State Science Policy Experiments in the Laboratories of Democracy

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> "It is one of the happy incidents of the federal system that a single courageous State may, if its citizens choose, serve as a laboratory; and try novel social and economic experiments without risk to the rest of the country." (Justice Louis Brandeis, *New State Ice Co. v. Liebmann*, 1932)

In an attempt to encourage economic and employment growth, state governments in the United States have experimented with programs that fund university research, attract talented scientists, and encourage partnerships with industry. Following the logic of Brandeis's *Laboratories of Democracy,* states in the US have experimented with science policy in an attempt to create conditions conducive to economic development and prosperity. Fiscal federalism dictates that different levels of government have certain obligations, with each state responsible for funding its public universities and also exerting influence over private institutions within their borders. States also have great latitude in designing new initiatives that may be particularly suited to local circumstances. This experimentation is an underappreciated aspect of science policy.

There are disproportionately few studies that consider *state* R&D investments despite a sizeable literature that examines federal investment in research and development (R&D) (David, Hall, & Toole, 2000; Feller, 2007; Payne, 2001; Ruegg & Feller, 2003; Santoro & Gopalakrishnan, 2001). State government investments in science follow the logic of the linear model: science is a fundamental asset in the innovation process and the ultimate realization of growth. The pronounced tendency for innovative activity to cluster spatially creates an opportunity for states to attempt to leverage investments in science as an economic development strategy. With federal funding agencies focused on developing regional centers of innovation with a series of cluster initiatives, states are able to leverage this funding. As a result since 1980, state government expenditures for university R&D programs have increased threefold to $3.13 billion, and now account for 5.8 percent of all university research in the U.S in 2011.[1]

Within the US individual states have flexibility to design programs to build capacity to increase the amount of federal R&D expenditures for academic research and to influence the location decisions of individual firm's R&D activity that better aligns to the state's economic and research climate (Bozeman, 2000). States have simultaneously offered R&D tax credits and attempted to create good business

[1] Data retrieved from NSF WebCASPAR; NSF Survey of Research and Development Expenditures at Universities and Colleges/Higher Education Research and Development Survey. University R&D estimates are adjusted for inflation using the Fiscal yr GDP Implicit Price Deflators – base year 2005. State activity is derived from the State/Local Govt Financed Higher Education R&D Expenditures for S&E metric.

climates (Wilson, 2009; Hearn et al., forthcoming). However, other state programs and initiatives that attempt to capture the economic benefit of technology-based development are less well known. Thus while the federal government has taken the lead in providing public funds to support R&D activity, state governments arguably hold the responsibility to invest in R&D as well.

Despite this policy interest, there is little guidance to suggest which policies are most appropriate in different circumstances or to even understand what motivates the adoption of certain policies. The creation of a recent typology (Feldman, Lanahan & Lendel, forthcoming) allows us to examine the factors associated with the adoption of state programs. Moreover, it allows us to test if states are attempting to promote an enterprise that complement other public efforts and to assess if states promote these programs to catch up or to lead in terms of R&D activity. The next section provides background on state science policy, with emphasis on state university R&D programs. This section highlights the trends in the progression of adoption of this portfolio, which includes the Eminent Scholars, University Research Grants, and Centers of Excellence programs. The following sections present the methods and empirical analyses assessing state and national R&D-related factors associated with the adoption and continued support for each of these three programs. The final sections discuss the results for each program, consider the broader state policy portfolio, and conclude with policy recommendations and considerations for further research.

Background on State Science Policy

Sapolsky (1971) argues that governor's attention to science and technology resulted from the tripling of federal appropriations in response to Sputnik from 1957 to 1963. The local economic effects of federal expenditures along Route 128 and what was to be later named Silicon Valley were already notable. Many governors sought to replicate that success, with an initial objective of increasing their share of federal science funding. In 1963 New York and North Carolina established entities to parallel the president's science advisor and created state science and engineering foundations modeled after the National Science Foundation (NSF). The US Department of Commerce's State Technical Service Program (STS) and NSF state science advisor's initiative encouraged active participation (Berglund & Coburn, 1995). By 1968, 12 governors had science policy advisors (Sapolsky, 1968).

In the 1970s, revenue sharing and the devolution of authority from the federal government provided states with the resources and political freedom to experiment with R&D programs (Vogel & Trost, 1979). From 1977 to 1979, 49 out of 50 states participated in the NSF State Science, Engineering and Technology (SSET) program, which encouraged states to develop and implement science and technology (S&T) related strategic plans (Berglund & Coburn, 1995). While funding that had been promised for implementation was not provided, the idea that academic research could be instrumental in the growth of state economies and that states could strategically leverage science was established (Feller, 1990).

The 1980 passage of the Bayh Dole Act, which granted universities the rights to commercialize intellectual property that resulted from publicly funded research, coupled with the monetary success of the Cohen-Boyer patents encouraged state legislatures to view universities as engines of economic development (Cozzens & Melkers, 1997). Concurrently, the decline of federal and industry support for university R&D created uncertainty and a search for alternative sources of revenue (Teich, 2009). In response, states initiated new programs that attempted to leverage academic research.

State S&T programs are typically announced with great fanfare and given colorful names. There is a tendency to describe each program as unique and innovative. In reality, however, there are only a few policy levers available to state policy makers. In an effort to build a typology of similar programs Feldman et al. (forthcoming) identify commonalities across state science initiatives.[2] Through this effort, they find three consistent state initiatives aimed to promote innovation capacity through university research institutions: Eminent Scholars, University Research Grants, and Centers of Excellence programs. Table 1 provides the year that each state initially adopted each of the three programs illustrating the variation in the order of adoption and in the combination of programs adopted.

The Eminent Scholars (ES) program provides funding for a chaired position to attract world-class senior researchers to public and private universities located within the state boundaries. This program can be conceptualized as an investment in human capital through the attraction of what Zucker and Darby (1996) term *Star Scientists.* This program demands substantial up-front costs, often ranging between $3-6 million per scholar, to support the scholar's salary, lab materials, graduate students, administrative support, and overhead. Despite these notable costs, this program is centrally premised on the idea that these scholars will recover the state's investment by the following: (i) building research capacity within the university; (ii) leveraging additional federal and private funds; (iii) serving as research magnets for industrial recruitment; and (iv) ultimately generating revenue from commercialized research (Bozeman, 2000; Feller, 1997). By providing funds for endowed chairs at research-university campuses, states seek to increase innovative activity by cultivating a rich knowledge economy rooted by these individuals.

Virginia was the first to adopt this program in the 1960s; however, other states did not begin to introduce the program until the 1980s. With Ohio serving as the second adopter in 1983, only five additional states implemented the program within the following decade; these include Tennessee, North Carolina, Louisiana, Georgia, and Arizona. During the latter part of the 1990s, only a handful of states

[2] Data collection efforts to identify the portfolio of state R&D university programs includes the following: (i) state-funded; (ii) codified in a policy document; (iii) focus on university R&D; and (iv) administered by a state agency (Feldman et al. 2014).

selected to adopt the program. However, this program gained the greatest traction after 2001 with nine states introducing it within a six-year period between 2002 and 2007. Arguably, this recent surge may have resulted from state reports published in the late 1990s highlighting the notable benefits of the state programs. As of 2009, 21 states were identified as having an ES program. State and local officials interviewed were very enthusiastic about the potential of the program to build academic resources (Feldman, Lanahan & Lendel, forthcoming).

The Georgia Research Alliance (GRA) and Kentucky's 'Bucks for Brains' stand out as exemplary ES programs (Bozeman, 2000; Youtie, Bozeman & Shapiro, 1999). One illustrative example of the program's benefits lies with a distinguished IBM researcher who was recruited to the GRA program for $1.055 million and in return secured an NSF grant to establish an Engineering Research Center in Electronic Packaging worth a total value of $40 million over a three-year period (Combes & Todd, 1996). Kentucky's 'Bucks for Brains' initiative increased the number of endowed chairs and professorships in the state by over five-fold from 1997 to 2010, while extramural research expenditures from two of Kentucky's research universities – the University of Kentucky and the University of Louisville – increased by roughly 250% over the same time period.[3]

The second state university-based program, the University Research Grants (URG), provides state grants to support university S&E research. Feldman et al.'s (forthcoming) defining criteria for the URG programs are the following: (i) grants oriented towards basic scientific research; (ii) grants available to all researchers at universities or research institutions within the state; (iii) grants that do not fund physical infrastructure; and (iv) grants that do not require supplemental funding by an industrial partner.[4] As of 2009, 29 states were identified as having an URG program.

The first state to adopt an URG program was Arkansas in 1983. Named the Basic Research Grant Program, the primary aim of the program was to build "the state's scientific infrastructure and improve the ability of Arkansas research scientists to compete for awards at the national level by awarding grants to researchers at the state's colleges and universities."[5] This program targeted individual researchers who had not previously received federal funding and required a 40% cash or in-kind contributions match by the individuals' home institution. The primary intention of this program, as stated in the research objectives, was "to use state funds as an incentive to get scientists interested in new areas of research and to provide them with a track record that will help them to compete for federal monies, thereby bringing more research funds to the state" (Berglund & Coburn, 1995, p. 84). The idea of improving the ability of

[3] Source: http://cpe.ky.gov/news/mediaroom/releases/nr_110811.htm
[4] We consider research grants that require matching funds from firms as a separate category that creates collaboration and leverages university resources. See the later discussion of Centers of Excellence.
[5] Source: ASTA's website, http://asta.ar.gov/

scientists to compete for federal funds is consistent for these programs, suggesting that states perceive themselves to be lagging in federal R&D funding.

The Center of Excellence (CE) – the third state university-based program – is geared for later-stage university research activity by focusing on university and industry collaboration. This program aims to build capacity by investing in physical infrastructure and strengthening research partnerships with industry. Connecticut adopted this program in 1965, followed by Alabama's adoption in 1975. As of 2009, 37 states were identified as having a CE program. These programs include state initiatives alternatively called University Research Centers, Advanced Technology Centers, and Centers of Advanced Technology. The important differentiating criterion of this program lies with the more central and active role of the university's industrial partners. Given the breadth of organizational forms and research foci across CE programs, both in terms of research scale and scope, scholars have struggled to reach a consensus on the definitive features that characterize these unique research organizations (Aboelela et al., 2007; Mallon & Bunton, 2007; Youtie, Libaers & Bozeman, 2006; Friedman & Friedman, 1982).

Feldman et al.'s (forthcoming) review identified four common features of CE programs. These include: (i) a directed research mission focused on basic and applied research; (ii) emphasis on graduate training; (iii) collaboration between universities and industry; and (iv) a strong research orientation directed toward a specific industry sector or technology. Despite these common features, some states place greater emphasis on the partnership with industry, while others are more concerned with the research program. The Massachusetts' Centers of Excellence (2004) serves as an exemplar of the latter, placing a concerted aim on improving emerging technologies such as biotech and nanotech. The Florida Technology Development Initiative, however, exemplifies the former. This CE program promotes both functions of promoting research excellence and facilitating collaboration with industry for conduit building.

Most of this state policy adoption activity for this portfolio of programs took place after 1980. Figure 1 presents a series of snapshots of the continental US illustrating the path of diffusion of this portfolio of programs over the past three decades.[6] By 1990, marking one decade of state policy adoption activity, both North Carolina and Georgia established all three programs; by 2000, New York, Ohio, and South Carolina joined this cohort; and by 2009, five additional states adopted the entire portfolio.[7] These maps highlight a concentration of state-funded university R&D programs along the east coast and Midwest with states in the southeast, Rust Belt region, and lower Midwest demonstrating greater state

[6] A map for the baseline year was not included given the dearth of state university R&D policy activity at this time. In 1980, only four states – AL, CT, NC, and VA – had one of the three programs. Figure 1 is intended to reflect the diffusion of adoption, thus the first image of state policy activity is 1990.
[7] These states include: AR, CT, KS, KY, and OK.

policy efforts by adopting more programs. As of 2009, 44 states had at least one university R&D policy; of those, 33 had two policies and 10 had adopted the entire portfolio.

Table 2 presents descriptive statistics for the years of adoption for having a first, second, and third policy, respectively. On average, states adopted one of these policies by 1989 – with Virginia leading as the first adopter in 1964 and North Dakota serving as the most recent state to adopt their first state university-based policy in 2006. Of those states with more than one policy, on average, they adopted a second policy by 1996 and a third by 1999, respectively. For those states with more than one policy, Table 3 provides information on the time lag between adopting a second and third policy. On average, the time lag between adopting the first and second policy was roughly 10 years; the average lag decreased slightly to 8.5 years for states between adopting the second and third policy.

Among the portfolio of university programs the CE is not only the most widely diffuse, more states tend to adopt this program first. This suggests a prioritization of making investments in academic research directly linked to industrial activity over supporting more upstream efforts that are characteristic of the ES and URG programs. The descriptive statistics presented in Table 4 show that 28 states adopt the CE first with CT adopting the first CE program in 1965. Fourteen states initially adopted the URG, and nine initially adopted the ES program. These trends of adoption demonstrate a slightly different progression of state policy actions than presented by Plosila (2004). He groups the evolution of state S&E policy activity linked to economic development programs and practices into three stages – 1960s – 70s; 1980s; and 1990s – with the first focused on bolstering S&T programs, the second marking a shift towards university-based economic development initiatives, and the third directed to technology alliances and trade associations linking S&T to economic growth. Feldman et al.'s (forthcoming) review of the portfolio of state university-based programs, however, finds little state activity prior to the 1980s with the pace of adoption remaining strong in the most recent decade. Moreover, over the past thirty years states have adopted a range of programs from more upstream programs aimed to bolster the basic research enterprise within the university (ES and URG) to more downstream initiatives that link university research with industry (CE).

This descriptive analysis suggests that state science policy adoption is not random, but rather maps out in a systematic manner. Currently, our understanding relies on case studies that examine single programs and tends to provide more operational details rather than considering the motivation to adopt programs. While there is little theory to directly guide choices for state science programs, there are two broad literatures that we can draw from, specifically the state policy diffusion literature and literature on science policy. This analysis draws from these two distinct, yet complementary literatures to identify a series of factors that likely motivate state university R&D policy activity.

Governor Dave Heineman's 2011-12 National Governor's Association Initiative, *Growing State Economies*,[8] presents the case that states need to invest in science for future economic growth. Indeed, Combes and Todd (1994) argue that originally legislatures were motivated to establish public universities to improve their state's economy. The economic restructuring in the 1980s motivated the state science policy programs that we study. We expect that states invest in science initiatives as an effort to augment their existing R&D capacity, to employ their S&T workforce, and to develop technology-based industry.

The idea that states benchmark against one another is well established. Many times states that are lagging in terms of R&D expenditures or high tech industry will be motivated to adopt science policy initiatives in order to catch up with their peers. Taylor's (2012) recent paper on the role of governors as economic problem solvers argues that a lagging economy or a low level of R&D may provide an incentive to implement S&T initiatives. While the precise referent group may be difficult to define the literature has considered diffusion among contiguous states. These data do not support that pattern but the prominence of the National Governors' Association suggests that benchmarking may be national. States that are behind the national average may be more likely to adopt science policies.

The ability to make these investments, however, will likely be related to the state's fiscal condition. In their influential study on state policy diffusion, Berry and Berry (1990) found that the fiscal health of the state budget influenced state lottery adoptions. While lotteries augment state budgets, S&T programs require slack resources and ability to fund programs that may be considered longer term investments and discretionary. As such, we anticipate that states would be more likely to have science policy programs in years when they have strong fiscal health.

In addition, national trends of federal and industry R&D activity likely drives state actions. Historically, federal and industry R&D investments have been primary sources of support for S&T activity overshadowing investment from states governments and other sources of funding. The federal government tends to lead in supporting more upstream activity, while industry is more prominent in supporting more downstream efforts. Moreover, research within the policy diffusion literature finds states rely on the federal government when making policy decisions. As an illustrative example, Baumgartner et al. (2009) consider the nature of vertical policy diffusion between congressional activity and state lobbying actions and found the top-down influence to be considerable. The results suggest that federal R&D actions guide subsequent state policy activity. In this case, we expect that increased federal R&D spending will prompt greater state attention to science policy initiatives. This expectation is reinforced by a series of studies (Blume-Kohout et al., 2009; David, Hall & Toole, 2000; Diamond, 1999; Payne, 2001) providing evidence that additional private support results from federal investment in R&D results, suggesting a complementary or crowding-in effect between these two sources. Although these studies

[8] Source: http://www.subnet.nga.org/ci/1112/

focus on the relationship between federal funding and private R&D, a complementary relationship likely holds for state governments as well as for the adoption of state policies designed to contribute to the R&D enterprise. Increased federal investment in science is likely to motivate state attention to science policy. We anticipate that state policy actions will complement federal and industry science investments.

Our understanding of state R&D activity is relatively nascent compared to federal R&D policy actions, thus the quantitative analyses in the next section serves as an exploratory effort toward understanding whether and how state R&D-related factors influence the state science policymaking. We estimate the impact of the state-level factors associated with states having one of the three university state science programs, respectively.

Methods

Initial adoption is a limited event; however, public programs are evaluated on an ongoing basis and are subject to termination. States governments operate with a limited budget, and therefore annually assess their portfolio of expenditures. Thus, we argue there is utility in looking beyond the date of initial adoption to consider state reauthorizations. The literature typically employs an event history analysis to identify the antecedent factors that influence state policy adoptions. While a hazard model determines the causal attributes that influence initial policy adoption, this analysis employs OLS econometric estimation to include data beyond the initial adoption of the program.

Our empirical model is specific to state *i,* and year *t.* $ADOPT_{pit}$ is our primary outcome variable of interest, where *p* denotes the specific policy – ES, URG, or CE, respectively. This dichotomous variable is coded 1 in the years a state has one of the three respective science policies and 0 otherwise.

$$ADOPT_{pit} = \alpha_i + \beta_1 FISCAL_{it} + \beta_2 HIGH\ TECH\ INDUSTRY_{it} + \beta_3 S\&E\ DEGREES_{it} + \beta_4 UNIVERSITY\ R\&D_{it} + \beta_5 EPSCoR_{it} + S\&E\ HE\ EXP_t + \varepsilon_{it} \quad (1)$$

Building off Berry and Berry's (1990) study on state lottery adoptions, we include $FISCAL_{it}$, which captures the fiscal health of the state budget. This measure estimates the state's slack resources and ability to afford science programs.

In addition, we include two state-level measures that capture the R&D capacity of the state. $HIGH\ TECH\ INDUSTRY_{it}$ measures the annual high-tech employment for a state. To compute this indicator, we use the Bureau of Labor Statistics definition of high-tech industries (Hecker, 2005),[9] and

[9] Hecker's classification of high tech industries is used for the National Science Board's definition of high tech sectors, and therefore serves as a valid source for defining the list of NAICS and SIC codes that constitute high technology industries. Using employment data from the Bureau of Economic Analysis (BEA), we matched Hecker's list by industry title to the BEA's LineCode classification scheme at the 3-digit industry.

compute the ratio of high tech employment to total employment. *S&E DEGREES*$_{it}$ measures the extent to which the state's higher education graduates are concentrated in the fields of science and engineering (S&E). This measure is drawn from the National Science Board's S&E State Indicators on Higher Education activity and estimates the ratio of S&E graduates to total graduates. We expect that states may benchmark themselves against other states, thus we compute state location quotients and subsequent quartile rankings of the location quotients for these two state R&D-related measures (*HIGH TECH INDUSTRY* and *S&E DEGREES*). For the computation of the location quotient, the national ratio serves as the reference area in the denominator. Regarding the quartile indicators, the fourth quartile – the cohort of states with the highest rankings – serves as the referent category for both sets of variables. With the fourth quartile as the referent category, we expect the sign of the coefficients for the LQ and quartile dummies to be the inverse of one another. We include the quartile dummies for these two variables to assess whether there is variation based on the relative ranking of the states.

EPSCoR$_{it}$ is another benchmarking indicator as a dichotomous variable that denotes the status of the state in the Experimental Program to Stimulate Competitive Research (EPSCoR) program. Administered by NSF, EPSCoR is a federal program that began in 1980 to support and encourage disadvantaged states to improve their research and development activity (Hauger, 2004). As of 2009, 25 states have received EPSCoR status. The first cohort of EPSCoR states in 1980 included Arkansas, Maine, Montana, South Carolina, and West Virginia. A second cohort was added in 1985: Alabama, Kentucky, Nevada, North Dakota, Oklahoma, Vermont, and Wyoming. The third cohort of states was added in 1987 included Idaho, Louisiana, Mississippi, and South Dakota. In 1992, Kansas and Nebraska joined. Between 2001 and 2009, seven additional states have been added: Alaska, Hawaii and New Mexico in 2001, Delaware and Tennessee in 2003, New Hampshire in 2005, and Utah in 2009.[10]

We also include a set of federal and industry metrics to account for national R&D-related trends. We expect that the larger spending environment will influence state science policy activity. *UNIVERSITY R&D*$_{it}$ denotes the sum of federal and industry investment in each specific state's university research activity. In addition, we control for annual macroeconomic shocks using a national aggregate measure of higher education expenditures in S&E, *S&E HE EXP*$_t$. The former measure controls for state-level variation in federal and industry support for university R&D research activity. The latter is an aggregate variable that only varies by year and is used in lieu of year fixed effects, since the degrees of freedom are a concern with state-level models.

Given that the three university programs have different aims we adjust our measurement of the national R&D-related measures (*UNIVERSITY R&D*$_{it}$ and *S&E HE EXP*$_t$*)*. ES and URG programs are

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[10] Three additional states have received EPSCoR status after 2009: Rhode Island in 2010, Iowa in 2011, and Missouri in 2012.

designed to support earlier stage, more upstream R&D activity; therefore, for the variable *UNIVERSITY* $R\&D_{it}$ in Equation (1) we include the federal investment in university R&D for these two sets of models. The CE program aims to support later-stage university R&D activity that should be more responsive to industry R&D investment. Thus, we include industry investments in university R&D for this model. Although we are unable to discern the precise direction of causality in this analysis, these measures approximate whether federal or industry university R&D investment in a given state complements or substitutes that state's university science policy activity. This same approach is used for the *S&E HE* EXP_t variable. We include total federal investment in higher education in the ES and URG regressions and total industry investment in higher education for the CE models. In addition to controlling for annual trends, this variable measures the association between state policymaking and national-levels of federal and industrial R&D budgetary activity.

State-specific time-invariant factors are controlled for using state fixed effects. Table 5 provides more detailed information on the list of variable descriptions, data sources, and functional forms. Table 6 provides descriptive statistics and table 7 presents correlation coefficients.

We estimate the regressions as Linear Probability Models (LPM) with state fixed effects. With the primary outcome variable, $ADOPT_{pit}$, taking a value of 1 when the program was in use and 0 otherwise, we also ran logit fixed effects and pooled cross-sectional LPM and logit models. The results were robust across all models. We present the results for the LPM state fixed effect model due to ease of interpretation of marginal effects and the fact that the state fixed effect models offers a more conservative estimate of the association with additional controls for the state and year time-invariant covariates.[11]

Empirical Results

Tables 8 – 10 present the results for the three state science policy programs. Model 1 provides a baseline. Models 2 – 4 include the location quotient (LQ) for the state R&D-related variables (*HIGH TECH INDUSTRY* and *S&E DEGREES*). Models 5 – 9 report these indicators using quartile rankings of the LQ for the two variables. The empirical results for each policy are discussed in turn.

Eminent Scholar Results

Table 8 reports the coefficients from Equation 1 for the ES program. The effect of the state's fiscal health (*FISCAL*) on having the ES program is not statistically significant. The effect of *HIGH TECH INDUSTRY* on ES policy adoption is negative and statistically significant for the LQ indicator and

[11] Out-of-range predictions were 20% for the ES regressions, 7% for the URG regressions, and 2% for the CE regressions. Despite the relatively large share of out-of-range predictions with the ES regressions, we chose to use the LPM state fixed effect models due to ease of interpretation and because we are not concerned with predictions in this analysis.

positive and statistically significant for the quartile dummies. States with lagging high technology industrial capacity – in terms of the ratio of high tech labor supply to total labor supply – are more likely to adopt and maintain the ES program than leading states. Moreover, the coefficients on the quartile dummies indicate that the likelihood of policy adoption increases as states fall in rank with respect to the relative strength of the state's high tech capacity. In other words, in contrast to the leading cohort of states in terms of high tech capacity (Q4 serving as the referent category), states in the lowest quartile have a greater likelihood of adoption, after controlling for other state and national R&D-related measures. The size of the coefficient for Q1 is larger than the coefficient for states just below the national mean (Q2). Moreover, the effect is null for states just above the national mean (Q3). The strength of the association between the high tech industrial capacity and having the ES program is strongest for the states with the lowest rank. States that are above the national high tech industrial capacity average ranking do not have this program.

The coefficients for *S&E DEGREES* are statistically significant and show the opposite sign of the *HIGH TECH INDUSTRY* indicators. States with greater concentrations of S&E graduates are more likely to have this program. The coefficients from the quartile dummies indicate that the association with having the program decreases as states fall in rank; in other words states increase the likelihood of adoption as they improve relative rank. This suggests that policymakers may justify adoption and continued support of the ES program due to the strength of the S&E capacity among the state's university institutions. The coefficients on *UNIVERSITY R&D* are significant and positive suggesting a complementary association between state R&D university policymaking and federal university R&D investment in a state. The *EPSCoR* coefficient is statistically significant and negative demonstrating that lagging states, even after controlling for other factors are less likely to try to attract eminent scholars. This result has similar implications to the *S&E DEGREES* coefficients, which is expected given that a state's *EPSCoR* status is partially determined by university R&D activity. The coefficient on *S&E HE EXP* is positive and significant with the exception of models 3, 4, and 8. Although the association is not robust across all models, the statistical significance in model 9 suggests that the aggregate trends of federal spending incentivize this state policy activity.

University Research Grant Results

Table 9 reports the coefficients for the LPM state fixed effects model for the URG program. A number of the state R&D coefficients mirror the results from the ES model. Most notably, *FISCAL*, measuring the state's fiscal health, is again not statistically significant. States with lagging high tech industrial capacity (*HIGH TECH INDUSTRY*) tend to adopt the URG program as demonstrated by the negative, statistically significant effects of the LQ indicator and positive, statistically significant effect of the quartile dummies. In contrast to ES results, however, the size of the coefficients for the quartile dummies are roughly equivalent, thus we see no trend of having the program decrease as states improve rank between Q1 and Q3. The results generally imply that states not in the leading quartile are more likely to adopt the policy than the leading referent group. Federal investment in university R&D (*UNIVERSITY R&D*) is not significant; however, the positive coefficient for *S&E HE EXP* is. While federal investment in each state's university R&D activity does not exhibit an association with URG policy adoption, national R&D spending activity does complement URG policy adoption. We attribute the lack of significance for the former covariate to multicollinearity between the two variables. With the exception of the coefficient for the third quartile for *S&E DEGREES* in models 8 and 9, the results on *S&E DEGREES* and *EPSCoR* are not statistically significant.

Centers of Excellence Results

Table 10 presents the results of Equation 1 for the CE program. As with the previous two policies, *FISCAL* is not statistically significant. *HIGH TECH INDUSTRY* also is negative and significant in models 2 and 3, though the effect is not robust across all models. Additionally, *S&E HE EXP* is positive and significant, suggesting that aggregate industrial spending trends in R&D influences state policymaking activity.

The remaining covariates differ from the previous two sets of regressions for the ES and URG program. The coefficient on *S&E DEGREES* is negative and statistically significant for the LQ indicator and positive and statistically significant for the quartile dummies. Contrary to the results on this coefficient for the ES policy, this suggests that states with a lagging S&E concentration within their academic institutions – in terms of the share of S&E graduates – tend to have this program. The results from the quartile dummies offer additional insight indicating that the size of the effect for having a CE program decreases as the state improves rank. The coefficient on *UNIVERSITY R&D* is negative and significant suggesting a substitutive association between state-level industry investment in university R&D and having the CE program. This is surprising, given that the *S&E HE EXP* was positive and significant. We expected the sign of the coefficients to be consistent for these two measures. Lastly, the coefficient on *EPSCoR* is negative and significant which indicates that states leading in terms of university R&D activity tend to have the program. This points to a proactive state-level political move for states – not necessarily those lagging in terms of R&D activity – to remain competitive and improve ED activity within the state through university R&D activity.

Discussion

To improve our nascent understanding of state science policymaking, this analysis presents the results from three empirical models to identify factors associated with the adoption and continued support of the ES, URG, and CE programs. As mentioned above, this analysis serves as an exploratory exercise to identify trends with state policymaking activity rather than presenting models claiming causality.

For all three state university R&D policies, the associations of fiscal health, high tech industry, and science and engineering aggregate expenditures are similar. Notably, the state's fiscal health on having a university state science policy is not statistically significant; lagging states in terms of the ratio of high tech industrial labor supply tend to have the policy; and national trends of R&D spending activity complements the state science policy activity. Although we anticipated that the FISCAL variable would be positive and significant, the results are not robust. The state R&D-related covariates, however, demonstrate an effect. The negative coefficients on *HIGH TECH INDUSTRY* shed light on the possible motivations behind the longer-term aims state policy makers have when adopting and continuing the support of these programs. It appears as though states with a lagging high tech industrial capacity invest in these more upstream, university-based policies to improve the performance downstream. As for the positive coefficients on *S&E HE EXP*, national trends of R&D spending activity appear to complement state policymaking activity.

In addition to these commonalities across the portfolio of programs, the results from the other variables suggest that state governments rely on a different set of incentives when adopting and maintaining these programs. The differences are most notable between the ES and the CE program. The coefficients on *S&E DEGREES* and *UNIVERSITY R&D*, in particular, have opposite signs for these two policies. Both the *S&E DEGREES* and *UNIVERSITY R&D* covariates and ES program measure more upstream R&D activity – in comparison to the CE program – thus the positive statistically significant coefficients for the ES regressions suggest that states consider the relative strength of the R&D capacity that directly aligns with the upstream aspects of the program. Moreover, the results imply that external federal investment in a state's university R&D activity complements this state policy action. This suggests that states consider their relative university R&D capacity when considering this program.

We see the opposite effect with the *S&E DEGREES* and *UNIVERSITY R&D* covariates and the CE program. We interpret the negative coefficients as having a substitutive association between the more upstream R&D covariates with the more downstream university state science policy action. The general trend with the CE regression results implies a reactive response from state policymakers suggesting that state governments adopt and maintain this policy to catch up. We attribute this difference between the ES and the CE program to the structure of the state programs; with the ES program aimed at supporting earlier stage, more basic university R&D activity and the CE program designed to support later-stage

R&D activity. Arguably as a more downstream policy, lagging states opt to adopt the CE policy since this investment is closer to more tangible, economic outcomes. On the converse, the payoff for the ES program – being a more upstream, earlier stage policy – is further removed from tangible economic outcomes. Thus the results for the ES policy imply that state commitment to the ES policy requires a stronger S&E capacity to offset the more upstream investment.

The coefficients on *EPSCoR* are negative for both the ES and CE program and null for URG. Given the results from the *S&E DEGREES* covariate, we would expect the sign of the coefficient to be positive for the CE policy given the overlap in the two variables. Nevertheless, the results indicate an inverse relationship between the *EPSCoR* status and university state science policy adoption. This implies that state university R&D policy activity is not merely a process of playing "catch up" with the national trend or leading states, but rather state governments proactively adopt these programs to bolster competitiveness.

Although the state-level indicators *S&E DEGREES* and *HIGH TECH INDUSTRY* both measure aspects of R&D activity, the results from this analysis highlight their differences. With the former measuring more upstream activity and the latter measuring more downstream, these results affirm what scholars already know about the complexity of the R&D process: strength along one dimension of R&D does not necessarily ensure strength along another. To better understand the differences of these two indicators Figure 2 presents a series of maps of these two measures showing how these measures have changed over the past 40 years.

Most notably the leading cohorts of states for both measures vary. The left column in Figure 2 illustrates a general trend that the states with leading ratios of *S&E DEGREES* are concentrated along the west coast and rocky mountain region, with a few located in New England and in the mid-Atlantic region. The lagging states demonstrate a greater concentration in the Plains and Southeast. California, New York, Virginia, Maryland, and Washington are among the leaders along this measure, which is not surprising given their demonstrated R&D and economic performance. What is more unexpected, however, is the group of EPSCoR states – including Montana, Wyoming, Vermont, and Maine – that lead along this dimension as well. While the latter cohort lags in terms of its relative share of R&D activity – which qualifies them for EPSCoR status – these states produce a greater ratio of S&E degrees compared to the US average. This figure illustrates that the concentration of S&E degrees is more varied and does not directly align with more traditional, downstream measures of R&D. The more traditional, downstream activity is illustrated in the right column in Figure 2. These maps of *HIGH TECH INDUSTRY* more closely mirror the overall economic health of the state. This is illustrated by the notable concentration in the Rust Belt region in the 1980s and 1990s followed by a shift to mid-Atlantic states and Washington, Colorado, Illinois, and Minnesota in the more recent decades.

Reflective Conclusions

Improved understanding of state R&D initiatives promises to help guide federal policy makers and policy makers of other states and countries. The U.S.'s federalist structure was intentionally put in place to create checks and balances on the national government. However, in addition to providing protection against potential political abuse, this structure places state governments in competitive laboratories of democracy to experiment and vet the efficacy of varying programs. This competitive structure between states promotes a process of trial and error that propels states to experiment and maximize their intended goals (Karch, 2007). Scholars and policy makers thus have an opportunity to evaluate the successes and failures of these state "experiments" and arrive at more enlightened policy recommendations. State-level policy analysis therefore has the potential to improve policymaking and even the playing field for those states that suffer losses from a peer state's effective policy.

The increased prevalence of these state-based university programs suggests that state policy makers have come to justify and sustain support of university R&D programs under the premise that R&D will stimulate innovation and thereby foster local entrepreneurship and economic activity. Additional analysis is required to see if these measures have had the desired impact. These quantitative analyses serve as an exploratory effort toward understanding whether and how state R&D-related factors influence the state university R&D policymaking process.

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Figures

Figure 1: Distribution of state university R&D portfolio – 1990, 2000, and 2009

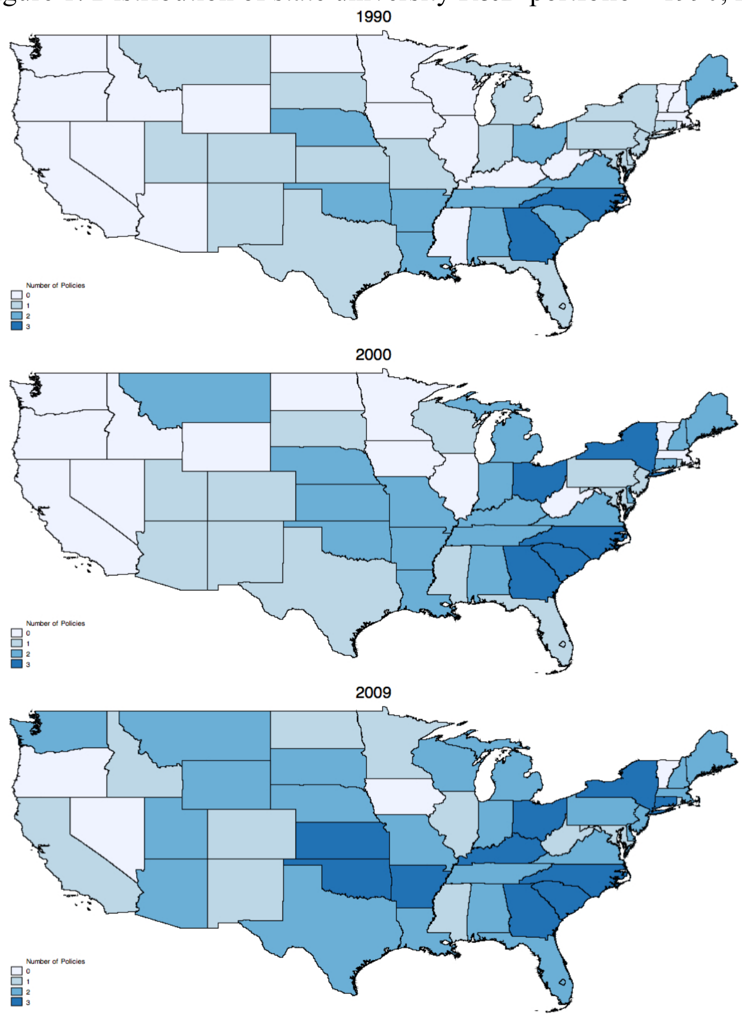
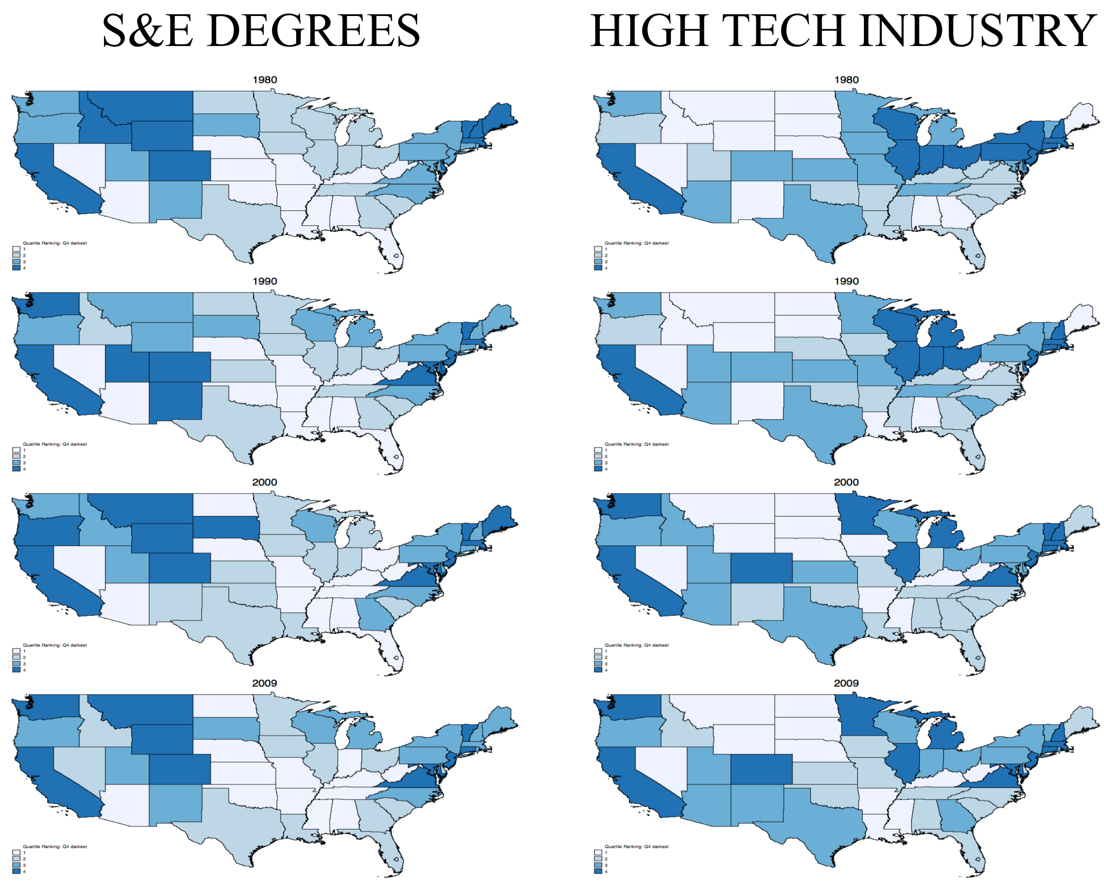


Figure 2: Quartile rankings of *S&E DEGREES* and *HIGH TECH INDUSTRY* for 1980, 1990, 2000, and 2009



Tables

Table 1: Year of Policy Adoption: Eminent Scholars, University Research Grants and Centers of Excellence

	Eminent Scholars	University Research Grants	Centers of Excellence
Alabama		1983	1975
Alaska			
Arizona	1991	2006	
Arkansas	2002	1983	1990
California		2005	
Colorado			1983
Connecticut	2006	1993	1965
Delaware		1984	1994
Florida	2006		1982
Georgia	1990	1990	1990
Hawaii			
Idaho			2003
Illinois			2003
Indiana		1999	1983
Iowa			
Kansas	2004	2000	1983
Kentucky	1997	1997	2003
Louisiana	1987	1987	
Maine		1990	1988
Maryland			1985
Massachusetts		2004	2009
Michigan		1999	1981
Minnesota			2005
Mississippi			1999
Missouri	1995		1986
Montana		1999	1988
Nebraska		1988	1987
Nevada			
New Hampshire		1991	1991
New Jersey		2007	1984
New Mexico			1983
New York	1999	2000	1983
North Carolina	1986	1984	1980
North Dakota			2006
Ohio	1983	1998	1984
Oklahoma	2006	1985	1989
Oregon			
Pennsylvania	2006		1988
Rhode Island			1996
South Carolina	1997	1983	1983
South Dakota		1987	2004
Tennessee	1984		1984
Texas	2005	1987	
Utah		2006	1986
Vermont			
Virginia	1964		1986
Washington	2007	2005	
West Virginia		2004	
Wisconsin	1998	2007	
Wyoming	2005		2008

Source: Feldman et al. forthcoming

Table 2: Adoption years for portfolio of state university R&D programs

Number of policies	**Number of states**	**Year adopt (state)**		
		Mean	*First adopter*	*Most recent adopter*
1	44	1989	1964 (VA)	2006 (ND)
2	33	1996	1983 (SC)	2009 (MA)
3	10	1999	1986 (NC)	2006 (CT)

Table 3: Duration between policy adoptions within states

Policy Time Lag	**Number of states**	**Mean (years)**	**Standard Deviation**	**Min**	**Max**
First to Second	33	9.94	8.61	0	28
Second to Third	9	8.56	6.67	0	17
First to Third	9	17.11	11.37	0	41

Table 4: Trends of initial policy adoption of CE, URG, and ES programs

Policy	**Number of states**	**Year adopt first program (state)**		
		Mean	*First to adopt*	*Most recent to adopt*
CE	28	1987	1965 (CT)	2006 (ND)
URG	14	1992	1983 (AR, SC)	2005 (CA, WA)
ES	9	1988	1964 (VA)	2005 (WY)

Table 5: Indicators Used to Measure Independent Variables

Variable	**Metric**	**Source**
FISCAL	$\frac{total\ revenue_{it} - total\ expenditure_{it}}{total\ expenditure_{it}}$	US Census State Government Finances
HIGH TECH INDUSTRY[12]	$\frac{high\ tech\ employment_{it} / total\ employment_{it}}{high\ tech\ employment_{t} / total\ employment_{t}}$	Bureau of Economic Analysis
S&E DEGREES[13]	$\frac{higher\ ed\ S\&E\ degrees_{it} / higher\ ed\ degrees_{it}}{higher\ ed\ S\&E\ degrees_{t} / higher\ ed\ degrees_{t}}$	National Science Board S&E State Indicators on Higher Education
UNIVERSITY R&D[14]	$Univeristy\ R\&D\ expenditures_{it}\ (logged)$	NSF Survey of R&D Expenditures
EPSCoR	$EPSCoR\ status_{it}$	National Science Foundation
S&E HE EXP[15]	$Total\ S\&E\ Higher\ Education\ Expenditures_{it}\ (logged)$	NSF Survey of R&D Expenditures

Note: *i* denotes state and *t* denotes year.

[12] High tech industries were based on the BLS definition (Hecker, 2005). Models 4 – 8 report the quartile rankings of the HIGH TECH IND location quotient with Q4, the quartile of states each year with the highest location quotient, serving as the referent category.

[13] S&E degrees are defined by the National Science Board and include physical, life, earth, ocean, atmospheric, computer, and social sciences; mathematics; engineering; and psychology. Higher education degrees include bachelor's, master's, and doctoral degrees but exclude associate's degrees. Models 4 – 8 report the quartile rankings of the S&E DEGREES location quotient with Q4, the quartile of states each year with the highest location quotient, serving as the referent category.

[14] This includes federal and industry R&D expenditures in S&E fields, including direct and recovered indirect costs, respectively. The data are logged expenditures of university R&D (in real dollars).

[15] The data are logged expenditures of university R&D (in real dollars).

Table 6: Descriptive statistics

	Mean	**Standard Deviation**	**Minimum**	**Maximum**
ES[16]	0.167	0.373	0	1
URG	0.293	0.455	0	1
CE[17]	0.467	0.499	0	1
FISCAL	0.083	0.140	-0.761	1.249
HIGH TECH INDUSTRY (LQ)	0.880	0.254	0.228	1.939
S&E DEGREES (LQ)	0.989	0.145	0.578	1.469
UNIVERSITY R&D (federal, logged)	18.639	1.392	14.660	22.165
UNIVERSITY R&D (industry, logged)	16.346	1.392	11.925	20.043
EPSCoR	0.334	0.472	0	1
S&E HE EXP (federal, logged)	23.248	0.638	22.134	24.207
S&E HE EXP (industry, logged)	20.923	0.717	19.279	21.885

Note: Unless otherwise noted, the number of observations is 1,500 (50 states over 30 years – 1980-2009).

[16] Due to early adoption, VA (1964) was removed. The number of observations is 1,470.
[17] Due to early adoptions, CT (1965) and AL (1975) were removed. The number of observations is 1,440.

Table 7: Correlation Matrix

	ES	URG	CE	FISCAL	HIGH TECH INDUSTRY	S&E DEGREES	UNIVERSITY R&D (Fed)	UNIVERSITY R&D (Ind)	EPSCoR	S&E HE EXP (Fed)	S&E HE EXP (Ind)
ES	1										
URG	0.3359	1									
CE	0.2212	0.3016	1								
FISCAL	-0.0859	-0.1023	-0.1018	1							
HIGH TECH INDUSTRY	0.0471	0.0281	0.1578	-0.1242	1						
S&E DEGREES	-0.2116	-0.1218	-0.0387	0.0959	0.1137	1					
UNIVERSITY R&D (Fed)	0.3114	0.0864	0.3021	-0.1799	0.559	0.0658	1				
UNIVERSITY R&D (Ind)	0.3215	0.1486	0.3189	-0.1413	0.5112	-0.0068	0.8972	1			
EPSCoR	-0.0107	0.2794	-0.0123	-0.0455	-0.4768	-0.1743	-0.4444	-0.3688	1		
S&E HE EXP (Fed)	0.3174	0.3768	0.3647	-0.1951	0.0404	-0.0013	0.486	0.4302	0.2548	1	
S&E HE EXP (Ind)	0.2956	0.3614	0.3767	-0.1566	0.0511	-0.0078	0.4607	0.4518	0.255	0.96	1

Table 8: Effect of state R&D factors on ES policy adoption

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	ES	ES	ES	ES	ES	ES	ES	ES	ES
Fiscal	-0.036	-0.022	-0.030	-0.033	-0.041	-0.050	-0.052	-0.041	-0.049
	(0.048)	(0.048)	(0.048)	(0.048)	(0.048)	(0.048)	(0.047)	(0.048)	(0.047)
High Tech Industry (LQ)		-0.256***	-0.315***	-0.277***					
		(0.065)	(0.066)	(0.066)					
SE Degrees (LQ)			0.389***	0.329***		0.341***	0.290**		
			(0.120)	(0.120)		(0.120)	(0.120)		
University R&D (Fed)			0.125***	0.140***		0.092**	0.111***	0.113***	0.113***
			(0.039)	(0.039)		(0.039)	(0.039)	(0.039)	(0.039)
EPSCoR				-0.096***			-0.117***		-0.110***
				(0.027)			(0.027)		(0.027)
S&E HE Exp (Fed)	0.184***	0.187***	0.052	0.054	0.184***	0.084*	0.085**	0.062	0.082*
	(0.010)	(0.010)	(0.043)	(0.043)	(0.010)	(0.043)	(0.043)	(0.043)	(0.043)
High Tech Industry Q1					0.256***	0.263***	0.271***		0.268***
					(0.042)	(0.042)	(0.042)		(0.042)
High Tech Industry Q2					0.100***	0.120***	0.130***		0.129***
					(0.034)	(0.035)	(0.035)		(0.034)
High Tech Industry Q3					0.005	0.015	0.022		0.021
					(0.028)	(0.028)	(0.028)		(0.028)
SE Degrees Q1								-0.166***	-0.147***
								(0.043)	(0.043)
SE Degrees Q2								-0.111***	-0.098***
								(0.034)	(0.034)
SE Degrees Q3								-0.048*	-0.050**
								(0.025)	(0.025)
Constant	-4.118***	-3.960***	-3.481***	-3.743***	-4.188***	-3.921***	-4.222***	-3.303***	-3.830***
	(0.234)	(0.236)	(0.369)	(0.375)	(0.230)	(0.367)	(0.371)	(0.342)	(0.346)

Notes: The number of observations is 1,470 (49 states over 30 years – 1980 – 2009). Virginia has been removed due to early adoption of the policy. Coefficients are from an LPM state fixed effects model. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 9: Effect of state R&D factors on URG policy adoption

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	URG	URG	URG	URG	URG	URG	URG	URG	URG
Fiscal	0.040	0.052	0.051	0.053	0.046	0.044	0.044	0.034	0.039
	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)
High Tech Industry (LQ)		-0.247***	-0.261***	-0.274***					
		(0.072)	(0.073)	(0.074)					
SE Degrees (LQ)			0.064	0.088		0.068	0.074		
			(0.135)	(0.136)		(0.136)	(0.136)		
University R&D (Fed)			0.045	0.039		0.023	0.021	0.028	0.018
			(0.044)	(0.045)		(0.044)	(0.045)	(0.044)	(0.044)
EPSCoR				0.038			0.012		0.013
				(0.031)			(0.030)		(0.031)
S&E HE Exp (Fed)	0.269***	0.273***	0.224***	0.224***	0.269***	0.244***	0.244***	0.239***	0.247***
	(0.011)	(0.011)	(0.049)	(0.049)	(0.011)	(0.049)	(0.049)	(0.049)	(0.049)
High Tech Industry Q1					0.152***	0.153***	0.152***		0.155***
					(0.047)	(0.047)	(0.047)		(0.047)
High Tech Industry Q2					0.126***	0.129***	0.128***		0.132***
					(0.037)	(0.037)	(0.038)		(0.037)
High Tech Industry Q3					0.138***	0.140***	0.139***		0.139***
					(0.030)	(0.031)	(0.031)		(0.030)
SE Degrees Q1								-0.028	-0.052
								(0.049)	(0.049)
SE Degrees Q2								-0.027	-0.044
								(0.038)	(0.039)
SE Degrees Q3								-0.051*	-0.060**
								(0.028)	(0.028)
Constant	-5.970***	-5.837***	-5.597***	-5.500***	-6.082***	-5.995***	-5.965***	-5.757***	-5.867***
	(0.259)	(0.261)	(0.415)	(0.422)	(0.259)	(0.417)	(0.424)	(0.385)	(0.396)

Notes: The number of observations is 1,500 (50 states over 30 years – 1980 – 2009). Coefficients are from an LPM state fixed effects model. Standard errors are in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 10: Effect of state R&D factors on CE policy adoption

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	CE	CE	CE	CE	CE	CE	CE	CE	CE
Fiscal	0.059	0.068	0.076	0.068	0.062	0.073	0.066	0.066	0.060
	(0.054)	(0.054)	(0.053)	(0.053)	(0.054)	(0.053)	(0.053)	(0.053)	(0.053)
High Tech Industry (LQ)		-0.191**	-0.138*	-0.104					
		(0.079)	(0.081)	(0.081)					
SE Degrees (LQ)			-0.382***	-0.443***		-0.408***	-0.451***		
			(0.136)	(0.137)		(0.136)	(0.136)		
University R&D (Ind)			-0.044**	-0.046***		-0.042**	-0.045**	-0.048***	-0.049***
			(0.017)	(0.017)		(0.017)	(0.017)	(0.017)	(0.017)
EPSCoR				-0.110***			-0.117***		-0.117***
				(0.031)			(0.030)		(0.031)
S&E HE Exp (Ind)	0.268***	0.272***	0.311***	0.330***	0.269***	0.306***	0.328***	0.312***	0.331***
	(0.010)	(0.010)	(0.018)	(0.019)	(0.010)	(0.018)	(0.019)	(0.018)	(0.019)
High Tech Industry Q1					0.005	-0.004	0.009		0.017
					(0.048)	(0.048)	(0.048)		(0.048)
High Tech Industry Q2					0.054	0.027	0.038		0.050
					(0.037)	(0.037)	(0.037)		(0.037)
High Tech Industry Q3					0.046	0.032	0.040		0.048
					(0.030)	(0.030)	(0.030)		(0.030)
SE Degrees Q1								0.098**	0.115**
								(0.048)	(0.049)
SE Degrees Q2								0.072*	0.081**
								(0.038)	(0.039)
SE Degrees Q3								0.058**	0.059**
								(0.028)	(0.028)
Constant	-5.151***	-5.072***	-4.823***	-5.118***	-5.190***	-4.873***	-5.201***	-5.325***	-5.729***
	(0.209)	(0.211)	(0.250)	(0.262)	(0.210)	(0.256)	(0.269)	(0.213)	(0.236)

Notes: The number of observations is 1,440 (48 states over 30 years – 1980 – 2009). Alabama and Connecticut have been removed due to early adoption of the policy. Coefficients are from an LPM state fixed effects model. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1