universities and Colleges. The data were obtained from the WebCASPAR—an integrated science and engineering resources data system managed by the NSF (n.d.).

In this study, I use the percentage of population with a bachelor's degree as the measure of the educational attainment of the population of a particular state for the human capital variable (*HC*) (U.S. Department of Commerce, Office of Technology Policy, 2004). The educational attainment measure may be endogenous because the growth of high-technology establishments may attract more workers with bachelor's or higher degrees. But the endogeneity issue is not serious because most of the new hires hold degrees in science and engineering, whereas the selected measure covers all academic disciplines and is a measure of general rather than science- or technology-specific education attainment.

As the most important indictor of business environment, state corporate income tax is likely to affect new business location, including high-technology establishments. The state corporate income tax rate data are from the World Tax Database, which is managed by the Ross School of Business in the University of Michigan (n.d.).

The panel includes 49 states (excluding Alaska and the District of Columbia) from 1994 to 2002. The 9-year period is selected because of the availability of data for high-technology establishments. In this period, 18 states initiated their R&D tax credit program, the largest and the most recent initiator group being added to the cohort.[18] This provides a good opportunity to examine the effects of state R&D credit on high-technology establishments. A summary of variable definition and data source is offered in Table 3, and some descriptive statistics are provided in Table 4.

Figure 1 includes graphs of high-technology establishments per 1,000 of state population with the year line showing the year when the state R&D credit program was initiated. The graphs show that the high-technology sector responded to the offer of state R&D tax credit in the expected way. The high-technology establishment measure increased at a faster pace in the year following the launch of the program in the initiator states except Montana and Pennsylvania.[19] The graphs provide solid intuitive

Table 2
High-Technology Industries

NAICS Code	High-Technology Industries
32411	Petroleum refineries
3251	Basic chemical manufacturing
3252	Resin, synthetic rubber, and artificial and synthetic fibers and filaments manufacturing
3253	Pesticide, fertilizer, and other agricultural chemical manufacturing
3254	Pharmaceutical and medicine manufacturing
3255	Paint, coating, and adhesive manufacturing
3256	Soap, cleaning compound, and toilet preparation manufacturing
3259	Other chemical product and preparation manufacturing
332992	Ordnance and accessories manufacturing—small arms ammunition manufacturing
332993	Ordnance and accessories manufacturing—ammunition (except small arms) manufacturing
332994	Ordnance and accessories manufacturing—small arms manufacturing
332995	Ordnance and accessories manufacturing—other ordnance and accessories manufacturing
3331	Agriculture, construction, and mining machinery manufacturing
3332	Industrial machinery manufacturing
3333	Commercial and service industry machinery manufacturing
3336	Engine, turbine, and power transmission equipment manufacturing
3339	Other general purpose machinery manufacturing
3341	Computer and peripheral equipment manufacturing
3342	Communications equipment manufacturing
3343	Audio and video equipment manufacturing
3344	Semiconductor and other electronic component manufacturing
3345	Navigational, measuring, electromedical, and control instruments manufacturing
3346	Manufacturing and reproducing magnetic and optical media
3353	Electrical equipment manufacturing
33599	All other electrical equipment and component manufacturing
3361	Motor vehicle manufacturing
3362	Motor vehicle body and trailer manufacturing
3363	Motor vehicle parts manufacturing
3364	Aerospace product and parts manufacturing
3391	Medical equipment and supplies manufacturing
5112	Software publishers
514191	Online information services
5142	Data processing services
5413	Architectural, engineering, and related services
5415	Computer systems design and related services
5416	Management, scientific, and technical consulting services
5417	Scientific research and development services
6117	Educational support services
811212	Computer and office machine repair and maintenance

Note: NAICS = North American Industry Classification System.

Table 3
Variable Definitions and Data Sources

Variable	Definition	Data Source
HTESPK	High-technology establishments per 1,000 of population	U.S. Census Bureau (1994-2002)
HTESHR	High-technology share of all business establishments	U.S. Census Bureau (1994-2002)
HC	Percentage of population with a bachelor's degree	U.S. Department of Commerce (2004)
PRDG	R&D from all federal sources to U.S industrial firms per capita	National Science Foundation (n.d.)
ARD	Total academic R&D expenditures per capita	National Science Foundation (n.d.)
GRD	R&D from all federal sources to federal intramural per capita	National Science Foundation (n.d.)
CTR	State corporate income tax rate	University of Michigan (n.d.)
DSTC	Dummy of state R&D tax credit	R&D tax credit forms, state statutes of U.S. states
DSTCER	Deviation of effective state R&D tax credit rate	R&D tax credit forms, state statutes of U.S. states

Table 4
Descriptive Statistics

Variable	Definition	*N*	*M*	*SD*	Minimum	Maximum
HTESPK	High-technology establishments per 1,000 of population	441	1.317	0.439	0.507	2.757
HTESHR	High-technology share of all business establishments	441	0.050	0.015	0.021	0.087
HC	Percentage of population with a bachelor's degree	441	0.238	0.046	0.114	0.387
PRDG	R&D from all federal sources to U.S industrial firms per capita	441	97.44	127.82	0.499	781.39
ARD	Total academic R&D expenditures per capita	441	96.72	43.24	27.44	331.75
GRD	R&D from all federal sources to federal intramural per capita	441	61.29	134.33	1.63	987.25
CTR	State corporate income tax rate	441	0.065	0.030	0	0.120
DSTC	Dummy of state R&D tax credit	441	0.49	0.50	0	1
DSTCER	Deviation of effective state R&D tax credit rate (in %)	387	0.000	39.93	–69.52	162.98

evidence that the state tax credit for industrial R&D played a positive role in the growth of states' high-technology sector.

Results and Discussion

The statistical results from estimating the model are presented in Tables 5 and 6, which correspond to two alternate measures of the state high-technology sector. Table 5 contains results for the count of high-technology establishments per 1,000 of state population, and the estimates in Table 6 are based on the high-technology share of all business establishments. In each table, I first run a fixed-effects model without correcting autocorrelation.[20] Because the estimations are based on time series level data, I expect autocorrelation to exist in the errors.[21] Thus, I also present estimates of a fixed-effects model adjusted for standard first-order autocorrelation.[22]

I apply each of the two empirical models to two specifications of the equation, depending on what measure is used for state R&D tax credit variable. The first specification, which uses only the dummy variable for state R&D credit, is based on a panel of 49 states (441 observations). The other specification, which includes both the state R&D credit dummy and the deviation of effective credit rate, is estimated on a 43-state panel (387 observations) because 6 states do not follow the basic rate-on-increment structure and are therefore excluded from the panel.

As discussed before, the growth of the high-technology sector may result from some common national trends, such as changes in federal policies and overall economic factors. Therefore, I include time dummies for all years from 1995 to 2002 in all estimations to control the national effects on high-technology industries. It turns out that almost all the year dummies are highly significant, showing that some nationwide factors do have significant impacts on high-technology businesses.

With full control for both nationwide and state-specific effects on high-technology industries, the estimate of the state R&D credit dummy variable is still statistically significant no matter what high-technology measure or empirical model is employed.[23] The estimate in the fixed-effects model with autocorrelation adjustment is much smaller than that in the fixed-effects model without autocorrelation adjustment. It shows that the autocorrelation in the errors does inflate the estimate of the R&D credit dummy variable if it is not rectified. The estimate of the R&D credit dummy based on high-technology establishments per 1,000 of population ranges from 0.0153 to 0.0187 in the adjusted fixed-effects model and from 0.0665 to 0.0719 in the unadjusted fixed-effects model. The estimate of R&D credit dummy based on high-technology share of business establishments is 0.0007 in the adjusted fixed-effects model and 0.0017 in the unadjusted fixed-effects model.

Although the significance of the dummy of state R&D tax credit is high and consistent, the estimate for the deviation of effective credit rate is either insignificant in three of four regressions or significant at the 10% level in one regression but with a virtually zero value. This may raise some concern with the possibility that the dummy's effect may reflect reverse causation. For instance, states that have experienced growth of high-technology industries in the recent past may be more likely to adopt a credit, and the future growth of the high-technology sector may partially result from the past growth. Further examination indicates that the adoption of state R&D tax credit does not show a consistent relationship with high-technology growth in the recent past. Five states (Georgia, Maine, North Carolina, Pennsylvania, and South Carolina) enacted tax credits when they experienced a higher growth rate of high technology than in the preceding year, whereas seven other states (Delaware, Hawaii, Idaho, Maryland, New Mexico, Montana, and Utah) initiated their credit when the growth rate was lower than the preceding year. The

Table 5
Summary of Statistical Results for High-Technology Establishments per 1,000 of State Population (HTESPK)

Variable	FE Without Credit Rate[a]	FE With Credit Rate[a]	FE With AR Adjustment Without Credit Rate[b]	FE With AR Adjustment With Credit Rate[b]
Percentage of population with a bachelor's degree (1-year lag)	0.1370	0.1291	0.0169	–0.0104
	(0.2347)	(0.2501)	(0.0874)	(0.0936)
Academic R&D expenditures per capita (1-year lag)	–0.0014***	–0.0015**	–0.0004	–0.0004
	(0.0005)	(0.0006)	(0.0003)	(0.0003)
R&D from federal sources to industries per capita (1-year lag)	0.0000	–0.0000	0.0000	0.0000
	(0.0001)	(0.0001)	(0.0000)	(0.0000)
Federal intramural R&D per capita (2-year lag)	0.0001	0.0000	0.0000	0.0000
	(0.0002)	(0.0003)	(0.0001)	(0.0001)
State corporate income tax rate	0.0256***	0.0289***	–0.0031	–0.0032
	(0.0097)	(0.0098)	(0.0084)	(0.0085)
Dummy of state R&D tax credit (1-year lag)	0.0665***	0.0719***	0.0187***	0.0153*
	(0.0145)	(0.0161)	(0.0071)	(0.0081)
Deviation of effective state R&D tax credit rate (1-year lag)	—	–0.0002	—	–0.0000
	—	(0.0002)	—	(0.0001)
N	441	387	392	344
R^2 (within)	0.863	0.876	0.588	0.611

Note: The dependent variable is HTESPK. Standard errors are in parentheses.
a. These two specifications are estimated by the fixed-effects (FE) model (*xtreg* in Stata).
b. These two specifications are estimated by the fixed-effects (FE) model with AR(1) disturbance (*xtregar* in Stata).
$^*p < .10$. $^{**}p < .05$. $^{***}p < .01$.

reverse causation may still exist, but its impact is likely to be limited, at least in this panel. In addition, the autocorrelation adjustment may help to correct the effects of interconnection between some adjacent observations.

Other variables are not statistically significant in the estimations being adjusted to autocorrelation except the percentage of population with a bachelor's degree. The significant and positive estimates of this measure of education attainment provide some support to the perspective that one major contribution of universities to technological innovation is to supply educated and trained individuals.

The statistical significance of the state R&D tax credit dummy variable corroborates the intuitive evidence in the graphs of Figure 1 with regard to the stimulating role of the state R&D tax credit. As to magnitude, the estimates show that the initiation of the R&D credit program results in about 17 more high-technology establishments per 1 million of state population, or an increase of high-technology establishments by 0.07% of the total number of business establishments in the state.[24] To better demonstrate the size of the effects, I estimated the induced high-technology establishments and employment due to the offer of R&D tax credit. The results show that the average estimated effects of a state R&D tax credit are 1.35% to 1.47% of the high-technology establishments in the state. Although these percentages are very small, the effects become more impressive with the number of induced high-technology establishments and jobs. The tax credit helps to create 101 to 106 high-technology establishments and 2,306 to 2,422 high-technology jobs on average. The statistics of the estimated effects of state R&D tax credits are summarized in Table 7.

The states forego some tax revenues to finance their R&D tax credits. However, a comprehensive cost analysis of state R&D tax credits is not feasible because the data of the foregone revenues are sparse. I select the state of Washington as an example to show how much it would cost to create high-technology jobs through an R&D tax credit program. The state of Washington initiated an R&D credit program in 1995. The estimate of induced high-technology employment in 1996 due to the offer of R&D tax credits was 2,437, and the total amount of R&D credits was about $22 million. A simple calculation shows that Washington's R&D tax credit program created one high-technology job at a cost of about $9,000 in that year.[25] Assuming that the state would forego the same amount of tax revenues for 20 years, the present value of the foregone revenues would amount to about $112,000 for one high-technology job that would exist for 20 years.[26]

The cost of induced high-technology employment may vary across states. Because the number of induced

Table 6
Summary of Statistical Results for High-Technology Share of All Business Establishments (HTESHR)

Variable	FE Without Credit Rate[a]	FE With Credit Rate[a]	FE With AR Adjustment Without Credit Rate[b]	FE With AR Adjustment With Credit Rate[b]
Percentage of population with a bachelor's degree (1-year lag)	0.0120*	0.0149**	0.0081*	0.0092**
	(0.0069)	(0.0074)	(0.0042)	(0.0046)
Academic R&D expenditures per capita (1-year lag)	–0.0000***	–0.0000***	–0.0000	–0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
R&D from federal sources to industries per capita (1-year lag)	–0.0000	–0.0000*	–0.0000	–0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Federal intramural R&D per capita (2-year lag)	0.0000	0.0000	–0.0000	–0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
State corporate income tax rate	0.0003	0.0004	0.0002	0.0003
	(0.0003)	(0.0003)	(0.0004)	(0.0004)
Dummy of state R&D tax credit (1-year lag)	0.0017***	0.0017***	0.0007**	0.0006
	(0.0004)	(0.0005)	(0.0003)	(0.0004)
Deviation of effective state R&D tax credit rate (1-year lag)	—	0.0000	—	–0.0000*
	—	(0.0000)	—	(0.0000)
N	441	387	392	344
R^2 (within)	0.896	0.903	0.668	0.682

Note: The dependent variable is HTESHR. Standard errors are in parentheses.
a. These two specifications are estimated by the fixed-effects (FE) model (*xtreg* in Stata).
b. These two specifications are estimated by the fixed-effects (FE) model with AR(1) disturbance (*xtregar* in Stata).
$*p < .10$. $**p < .05$. $***p < .01$.

Table 7
Estimated Effects of State R&D Tax Credits on High-Technology Establishments and Employment

Estimated Effects of State R&D Tax Credit		*N*[a]	*M*	*SD*	Minimum	Maximum
Estimates based on high-technology establishments per 1,000 of population	Percentage of induced high-technology establishments	200	1.35	0.52	0.62	2.97
	Number of induced high-technology establishments	200	101	114	11	595
	Number of induced high-technology employees[b]	116	2,306	2,440	134	13,386
Estimates based on high-technology share of business establishments	Percentage of induced high-technology establishments	200	1.47	0.54	0.80	3.38
	Number of induced high-technology establishments	200	106	110	14	589
	Number of induced high-technology employees[b]	116	2,422	2,361	165	12,931

a. *N* is the total state years with state R&D tax credit.
b. The induced high-technology employment estimates are based on a smaller number of observations because of unavailability of employment data.

high-technology jobs in Washington is very close to the mean value, the cost estimate of Washington's R&D tax credit may be a good indicator of the average cost of state R&D tax credits needed to create one high-technology job. More comprehensive cost analysis will provide valuable information to policy makers as they consider the issue of whether it is plausible that the social benefits from such induced high-technology jobs are greater than the tax credit's costs in their specific situation.

Conclusion

With the evolution of the technology-based economy, the high-technology sector has been playing an increasingly important role in promoting business growth, market expansion, new employments, and global competitiveness. Numerous incentives and assistances have been provided to facilitate the development of high-technology industries in the past two decades. As one popular and important incentive for industrial R&D and high-technology industries, the state R&D tax credit has been offered to pursue economic development.

I intend to examine the effects of state R&D tax credits on the growth of the high-technology sector in the states. The choice of the high-technology sector is based on its essential role in linking R&D tax incentives with longer term economic results. Additional industrial R&D efforts that are likely to take place in response to the tax incentives are also expected to expand the state's high-technology sector, the primary recipient of R&D tax incentives. The improvement in economic results is primarily dependent on the size of the high-technology sector in the state, and hence the high-technology establishments are a good measure of the high-technology sector to examine the effectiveness of the state R&D tax credit program.

The graphic description and statistical results support the hypothesis that state R&D tax credits may have positive effects on the growth of states' high-technology establishments. Being eligible for R&D tax credit, research-intensive, high-technology companies face a lower state income tax liability than do other businesses and thus are likely to set up new establishments in or move existing ones to a state with such a pro-technology tax incentive. An expanded high-technology sector is likely to create more well-paid technical positions in the short term and new or enhanced products, productivity improvement, and other economic benefits in the state in the long term.

This empirical study is an initial step toward a full evaluation of state R&D tax incentives. Although the size of the high-technology sector is a better measure than industrial R&D spending in several aspects, it would be more informative if other state-level measures could be developed and used to examine the effects of this incentive program on other economic indicators, such as employment and income.[27] In addition, although the initiation of state R&D tax credit may generate a significant number of additional high-technology establishments and jobs in the state, more complete data of the tax expenditures to finance state R&D credit programs would allow better estimation of the direct cost of creating R&D-related jobs. A more persuasive case could be made with a more thorough cost-benefit analysis.

Notes

1. One recent example is that state governments increased investments in selected technology programs and selected areas of technology of public research universities to promote technology-based economic development (Feller, 2004).

2. Some states, such as Minnesota, pioneered in R&D tax credit programs at the beginning of the 1980s. The popularity of R&D tax credits has continued into this millennium. By 2004, 34 states had established this incentive program.

3. The most recent extension was made on December 20, 2006, when President Bush signed into law the Tax Relief and Health Care Act of 2006.

4. The fixed-base percentage is the ratio of a company's research expenses to its gross income in three of the years from 1984 to 1988.

5. The R&D tax credit has slightly different names in various states. For instance, it is called *research credit* in California and Massachusetts, *research and development expenses credit* in Arizona, *research and experimental activities credit* in Colorado, *research and development credit* in Illinois, and *research and development tax credit* in New Jersey.

6. For instance, in the state of Washington before 2004, the R&D credit was 1.5% of qualified research and development expenditure in five technology categories.

7. One metropolitan-level empirical study shows that the strength of the explanatory power of high-tech industries in determining the relative economic growth is high and the relationship is robust (DeVol, 1999).

8. The best source of time-series industrial R&D expenditure data by state is the National Science Foundation (NSF) survey of industrial research and development (see NSF, 2006). One big problem with this source is that there are many missing data in the published data set, either because the data are not separately available or the data have been withheld for confidentiality reasons. Also, because the individual reporting companies used their own accounting methods to report the R&D expenditures, R&D expenditure estimates across companies and states may not be comparable.

9. One report from the U.S. Congress, Office of Technology Assessment, mentioned this possible "relabeling" effect in the R&D expense data reported by companies (U.S. Congress, Office of Technology Assessment, 1995).

10. According to the data in Table 2, "Summary Data for Companies Performing Industrial R&D in the United States, by Industry and Size of Company: 2001-2002" (NSF, 2006), the R&D performed in high-technology industries from companies and other sources accounted for at least 70% of total industry-performed R&D in 2001 and 2002.

11. The user cost approach is motivated by the first-order condition for R&D demand based on the assumption of profit maximization.

12. The general design of R&D tax credit programs includes the tax credit rate, definition of qualified R&D expenses, base amount calculation, carry-forward stipulation, and some type of cap imposition.

13. Some states (such as California) explicitly require reducing the business expense deduction in corporate income by the amount of R&D tax credit claimed.

14. As reviewed in David, Hall, and Toole (2000), the empirical evidence is mixed but more likely to support a positive role of public R&D funds in facilitating private R&D investment.

15. This scaling helps to control for the impact of size of the states and makes the data comparable for both large and small states.

16. See "Technical Note: Defining High-Technology Industries" (National Science Board, 2006).

17. The high-technology establishment data are based on the Standard Industrial Classification (SIC) before 1998 and the North American Industry Classification System (NAICS) beginning from 1998. See http://www.census.gov/epcd/naics02/ for mappings from SIC to NAICS.

18. The initiator states in this period are Arizona, Delaware, Maine, Georgia, Hawaii, Idaho, Maryland, Missouri, Montana, New

Jersey, New Mexico, North Carolina, Pennsylvania, Rhode Island, South Carolina, Texas, Utah, and Washington.

19. For Montana and Pennsylvania, the graphs show that the measure of high-technology establishments grew in the year right after the launch of R&D credit. The faster growth of high-technology establishments happened either in the initiation year (Pennsylvania) or after the lag of one more year (Montana).

20. This is done using the *xtreg* command in Stata.

21. The Baltagi-Wu locally best invariant test statistics are far less than 2, showing significant presence of autocorrelation in the errors.

22. This is done using the *xtregar* command in Stata.

23. Only one of the estimates of the R&D credit dummy on high-technology share of business establishments is not significant at the 10% level probably because of the reduced panel size. However, its *p* value, .12, is still very close to the significance level of 10%.

24. The estimates of induced high-technology establishments and employment are based on the statistical results in the fixed-effects model with autocorrelation adjustment. Because the estimate of the R&D credit dummy ranges from 0.0153 to 0.0187 on high-technology establishments per 1,000 of population, I use the average of the two estimates, 0.017, in the estimation of its effects.

25. The tax expenditure data of Washington's R&D tax credits are from *High Technology R&D Tax Incentives Study* (Washington Department of Revenue, 2003).

26. The present value is based on a 20-year time frame and 5% discount rate.

27. The effect on employment or income is likely to be long term because of the significant lag from R&D inputs to the ultimate economic results. In addition, the long-term economic benefits may not be fully confined within state boundaries, given the easy mobility of innovation outputs.

References

Audretsch, D., & Feldman, M. (1996). R&D spillovers and the geography of innovation and production. *American Economic Review*, *86*(3), 630-640.

Bloom, N., Griffith, R., & Van Reenen, J. (2000). *Do R&D tax credits work? Evidence from an international panel of countries 1979-1997* (Working Paper No. W99/8). London: Institute for Fiscal Studies.

David, P., Hall, B. H., & Toole, A. (2000). Is public R&D a complement or substitute for private R&D? A review of the econometric evidence. *Research Policy*, *29*(4/5), 497-529.

DeVol, R. (1999). *America's high-tech economy: Growth, development, and risks for metropolitan areas*. Santa Monica, CA: Milken Institute.

Feller, I. (2004). Virtuous and vicious cycles in the contributions of public research universities to state economic development objectives. *Economic Development Quarterly*, *18*, 138-150.

Guellec, D., & Van Pottelsberghe de la Potterie, B. (2003). The impact of public R&D expenditure on business R&D. *Economics of Innovation and New Technologies*, *12*(3), 225-243.

Hall, B. H., & Van Reenen, J. (2000). How effective are fiscal incentives for R&D? A review of the evidence. *Research Policy*, *29*(4/5), 449-469.

National Research Council, Hamburg Institute for Economic Research, & Kiel Institute for World Economics. (1996). *Conflict and cooperation in national competition for high-technology industry.* Washington, DC: National Academy Press.

National Science Board. (1998). *Science and engineering indicators 1998* (NSB 98-1). Arlington, VA: National Science Foundation.

National Science Board. (2006). *Science and engineering indicators 2006* (NSB 06-1). Arlington, VA: National Science Foundation.

National Science Foundation. (2006). *Research and development in industry: 2002* (NSF 06-322). Arlington, VA: Author.

National Science Foundation. (n.d.). *WebCASPAR–Integrated Science and Engineering Resources Data System*. Retrieved October 15, 2006, from http://webcaspar.nsf.gov/index.jsp

Romer, P. (1990). Endogenous technological change. *Journal of Political Economy*, *98*(5, Part1), S71-S102.

Tassey, G. (2000). *R&D and long-term competitiveness: Manufacturing's central role in a knowledge-based economy.* Washington, DC: U.S. Department of Commerce, National Institute of Standards and Technology.

U.S. Census Bureau. (1994-2002). *County business patterns*. Retrieved October 15, 2006, from http://www.census.gov/epcd/cbp/view/cbpview.html

U.S. Congress, Office of Technology Assessment. (1995). *The effectiveness of research and experimentation tax credits*. Washington, DC: Government Printing Office.

U.S. Department of Commerce, Office of Technology Policy. (2004). *The dynamics of technology-based economic development: State science and technology indicators* (4th ed.). Retrieved October 15, 2006, from http://www.technology.gov/reports/TechPolicy/StateIndicators/2004/Sect4_Time_Series.pdf

University of Michigan, Ross School of Business. (n.d.).*The World Tax Database*. Retrieved July 5, 2005, from http://www.bus.umich.edu/OTPR/otpr/OTPRdataV3.asp

Washington Department of Revenue. (2003). *High technology R&D tax incentives study*. Retrieved on November 4th, 2006, from http://dor.wa.gov/content/statistics/2003/High_Tech_RandD_Study_2003/default.aspx

Wilson, D. J. (2007). *Beggar thy neighbor? The in-state, out-of-state, and aggregate effects of R&D tax credits* (Working Paper No. 2005-08). San Francisco: Federal Reserve Bank of San Francisco.

Wu, Y. (2005). The effects of state R&D tax credits in stimulating private R&D expenditure: A cross-state empirical analysis. *Journal of Policy Analysis and Management*, *24*(4), 785-801.

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