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UNIVERSITIES AND THE ENTREPRENEURIAL STATE: Politics and Policy and a New Wave of State-Based Economic Initiatives*

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ABSTRACT

The convergence of US federal science and economic policy that began in earnest in the Reagan administration formed the first stage in an emerging post-Cold War drive toward technological innovation. A frenzy of new state-based initiatives now forms the *Second Stage*, further promoting universities as decisive tools for economic competitiveness. State governments have largely become the political environment in which new policy ideas are emerging, influenced by a sense of increased competition among states and other international economies for economic growth. The paper outlines the characteristics of this *Second Stage*, and offers short case studies of two influential HT initiatives in California—a leading HT state. Among the author's conclusions: HT economic activity is already relatively widespread among the various states (more so than perhaps previously thought); leading HT states rely heavily on their university sectors and a highly educated workforce, yet are increasingly importing talent and neglecting investment in the education and skills of their native populations; the long-term commitment of states to financially support the frenzy of HT initiatives is unclear; and state initiatives are rationalized by lawmakers as filling a need not currently met by the private sector or universities and, in part, as a response to a sense of competition between states, and thus far with only a minor concern for global competition. As this paper explores, the politics of HT—including the focus on university-industry collaboration and neo-conservative religious/moral controversies over stem cell research—is a significant factor for understanding how and why most states are pursuing the *Second Stage*.

The discourse over the role and future of national and supranational systems of higher education, such as the nascent European Higher Education Area, is tied increasingly to the perceived and real economic benefits of state sponsored tertiary education, and

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arguably less to the socio-economic mobility of individuals than in the past. Governments and policymakers ubiquitously frame science policy and the productivity and interrelationships of universities with industry and innovation as the essential means for maintaining or advancing economic competitiveness within a globalizing economy. Even issues of access and degree production are increasingly discussed largely in terms of national or regional competitiveness.

In the US, and with significant influence internationally, one can trace the beginnings of this shift in government policy to the Reagan administration. Although universities in the US have a long tradition of being vehicles for regional and national economic development, the Reagan era introduced important policy shifts that influenced the behavior—and perceptions about the usefulness—of the academy. For the first time, federal science and technology policy in the United States shifted from being a primary means for military technological superiority to becoming a key component in national economic policy as well, with an increasing focus on university-industry relations and mechanisms for promoting innovation.[1]

For some two decades after 1980, much of the policy debate centered on federal initiatives and funding, including changes in intellectual property laws, R&D tax credits, federally funded science centers, and increased investment in basic research conducted by America's research universities. A fundamental assumption was that the nation depended on a class of high-quality research universities as a key driver for supporting high tech (HT) innovation.

The Bayh-Dole Act of 1980 opened the doors for universities and their faculty and researchers to own patents and issue licenses developed through federally funded research. That important legislation and the subsequent federal policy regime formed the First Stage in an emerging post-Cold War drive toward technological innovation and the convergence of science and economic policy.

Yet beyond general increases in funding for basic research over the past decade, the federal policy regime remains largely unchanged—indeed, at times regressive—in light of increased restrictions on visas for foreign students and talented faculty, who historically have been important contributors to the scientific and technological prowess of the US.

A wave of new state-based initiatives now form the *Second Stage* in this process of convergence, with the further promotion of universities as decisive tools for economic competitiveness. State governments have become the political environment in which new policy ideas emerge, marked by a sense of increased competition among states and with other developed and emerging economies of the world for economic growth.

The following discussion outlines the characteristics of the *Second Stage*, and then offers short case studies of two influential HT initiatives in California before providing an assessment of the pattern of other state initiatives and current concentration of HT businesses. The essay concludes with an initial analysis of this nascent movement and its potential influence on the economy of states.

This analysis indicates that HT economic activity is already relatively widespread among the various states (more so than perhaps thought previously); that leading HT states rely heavily on their university sectors and a highly educated workforce, yet are increasingly importing talent and neglecting investment in the education and skills of their native populations; that the long-term commitment of states to provide financial support for the frenzy of HT initiatives is unclear; and that state initiatives are rationalized by lawmakers as filling a need not currently met by the private sector or universities and, in part, as a response to a sense of competition between states.

It remains to be seen whether such initiatives are growth-enhancing, and whether they will benefit very specific sectors of the economy and labor force or a state's population as a whole.

The politics and rhetoric of HT, including the focus on university-industry collaboration, is a significant factor for understanding how and why most states are pursuing the *Second Stage*. The actions of individual states, particularly important HT states such a California, are influencing policymaking in other states. In short, there is a frenzy of state-based initiatives. Policymaking is, in part, driven by the rhetoric and realities related to the idea of postmodern economies and, at least in the initial stages of many state initiatives, often by individual advocates—politicians, sometimes HT industry leaders, or, as in the case of California's stem cell initiative, patient advocates, though seemingly marginally by those in the academy itself.

In one form or another, other nations with developed economies are all pursuing similar initiatives, convinced that fostering greater links between their universities and industry is a primary means of promoting innovation. The intent is to bolster their HT sectors and, in turn, partially transform their economies. A main theme of this essay is that there is an emerging politics of HT in which policymaking is shaped in part by political culture and the perceptions and agendas of lawmakers. The United States provides a large-scale case example with which to begin an exploration of the dynamics of this postmodern phenomenon that is prevalent in one form or another in all major economies.[2]

The Evolving Influence of the Bayh-Dole Act

Passage of the Bayh-Dole Act in 1980 is often cited as a critical juncture in the shift of federal policy that created an improved environment for promoting university and industry links, and for bolstering technological innovation and the tech sector of the US economy. By allowing universities and research staff to own jointly discoveries supported by federal research grants, Bayh-Dole is credited with providing an important market force for creating the entrepreneurial university and for bolstering activity in a key economic sector.

Recent studies, however, indicate that the influence of Bayh-Dole is generally exaggerated. While American universities since the 1980s have increased substantially their patenting and licensing activities, as well as the number of spin-off businesses and launches of their own start-ups, other factors help to provide the context for the emergence of a more entrepreneurial university.

For one, American universities, particularly the public universities, have an extensive historical tradition of serving local and regional economies. An academic culture has long existed, particularly in the engineering and agricultural fields, of pursuing research directly relevant to the labor and research needs of local businesses and industry. Second, much of new patent and licensing activity and spin-offs has occurred in biomedical sciences and communications where the required environment for increased tech-transfer rates has been created as a result of discoveries via long-term investment in basic or “blue sky” research. Third, this remarkable acceleration of discoveries in the life sciences, and resulting patents and licenses, has been facilitated by the extension of the definition of “patentable material” by the US Supreme Court and is reflected in new policies within the US Patent and Trademark Office.

It is clear also that patent and licensing activity and the number of spin-offs are not necessarily the most important evidence of the key role of universities in promoting economic development. The flow of information between university and business sectors and, perhaps most importantly, the movement of personnel to and from the academy are often cited as the critical factors for promoting a vibrant business climate.[3] The structure and vibrancy of a state’s economy are also important influences on the ability of universities to strategically increase their role in the economy.

A recent study indicates that larger firms with over 1,000 employees are the most likely to collaborate with universities and other public research institutes (non-profits). Further, most if not all of these firms are already engaged in R&D activity, sometimes via contracting research activity, and have therefore successfully built a capacity to absorb and use public-generated research.[4] Another study indicates, not surprisingly, that university-based start-ups are largely concentrated in states with the largest economies and with the largest levels of venture capital.[5]

Despite these important caveats, Bayh-Dole was extremely influential in two ways. First, it bolstered the interest of a cadre of already highly productive research universities in developing new strategic approaches to tech-transfer and, in turn, influenced the thinking of a second tier of universities (Comprehensive 1 and 2 under the Carnegie Classification) in creating new tech-transfer offices and policies. From 1980 to 1998, according to the Association of University Technology Managers, 2,578 new companies were formed based on a license from an academic institution. About 70% of such companies become "operational," which the association defines as having enough money to make progress toward their business goals. Larger companies later acquire these businesses.

While greater support of local businesses and an increased role in the economic activity of the nation formed one motivation, often a paramount concern was how to increase and diversify the sources of funding for universities—particularly public universities, which have faced nationally a steady decline in public investment on a per-student basis since the late 1970s.

Second, Bayh-Dole substantially accelerated (one might say, re-ignited) the interest of state governments, and to lesser extent municipal governments, in harnessing universities in new ways to support and grow their tech-based businesses. This relatively new and important phenomenon is the focus of this paper. With federal policies and funding for promoting university-business collaboration remaining relatively stable over the last two decades (and without the prospect of significant increases in funding for basic research or for new initiatives), states have emerged as extremely active agents.

This new policy and investment role was predicted, and encouraged, by a 1998 House Committee on Science report: “State-based organizations have considerable advantages over the federal government in assisting in the commercial development of new technologies including their proximity to the firms that will actually employ new technologies, their close relationships with local university systems, and their ability to focus on their efforts."[6]

The Focus of the Second Stage

In 2003, the National Governors Association (NGA) adopted its National Research, Development and Technology Policy position statement. At that time, the NGA focused on six issues for improving federal science policy to meet state economic development goals, including improved technology transfer from universities and federal laboratories and sustained federal funding for the Manufacturing Extension Partnership, the Advanced Technology Program, and aeronautical technology R&D. By 2005, the NGA called for a "State-Federal Technology Partnership to Encourage Commercialization," and stated:

> Technology and innovation drive the creation of new companies. Studies of company formation consistently show that a vital fraction of start-ups are founded around spun-out university developed technology. Yet, current practices in commercializing technology from public-funded research are not keeping up with the needs of the states and the nation in this critical area.
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> It is in the nation's best interest to develop a new system that will commercialize technology efficiently and effectively to increase the state and federal governments' return on investment. This system should be based on states' economic development capabilities in linking researchers and entrepreneurs with each other, and sources of capital and business expertise. Since states have more interaction and knowledge of local marketplaces, this new system could be locally managed by a state, independent entity, or locality, while the federal government could provide support and guidance to encourage the implementation of best practices.[7]

The NGA made two major recommendations, both intended to support the efforts of individual states. First, the governors asked that Washington help develop a national network in partnership with the states to accelerate the commercialization of technology in local marketplaces. And second, they asked the White House to "promote greater coordination and communication among federal agencies in their approaches to encourage innovation as an economic growth strategy."

Within the fifty states that constitute the US, there are significant variations in the policies pursued to increase economic activity. There are also huge differences among the states in their economic base and environment, in their rural versus urban populations, in their potential to grow high-technology industries, and in the quality and flexibility of their universities and higher education systems in general. There are important differences as well in the political cultures of the states—a reality reflected in interesting debates over stem-cell research prompted in large part by federal policies pursued by the Bush administration. Figure 1 provides a number of gauges of the total and relative size of the high-tech sector, both public and private, in six large states, all with productive research universities.

Figure 1. Gauges of High-Tech Research and Economic Activity: Sample of Twelve Large and Midsized States

SAMPLE OF LARGE STATES	California		Texas		Michigan		New York		Illinois		Florida	
> 12.5 Million People	#	Rank	#	Rank	#	Rank	#	Rank	#	Rank	#	Rank
Employment in HT Businesses in 2000**	1,397,776	1	703,206	2	514,017	3	513,472	4	491,433	5	339,093	9
% of Employment in HT in 2000**	10.8	6	8.8	20	12.6	1	7.0	37	8.9	18	5.5	44
Net Formation of HT Businesses in 2000**	2,452	1	306	6	196	16	841	2	248	11	596	3
Fastest Growing Tech Companies: 2002***	151	1	21	6	28	3	24	4	11	14	18	7
Total University R&D Expenditures	$4.422b	1	$2.244b	3	$1.107b	10	$2.476b	2	$1.280b	7	$.997b	10
University R&D/$1,000 of GSP	$3.25	23	$2.94	32	$3.45	20	$3.00	31	$2.69	35	$2.03	44
Industry R&D/$1,000 of GSP	$29.74	7	$12.88	27	$44.57	1	$13.17	26	$17.31	20	$7.64	33
Federal R&D/$1,000 of GSP	$1.66	12	$0.69	26	$0.37	39	$0.33	40	$0.17	48	$1.76	11
Venture Capital Invested/$1,000 GSP	$6.96	2	$1.68	10	$0.23	35	$0.97	20	$0.48	27	$0.73	23
# HT Incubators: 2003	123	1	43	5	20	11	76	2	26	10	36	7
Total US Patents Generated in 2000-02	20,647	1	6,632	3	4,194	6	7,097	2	4,241	5	3,044	10
Patents Issued/10,000 Businesses: 2000-02	256	2	140	17	177	9	144	16	138	18	70	32

SAMPLE OF MIDSIZED STATES	Ohio		Pennsylvania		Massachusetts		North Carolina		Washington		Wisconsin	
< 12.5 Million People	#	Rank	#	Rank	#	Rank	#	Rank	#	Rank	#	Rank
Employment in HT Businesses in 2000**	484,110	6	394,786	7	388,928	8	268,284	12	258,234	13	200,932	14
% of Employment in HT in 2000	9.7	13	7.8	30	12.6	1	6.2	39	11.4	5	9.1	15
Net Formation of HT Businesses in 2000**	129	19	257	10	300	7	238	13	253	10	54	30
Fastest Growing Tech Companies: 2002***	1	33	13	12	28	3	15	10*	15	10*	3	20
Total University R&D Expenditures	$.995b	11	$1.687b	4	$1.576b	6	$1.137b	8	$.706b	12	$.728b	11
University R&D/$1,000 of GSP	$2.67	36	$4.13	10	5.48	2	$4.13	11	$3.17	24	$4.11	12
Industry R&D/$1,000 of GSP	$17.91	17	$21.96	13	$39.05	3	$15.01	22	$38.98	4	$13.92	25
Federal R&D/$1,000 of GSP	$2.43	9	$0.44	35	$1.26	19	$5.08	26	$0.80	24	$0.23	46
Venture Capital Invested/$1,000 GSP	$0.59	25	$1.03	19	$8.21	1	$1.00	7	$2.69	6	$0.36	31
# HT Incubators: 2003	37	5	58	3	36	6	34	8	13	17	48	4
Total US Patents Generated in 2000-02	3,999	7	3,829	9	3,883	8	2,202	12	2,202	12	2,150	14
Patents Issued/10,000 Businesses: 2000-02	148	14	130	21	219	5	108	25	134	20	153	12

* States are tied
** HT Businesses as classified by NAICS codes, US Dept of Commerce
*** 2002 Ranking of Technology Fast Companies by Deloittee & Touche based on revenue growth; note that some 29 states had 2 or fewer fast growth HT businesses.
Source: US Office of Technology Policy, State Science and Technology Indicators, 2004.

California has the greatest number of high-tech businesses and the fastest growing HT companies, it secures the most research dollars, it has one of the highest concentrations of venture capital and the most HT incubators, and it generates the greatest number of patents. It is a major source of business activity in communications and computing and has the greatest concentration of biotech companies in the nation—indeed the world—most of which are located within a mile of a University of California (UC) campus.[8] California hosts the largest and highest-quality system of public research universities, along with Stanford University and Cal Tech, as well as the University of Southern California, which is emerging as a significant source of S&T discoveries.[9]

UC alone generates more than 320 US patents a year and has a portfolio of some 2,753 US and 2,364 foreign patents (as of fiscal year 2003). In California, one in three biotechnology firms is the creation of a UC scientist (and one in six nationwide). A UC scientist founded one in six businesses focused on communications. California biotech garnered 46% of the venture capital invested in biotech between 1992 and 2001 and accounts for 40% of the nation's biotech jobs.[10]

California is also the most populous state, with over thirty-five million people. Its overall economy is twice the size of the next-largest state, and it is ranked as the seventh-largest economy in the world. When adjusted for its overall size (as provided in a number of variables in Figure 1), the state remains a leader in most gauges of HT activity and start-ups. Yet other states are also extremely productive and competitive, claiming significant federal funding and generating significant activity that attracts and promotes private-sector investment and businesses. With ten million people, Michigan, for instance, has a higher concentration of employment in the HT sector relative to its overall economy. Reflecting both the success of a life-science corridor near the University of Michigan's main campus and businesses related to the auto industry, Michigan has the highest concentration of industry-based R&D relative to its Gross State Product (GSP).

New York, the third largest state in the Union with nineteen million people and with the second-largest GSP, is also a major center for HT employment; however, reflecting an economic base influenced in part by financial and commercial enterprises in New York City and the small size of many HT businesses, it has a relatively low ranking in the percentage of employment in HT. In total university R&D spending, New York ranks second to California, in large part because of the S&T productivity of Columbia University (largely in the life sciences), Cornell, parts of the SUNY system, and non-profit research centers.

While ranked eighth in total HT employment, Massachusetts has the highest percentage of its labor force in HT businesses. Its concentration of world-class universities within the Boston area leads to the state's frequent ranking as the most productive region for university-business collaborations, R&D expenditures relative to the overall size of the state's economy, and concentration of venture capital. Harvard, MIT, and other institutions in the Boston area attract both graduates and undergraduates from throughout the US and the world, providing a steady influx of S&T talent.

There are examples of specific state-funded and sanctioned programs related to promoting HT university-business collaborations that date back to the 1980s, such as Pennsylvania's Ben Franklin Program and Ohio's Thomas Edison Program. Both emerged in an era of significant economic decline in their older "rust-belt" industries and focused on creating university-business centers of "excellence" that, in turn, would generate and support new HT businesses. The Edison program focuses on bringing together technological providers and users to create commercial opportunities. In the first wave of state-sanctioned programs, the idea was largely to provide forums for the interchange of ideas and to foster relationships between academics (faculty and graduate students) and industry researchers. Most states as well have created state agencies to help promote HT via technological assistance and business incubators.

The new wave is now emerging in which states take a more direct involvement in funding research and providing capital. Most of these newer state initiatives are relatively recent (less than five years), and their full influence on the academy and on economic activity will not be known for many years. In a sense, the states have launched a great experiment shaped by a remarkable faith in science and technology as the primary driver of future economic growth and by a worry that state governments' lack of investment or enlightened direction would mean a potentially devastating disadvantage in the national and global economy. A widespread belief is that states will set the direction for the US battle for competitiveness.[11]

While differences among the states exist, there are emerging patterns that reflect, in part, the sense of increased competition among state governments and the replication of certain initiatives originally generated in "leadership" states.[12] Among these patterns:

- State funding and policies are largely focused on promoting or creating new university-business collaborative “clusters” that are co-located in key areas of the state with existing university and private-sector research centers, and targeted to building additional research capabilities in biotechnology, advanced communications and information systems, and the growing sectors of nanotechnology and technologies related to homeland security.
- States are increasingly targeting their efforts in terms of promoting and directly funding (beyond providing general operating funds to public universities) ”discovery” research, i.e., basic and applied, but generally not developmental research, that requires long-term investment, reflecting a relatively new political understanding of the nature of technological innovation.
- State initiatives are intended to leverage (and not replace) existing federal science funding and to attract additional industry and venture capital.
- For these targeted initiatives, many states are only marginally dipping into their state operating budgets, instead using funding derived from a huge 1998 settlement reached with the US tobacco industry or via bonds.
- Most state initiatives require some form of matching funding from private-sector businesses.
- Many states struggle with issues related to intellectual property rights related to state funded centers and sponsored research—essentially mirroring the debates over the Bayh-Dole Act.
- Policies to promote university-business collaborations and tech transfer are usually part of a larger set of Tech-Based Economic Development (TBED) policies that include tax incentives and building venture capital for start-ups, often focused on attracting existing high-tech businesses from other states or, like federal policies, on supporting and promoting small businesses.
- State initiatives often include financing for consortiums of universities within a state to “spread the wealth” and thus meet political needs of lawmakers and reduce opposition.
- Unprecedented federal restriction on research related to biotechnology (specifically stem cell research) is causing many states to generate their own funding sources, once thought largely the role of the national government.

As noted, state initiatives are usually not viewed as a replacement for federal basic research funding—with the anomaly of stem cell research. They are, instead, targeted attempts to improve their competitive position and leverage both federal and industry funding. Collectively, federal funding and these state initiatives mark a relatively new and concerted shift toward greater government funding of R&D in the US after years of private sector growth.

Private sector funding represents some 70 percent of all R&D investment. However, with the exception of the biomedical field, the private sector remains largely focused on development. Basic research, most of which is conducted in universities and non-profit research centers, is fundamental for the later development side of the innovation equation and remains dependent on government funding.

Academic R&D expenditures in 2003 were $40.077 billion, up from $36.37 billion in 2002. Federal sources account for 61.7% of the 2003 total, up from 60.1% in 2002. Direct state funding for R&D rose 5.9% between 2002 and 2003, yet still only represents 6.6% of the total. This does not include the large subsidies provided by states via general funding of the operating expenses of public universities.

On the other hand, total industrial support for academic R&D in 2003, as a percentage of total R&D funding at universities, declined for the second consecutive year. Industrial R&D funding totaled $2.162 billion in 2003, down $25 million from the 2002 figure. Industry's share of the total declined from 6% in 2002 to 5.4% in 2003.[13] But this reflected the downturn in the HT economy that is now recovering. Overall, between 1998 and 2003, total industry-financed R&D in universities grew by 14.5% in total dollars, yet actually fell when taking into account inflation.[14]

Important aspects of this rising tide of new state-based initiatives are their origin and the political value placed on S&T as a driver of economic growth. The vast majority of these second-stage initiatives come from government agencies and officials, influenced often by industry, but rarely the net result of proposals or ideas generated by the academy. Often, but not always, there is a substantial political process that influences the structural approach taken by states, with the governor of a state and his or her political views and ambitions major influences.

In the past as well as today, Republicans in Washington have been the key proponents of the importance of university R&D in supporting, either directly or potentially, S&T businesses and, hence, economic growth—a form of corporate welfare. Funding for academic R&D under the Bush Administration, for example, has steadily increased, largely rationalized as an investment in economic development.

President Bush recently introduced his American Competitiveness Initiative outlining a ten-year plan to double federal research funding to three key agencies and focused on basic research and promising areas for technological innovation.[15] Under the Clinton administration, funding for the National Institutes of Health (NIH) grew steadily, but funds for the physical sciences and engineering remained largely stagnant.

The Bush administration has targeted increases to the National Science Foundation, the National Institute of Standards and Technology, and the Department of Energy's Advanced Technology Program. Of the three, the NSF is by far the largest single source for basic science research—although the NSF's total budget is only $3.7 billion compared to the National Institute of Health's over $27 billion budget.

Congress appears prepared to pass legislation that would provide an additional $6.02 billion, or an 8 percent increase in funding, to the National Science Foundation. Reflecting aspects of the 1957 National Defense Education Act, a watershed in American science policy, the ACI initiative includes money for expanding science education.[16]

In the past, it has been Republicans, more so than Democrats, who have supported increases in federal funding for basic research conducted largely in US universities. Yet a bipartisan consensus has emerged both in the federal government and in most states that the value of S&T is its potential as a salvation for the US economy. Differences between the two political parties have focused on the relatively new ethical and religious implications of S&T, highlighted by a national debate regarding stem-cell research—although a division within Republican ranks makes this a more complex story. In contrast to much of Europe, here the debate regarding genetically modified crops has been relatively quiet.

California's Two High-Tech Ventures

State initiatives focused on building the HT sector and university-business collaborations reflect a political consensus: technological innovation fuels sustainable economic expansion that, in turn, generates higher wages, provides one of the few viable exports of the US economy, and promises, in short, to increase productivity within a globalizing economy. California provides an important case study because of the sheer size of its economy, its leadership role in the HT sector, the pivotal role of universities (in particular Stanford and a number of campuses within the ten-campus University of California system), and the political process that has led to two major state initiatives.

The New California Institutes for Science and Innovation

In the late 1990s, California enjoyed a sizable surplus in its state coffers. No state enjoyed the benefits of the dot.com boom more (and no state would later suffer so greatly from its collapse), in part because of the high concentration of already existing HT businesses. The surplus generated ambitious plans by a state legislature controlled by liberal Democrats and particularly by the Democratic Governor Gray Davis. Major elements of the Davis agenda included reversing a long-term and significant decline in the quality of the state public schools, expanding public services for large-scale increases in population (in part fueled by immigration), and partially resurrecting social services cut during the recession. Promoting economic development also had a place in his plans, although no significant initiatives were formulated in the initial year of Davis' governorship.

In late 1999, Richard A. Lerner, a friend and supporter of Davis who served as his science advisor during his campaign for governor, met with John Moores, a member of the University of California's Board of Regents and a software entrepreneur. Lerner had the notion of the State of California funding a number of major research centers focused on university-industry collaborations in fields that promised significant technological progress.[17] They imagined a number of freestanding institutes along the lines of Bell Laboratories, linked to both public and private universities and local HT industries.

Both Lerner and Moores were from San Diego and important players in the region's booming high technology sector. Lerner was the president of the Scripps Institute in San Diego, a professor of immunochemistry and a world-renowned expert in catalytic antibodies, a field that takes as its principle goal an understanding of how the binding energy of proteins can be used to facilitate chemical transformations. Lerner had also been long involved with CONNECT (which is not an acronym), a program established in 1985 at the San Diego campus of the University of California at the urging of a growing local HT business community.

Lerner thought the state government should seek an aggressive policy to harness more fully California S&T research capabilities by subsidizing a number of centers focused on promising areas for future HT business growth. After his discussion with Moores, Lerner approached the governor and Richard C. Atkinson, then president of the University of California, about formulating a special initiative under the authority of the governor. Both were receptive. Atkinson was the former chancellor at the University of California's San Diego campus, had helped in the development of CONNECT, and saw the potential initiative as part of his larger effort as president to foster greater university-industry collaborations.[18] Davis felt that funneling state funds to private California universities such as Stanford or Caltech was politically unacceptable. California and most states avoid direct subsidies to private institutions.

Normally, any significant activity related to the teaching and research mission of the University of California required consultation with the university's academic community. However, timing for the pending state budget, the political desires of the governor, and the uncertainty and time needed for consultation with faculty or even the ten campus chancellors all resulted in Atkinson's essentially ignoring the process of shared governance in order to proceed with Lerner's idea. "I propose the creation of the Institutes for Science and Innovation," stated the governor at a news conference in January 2000 at which Atkinson joined him, "to help California maintain its premier standing in science and technology and to provide the technological underpinnings for the State's future economic growth."[19]

The governor's office provided a preliminary allocation of some $300 million in its pending state budget proposal for three centers on various UC campuses—a one-time allocation of $100 million for each center, largely for capital construction and equipment to launch each center, and requiring private-sector co-investment of twice that amount over a four-year period, largely for operating costs. At the same July 2000 press conference, Governor Davis announced the appointment of an "international panel of distinguished scholars and scientific experts" that would guide the competition.

The selection committee included five members, all from outside the University of California system and also not directly affiliated with the HT business sector. Lerner served as chair. The panel created a two-phase process for reviewing proposals, including an initial peer-review process, modeled on the peer-review process used by the National Science Foundation (NSF). Among the criteria for the selection process was the encouragement of multi-campus collaborations, "to attract faculty involvement from throughout the UC's ten-campus system, and to leverage the political advantages of a wide geographic distribution of the three centers."

By May 31, 1999, eleven preliminary proposals were submitted. Six were chosen for the second phase, and final proposals were requested by October 6. All the proposals in the first and second phase of the review process involved more than one campus. The university's Board of Regents was updated at each phase, and their final approval was required for the winning centers. In total, the six final proposals brought in 327 companies as partners in the new institutes, 212 of which were based in California. The budgets for the six projects totaled nearly $2 billion. Of that, only $525 million was being requested from the state. The remaining $1.4 billion was in the form of matching funds, largely from the private sector, indicating the substantial interest of the HT sector in collaborating with university researchers.[20]

On December 7, 2000, Governor Davis announced the selection of the three projects to constitute the California Institutes for Science and Innovation (CISI). A fourth institute was added later, based at the Berkeley campus and with the governor agreeing to increase the budget to $400 million of state funds for the initiative. The four institutes included:

- The *California Institute for Telecommunications and Information Technology* (Cal-IT), based at UC San Diego and in collaboration with UC Irvine (both in Southern California), and focused on developing digital wireless communications.
- The *California NanoSystems Institute* (CNSI), based at UCLA and in collaboration with faculty and researchers at UC Santa Barbara. Its purpose is to support university-industry research and to promote the transfer of nanosystems innovation to the marketplace.
- The *Institute for Bioengineering, Biotechnology and Quantitative Biomedical Research* (QB3), based at the University of California-San Francisco—UC's only campus devoted exclusively to health sciences—and in collaboration with the Berkeley and Santa Cruz campuses. Its purpose is to harness the quantitative sciences to integrate the understanding of biological systems at all levels of complexity, from atoms and protein molecules to cells, tissues, organs, and the entire organism.
- The *Center for Information Technology Research in the Interest of Society* (CITRIS), based at Berkeley, which sponsors research on problems that have a major impact on the economy, quality of life, and future success of California—conserving energy; promoting education; saving lives, property, and productivity in the wake of disasters; boosting transportation efficiency; advancing diagnosis and treatment of disease; and expanding business growth through much richer personalized information services.

A recent study on California's biotech industry supports the conceptual model pursued by Lerner and Governor Davis. Junfu Zhang and Nikesh Patel examined the role of venture capital in the formation of new firms, who is founding these firms, and the flow of existing firms into and out of the state. They concluded that biotechnology relies on knowledge even more than the information technology sector, with nearly half of the venture-backed biotech establishments founded by scientists.

Further, universities generate more biotech spin-offs than existing biotech companies, with two-thirds of these academic entrepreneurs remaining in the same state. In California, 82% of professors establish their new companies in the state, and despite increasing venture capital, the creation of new biotech companies did not increase markedly. This suggests that although the industry cannot survive without investment, capital alone will not sustain biotech growth.[21]

California's Stem Cell Initiative

In part to placate the religious fundamentalist wing of the Republican Party, in August 2001, President George W. Bush set limits on federal funding for research using stem cells. In a presidential directive to all federal funding agencies, with implications largely for the National Institutes of Health, Bush set strict limits on the lines of human embryonic stem cells that could be studied using federal research grants. He also capped federal funding for such research at $25 million per year. The intent was to restrict stem-cell research known as somatic cell nuclear transfer (SCNT) or "therapeutic cloning."

By limiting federal funding of stem-cell research, the Bush administration created a “wedge” issue useful for solidifying the president’s political base—a political strategy that would help reelect him as president in November 2004. No previous presidential administration had set such specific restrictions on scientific research. The president sanctioned the use of some sixty genetically diverse stem-cell lines already existing, created from “embryos that have already been destroyed, and they have the ability to regenerate themselves indefinitely, creating ongoing opportunities for research.”

While the president’s edict would not halt most private-sector research, it promised a significant impact on university research and important non-profit research centers. One unforeseen consequence of the federal edict has been to bolster further the interest of high tech states to create new avenues for public funding—a topic I return to later in this paper.

In California, with the largest concentration of biotech research and businesses in the US, a coalition of the state’s corporate HT sector sought a high-profile route to assure California’s place in the vanguard of the biotech movement. To a degree unmatched by any other state, California has used the process of propositions, directly voted on by the state electorate, to create law and amend the state’s constitution. The “California Stem Cell Research and Cures Initiative,” which became Proposition 71, emerged by early 2004. It proposed a $3 billion bond, which would generate $350 million a year over a decade. The proposition made nontraditional use of general-obligation bonds—a mechanism usually employed to pay for durable state assets such as highways, schools, or bridges—to finance its mission.

The coalition had to gain enough signatures of registered voters to place it on the ballot. Democratic real estate developer Robert Klein contributed millions of dollars for the campaign personally, buying advertisements and paying workers to stand in front of supermarkets and other large chain stores to gain a sufficient number of signatures.

Timing was important, and the effort was successful—Proposition 71 was placed on the 2004 presidential election ballot. (California was predicted to vote overwhelmingly for Bush’s presidential opponent, John Kerry.) The initiative called for the creation of a new independent agency to regulate and disperse the funds largely to university researchers—what one supporter called the “West Coast version of the National Institutes of Heath.”

The idea for the proposition came not from a scientist, but from Klein. With a son diagnosed with juvenile diabetes, a mother with Alzheimer's disease, and a father who died of heart disease, Klein sought to lead Proposition 71 in the wake of Bush’s decision. In this effort, Klein, like Lerner in his campaign, did not consult in any large measure with academic researchers or leaders. Although Klein expected general support from the California universities that would benefit from the bond, they were not essential to his personal campaign.

Proposition 71 won endorsements from Nancy Reagan, widow of the former president, and from Governor Arnold Schwarzenegger, a Republican. Schwarzenegger had defeated Gray Davis in a special election called in the aftermath of a severe energy crisis and a ballooning state deficit. Bush won the national election, but lost in California. At the same time, the bond measure was approved by 59% of the voters on November 2.

The measure set up a new agency, the California Institute for Regenerative Medicine. A twenty-nine-member Independent Citizens Oversight Committee governs the institute. As stated in the proposition, twenty-seven members are appointed by various state officials—the governor, lieutenant governor, treasurer, and controller—as representatives of California's university and non-profit research centers, as "patient advocates," or as members of the biotech business community. The oversight committee then chooses the two other members, a chair and vice chair.

Among the oversight committee members, David Baltimore, president of Caltech and a Nobel Prize winner for his work on RNA-to-DNA conversion, and Robert Birgeneau, chancellor of UC Berkeley and a physicist who focused his research on materials, were appointed as representatives from California's university community. In turn, the oversight committee appointed Robert Klein as the committee's interim and later permanent chair. He is serving a six-year term after gaining the support of Governor Schwarzenegger, a Republican.

Klein pledged to hold no biomedical stock or investment interest during his term of office. The committee also appointed Chiron Corporation co-founder Ed Penhoet, a professor at UC Berkeley, as vice chair, and neuroscientist Zach W. Hall, a former top administrator and faculty member at UCSF, as president of the new California Institute for Regenerative Medicine.[22]

As stated by Klein and others, because stem-cell science is in its very early stages, Proposition 71 funding would be directed as grants for creating an infrastructure of researchers and dedicated laboratories—largely in universities—as opposed to funding for specific therapies and clinical trials. As existing and new start-up private companies develop in the next three years, however, grants could go to the private sector.

Almost immediately after the passage of Proposition 71 and the formation of the oversight committee, a series of controversies erupted. A conservative anti-tax group asked the state Supreme Court to stop the formation of the institute, claiming the terms of the bond—and specifically the independence of the institute to manage bond funds, traditionally the purview of the legislature—were unconstitutional. Klein and others have viewed this challenge to the Stem Cell Initiative as largely the effort of antiabortion and neoconservative groups to block any and all stem cell research.

But there have been issues related to intellectual property that have slowed the dispersal of funds for research. A state senator who backed Proposition 71, Deborah Ortiz, a Democrat from Sacramento, introduced legislation to address a fear that most of the profits from the grant money would end up in the hands of private firms and might even drive up health care costs in the form of overly priced drugs. The public, she argued, should own discoveries funded with taxpayer monies.

Intellectual property rights have been a controversial issue in other states. In 2004, Arizona voters opposed a constitutional amendment to allow public universities to own and sell technologies developed with state funds even though the governor supported the measure as a means to stimulate the economy and attract new businesses to the state.[23]

In California, Proposition 71 had given the oversight committee the ability to set intellectual property policy, and the committee desired to follow the model provided by the Bayh-Dole Act—namely, to give patent and licensing rights to researchers and universities. The California government, it was claimed, would recoup the cost of bonds by increased HT business activity. Because legislation passed by the legislature would not be binding on the institute, Ortiz threatened a constitutional amendment (which would require a general vote by Californians) and gained support from a number of key lawmakers, including George Runner, a Republican from Los Angeles. Klein said that Ortiz' legislation had presented a "whole other layer of legal questions" that effectively ruled out quick progress toward issuing the first stem-cell grants of up to $350 million a year.[24]

By the summer of 2006, the legal issues and the policies on intellectual property had not all been resolved. But the legal process has nearly run its course and it appears that the $3 billion will soon be fully available to researchers. In Congress, the popularity of the president's restriction on stem cell research declined among Republicans. The House passed a bill to loosen the restrictions and the Senate followed, presenting a bill for the president's signature on July 18.[25]

But Bush, mindful of his thus far loyal religious conservative base, threatened to veto any measure that erodes his original edict—a restriction on federal research funding offered in his first prime-time television speech as president. A day after the Senate voted to modify the president's executive order, Bush vetoed the bill—the first veto of his administration.

A Policy Aftermath and Trends

In the wake of the president's steadfast embrace of ideology, California is not the only state to seek a special fund for stem-cell research or to support centers intended to bolster research thought key to the future of a state's HT businesses. Michigan, for example, committed $1 billion in 1999 to create, over a twenty-year period, a "life science corridor" using funds from the state's tobacco settlement and providing grants for basic research and investing in start-ups—a corridor that includes the University of Michigan at Ann Arbor, Michigan State University, Wayne State University, and the Van Andel Institute.

But California's initiatives did bring significant national attention because of the size and importance of California's powerful university and HT business mix, the overall scale of the California economy, and the financial magnitude of the California Institutes for Science and Innovation and Proposition 71. Both initiatives reflect increased focus on the role of statewide policies and initiatives to fund university and non-profit research centers—policies that complement and attempt to leverage both federal and private sector R&D funding.

States have pursued three general paths for enhancing their HT economic competitiveness: a) the development of new R&D institutes tied to universities; b) a number of stem cell related legislative initiatives, creating funds for research in reaction to the new federal restrictions; and c) expanded use of tax incentives and experiments with supporting venture capital initiatives.

State R&D Institutes

Shortly after California established the California Institutes for Science and Innovation, a number of key states either created new and similar institutes or bolstered their TBED programs significantly. In New York, lawmakers devised a plan for a set of some ten centers that would form partnerships between campuses of the State University of New York (SUNY) and the City University of New York (CUNY)—two separate public university systems in the state—and other universities in the state such as Cornell as well as regional HT businesses. Like CISI, the centers will support research funding by the private sector, encourage dialogue and collaboration between academics and private-sector researchers, and, via graduate fellowships, attract and promote the flow of highly skilled labor into local businesses.

Legislators worked with New York Governor Pataki to include in the state's 2006 budget a provision of $340 million for the new public authority, the New York State Foundation for Science, Technology and Innovation (NYSTAR), to be operating by January 1, 2006. NYSTAR will absorb some existing TBED programs directed by a previous state agency. What is new is that, like California, NYSTAR includes a thirteen-member board comprised of public and private representatives who will direct all existing NYSTAR programs and the new regional partnership programs in areas such as biotech, telecommunications, energy efficiency, and homeland security—a relatively new area of research with the promise of funding from the federal government. Out of the total allocated to the foundation, $90 million is targeted for capital construction.

NYSTAR will provide grants, "to fulfill the public purposes of furthering job creation and economic growth and advances in the fields of science, technology and innovation and to facilitate the commercialization of scientific and other innovations in New York State." What is different from California is that NYSTAR will have the ability to provide loans and venture capital for commercial enterprises. Further, New York has chosen to pre-determine the geographic dispersion of the various "partnership" centers within ten regions of the state—seemingly a political compromise to spread the investment.[26] Within each region, proposals will be solicited for university-business centers—a model arguably less competitive than that which determined California's institutes.

In May 2005, shortly after the announcement of the establishment of New York's new initiative, the state of Washington created a new $350 million Life Sciences Discovery Fund. The fund will be governed by a Life Sciences Discovery Fund Authority, which will consist of seven members to be appointed by the governor and four members of the state legislature. The intent is to fund grants that may, for example, positively impact health-care outcomes or promote public university and private collaboration in promising HT areas, and that have the potential to leverage additional funding support from other sources. Geographical dispersion of grants is also stated as a goal.

In Ohio, a ballot initiative was formulated to build on the state's science- and technology-based research under the title of the Third Frontier Project. Like a number of other states, Ohio is attempting to consolidate under one authority a number of TBED programs, in this case under the Ohio Third Frontier Commission. University-based research and university-business collaborations are only part of this larger effort. In total, if passed by voters, a bond will fund some $500 million over the next seven years for research, development, and commercialization projects, much of which will go to university-based research and faculty start-ups. Over seven years, $150 million will fund "Job-Ready Sites," which will prepare sites for industrial and business expansion to meet environmental and other requirements. And $1.35 billion over the next ten years will go to public-works bond renewal to assist local governments with roads, bridges, and water projects.

The Stem Cell Anomaly

The political debate over embryonic stem-cell research has garnered its own particular set of initiatives that often tie into state TBED strategies, yet remain separate because of ethical concerns and the ban on federal funding. The magnitude of Proposition 71 and the overall competitive position of California's biotech industry drew national attention and a series of similar state initiatives. Prior to Robert Klein's effort to push Proposition 71, New Jersey had committed smaller levels of funding for embryonic stem-cell research through a new state institute. A number of state legislatures, including California's, had also passed legislation "permitting" embryonic stem-cell research with state funds, largely a symbolic act in reaction to the Bush administration's executive order.

Reflecting differing political cultures, lawmakers in some states, on the other hand, called for a complete ban on public support of embryonic stem-cell research. Arkansas, Iowa, Michigan, North Dakota, and South Dakota banned therapeutic cloning. Louisiana and Nebraska had enacted laws previously that specifically prohibit research on human embryonic stem cells. In Missouri, legislation was proposed that would have made embryonic stem cell research a criminal offense, but this failed to pass.

Yet many states have essentially rebelled against the Bush administration's position and are seeking ways to fund stem-cell research. By the fall of 2005, state lawmakers in states with growing biotech sectors launched a competition for a method to generate and distribute funds. Illinois was considering a referendum to approve $1 billion worth of bonds to create the Illinois Regenerative Medicine Institute, with plans to place it on the November 2006 ballot.

California is using general bonds; the Illinois proposal calls for a 6% tax on elective cosmetic surgery to fund start-up costs and debt service on the bonds, according to Illinois Comptroller Dan Hynes' press office. The institute would be governed by an oversight committee to be appointed by state government and university officials and would provide stem-cell research grants to Illinois universities and institutions over a ten-year period.

The governor of Connecticut, Jodi Rell, allocated $20 million over a two-year period for grants for embryonic stem-cell research in her proposed state budget. Shortly thereafter, the legislature, controlled by Democrats and led by the president of Connecticut's state senate, wanted a more ambitious program: $100 million over ten years, a scale similar in magnitude to California's in light of Connecticut's rather small population. In May 2005, the Governor, a Republican, signed the bill.[27]

Maryland lawmakers nearly passed a bill to promote state-funded stem-cell research through a $23 million Stem Cell Research Fund. The fund would have provided grants and loans to public and private entities in the state. Governor Robert Erlich did not state a position on the proposed fund, and the bill narrowly lost, but supporters will reintroduce the legislation early in next year's session.

In New Jersey, lawmakers intend to approve a $230 million ballot initiative for stem-cell research and grants, with another $150 million in capital funds, to build the Stem Cell Institute of New Jersey that will include an independent panel of scientific experts to solicit and make grants.

In New York, legislation was forwarded to create the New York Institute for Stem Cell Research. The institute would make grants for stem-cell research, regenerative medicine, and related facilities, with funding of $100 million for the first year and $200 million for the second year. As in California, a board—appointed by the governor, the president of the senate, the speaker of the assembly, the attorney general, and the comptroller—would govern the institute, but the bill also prohibits cloning for reproductive reasons. In both New Jersey and New York, however, budget problems may delay these state initiatives.

An initiative to establish a similar institute was introduced in the state of Washington, described as in part a way to remain competitive with California's biotech industry. In November 2004, Wisconsin's governor introduced a proposal modeled on Proposition 71 that would invest $375 million over the next ten years in the Wisconsin Institute for Discovery, with specialists in biochemistry, nanotechnology, computer engineering, and bioinformatics. To be located on the University of Wisconsin-Madison campus, Wisconsin's institute would focus on issues besides stem-cell research. The state assembly also passed a bill that would provide an income and franchise tax break for companies engaged in stem-cell research.

Shortly after the presidential election, Texas lawmakers introduced contradictory bills. One bill would create a Texas Institute for Regenerative Medicine to be funded by a $900 million bond issue over the next six years. Governor Rick Perry, a Republican, opposes using state money for stem-cell research, however, and promised to veto any such proposal. In the same legislative session, another bill sought to restrict research to that related to regenerative or reparative therapies, and, as in Missouri, another would have made all human cloning a first-degree felony, but went even further, making it a felony to consult with researchers from another state or country involved in therapeutic cloning.

Perhaps the most interesting clash in the aftermath of California's Proposition 71 occurred in Massachusetts. Democrats control the state legislature in Boston, but the governor, Mitt Romney, is a Republican and a Mormon. Romney stated his strong opposition to embryonic stem-cell research. Under current law, the district attorney in Boston must approve any state funding used for cloning. Romney vetoed a state bill to end this restriction, and the legislature, with a two-thirds vote, proceeded to override him. In the meantime, state senate president Robert Travaglini has worked with Boston's biotech industry leaders to propose a $100 million state fund for embryonic stem-cell research facilities, with the stated purpose of keeping up with California and other competitor states.

The substantial press coverage of the promise of stem-cell research and the political saliency of the issue translated into a bi-partisan effort in Congress to modify the Bush administration's restrictive policies. In April 2005, representatives Mike Castle, a Republican from Delaware, and Diana DeGette, a Democrat from Colorado, introduced the Stem Cell Research Enhancement Act of 2005, intended to ease restrictions by giving the Secretary of Health and Human Services authority to conduct and support research on embryonic stem cells.

To meet the ethical concerns of the president, stem cells would have to come only from embryos donated from *in vitro* fertilization clinics. Other restrictions include a stipulation that embryos would not be implanted in a woman and would otherwise be discarded, and the individuals donating the embryos would do so with written consent and receive no financial incentives. The legislation had 195 cosponsors, and a similar bill was introduced in the senate, but with both houses (the house and senate) controlled by Republicans and in anticipation of a presidential veto, the bill died. As noted, a year later a bill to modify President Bush's edict did pass and was promptly vetoed.

With the declining political strength of a Bush White House mired in military conflicts in the Middle East, and the defeat of its major policy initiatives in areas such as social security, some relaxation of the federal ban on stem cell research funding seems inevitable. It may in fact be completely reversed by the next presidential administration. There is also initial research that may generate an alternative to stem cells or techniques that preserve the embryo and, somehow, mollify ardent foes. The likely legacy will be that state initiatives in this area will remain and the benefits of state investments may prove beneficial in unexpected ways.

Anecdotal evidence indicates that California's high profile initiative is drawing new domestic and international talent and companies to the state. They are drawn by the existing infrastructure of a vibrant biotech sector, and by the promise of state funds and, in turn, to even more robust access to venture capital.[28] But there is also an international variable now at play: a small but significant flow of important scientists are gravitating to emerging stem cell centers, such as Singapore, where they are supported by national governments and biotech firms alike.

From Venture Funds to Tax Credits

Over the past year, encouraged by their improved fiscal position, most states have initiated a range of other efforts to bolster the business climate for the HT sector. This includes an increasingly complex array of tax credits and state-established venture capital funds intended to attract and complement private-sector sources—a phenomenon more common in but not exclusive to smaller states with more nascent HT sectors.

While many of these initiatives are not directly tied to promoting university-business collaborations, they affect indirectly the vitality of this relationship and, for instance, the likelihood of university-based start-ups. Between January and August of 2005, virtually every state launched some type of major new HT initiative.[29]

Oregon’s legislature created a venture development fund to facilitate technology commercialization for students and faculty at the state's seven public universities. Revenue for the newly created funds will come from donors who, in turn, receive credit on their state income tax returns. The development funds will use capital raised through university foundations to bridge the gap between an idea and its development to the point where private investors become interested. The resulting monies will be used to fund university entrepreneurial programs, including transforming research and development concepts into commercially viable products and services.

In Texas, the state legislature approved $100 million in June 2005 for a new Emerging Technologies Fund (ETF) intended to foster emerging technologies, enhance university-industry collaboration, and promote technology commercialization. Another $100 million is to be added from the state's rainy-day fund if revenues exceed forecasts. In Utah, in July 2005 the newly elected governor announced his intention to revise the state’s TBED to include a new cluster-based strategy targeting state efforts in seven industry sectors: life sciences, software development and information technology, aerospace, defense and homeland security, financial services, energy and natural resources, and competitive accelerators such as nanotechnology and advanced manufacturing.

Iowa’s governor signed into law a bill creating a $500 million fund to expand its Grow Iowa Values Fund. The bill provided $500 million over ten years to support tech-based economic development and other economic development initiatives. Universities will receive $5 million per year for capacity-building infrastructure in areas related to technology commercialization, entrepreneurship, and business growth, and $7 million will support community-college training and retraining programs.

Arizona passed a bill in May to provide tax credits for “angel” capital investments in start-up Arizona tech firms. Individual investors, as well as limited partnerships or "S" corporations, will receive a state tax credit of 10% or more per year for three years for investments in qualified technology companies. Investments must be a minimum of $25,000 and only the first $250,000 of any investment is eligible for the tax credit. Qualifying technology firms must employ at least two individuals and have no more than $2 million in assets.

Recognizing the potential strength of regional partnerships, Maryland, Virginia, and District of Columbia officials agreed to form the Chesapeake Nanotechnology Initiative (CNI), a collaborative effort to strengthen the region’s capabilities in nanotech research, development, and commercialization. The governors from each state pledged to sign a memorandum of agreement to launch CNI. A twelve-member steering committee will direct CNI activities in 2006 and beyond, recommending ways to accelerate business development and scientific advancement in nanotechnology.

Evidence is mixed regarding the effectiveness of tax credits and other incentives, although there are a number of high profile cases where an HT business relocated in part because of such incentives.[30] While tax incentives are increasingly a part of state strategies, an Organisation for Economic Co-operation and Development (OECD) study recently compared R&D tax-relief programs for its member countries, ranking nations in terms of tax relief and style. The US favors direct funding while Canada, for example, uses primarily tax incentives to promote private-sector R&D. Canada ranked in the top five for both large- and small-company relief, while the US came in tenth for large and thirteenth for small companies.[31]

In addition, a number of states have seriously rethought or ended past S&T initiatives. Because of budget shortfalls, Texas, Michigan, and Wisconsin have reduced funding allocations to university-business development programs. Ohio's Thomas Edison Program will take a 20 percent reduction of $10 million in 2005. Alaska debated the appropriateness of public funding to support private S&T development. The state is also facing a significant decline in funds for its Alaska Science & Technology Foundation (ASTF), which is financed by revenues earned from investments of a permanent trust fund. Losses on the stock market reduced revenues by nearly 50 percent, from $10.3 million to $5.5 million.[32]

On the other hand, while California faces a long-term state budget problem, Governor Arnold Schwarzenegger has continued to support the California Institute for Science and Innovation—a proposal identified with past Governor Gray Davis.

The Nascent Entrepreneurial State—An Initial Analysis

A recent study on national policies intended to influence and promote concentrations of HT businesses, often including universities as a key component, offers a sobering conclusion. "Countless well intentioned but ineffectual cluster policies from all parts of the world," argue Peter Maskell and Leïla Kebir, "seem to highlight the limits of the nation state, or any other political authority, in creating economically sustainable competitive advantages by design from above. No kind of vague phrasings or remolded instrument packages can apparently alter the fact that the role of policy in the development of cluster advantages can only be marginal, indirect, and long term. Results are measured in decades, if measurable at all."[33]

Another study of the biotech industry concludes that, to date, only a handful of metropolitan areas have succeeded on a scale necessary to ensure industry sustainability. San Diego is at the top of that list, followed closely by Boston and the Raleigh-Durham-Chapel Hill metro area. The San Francisco Bay Area ranks seventh. "Clusters of existing and emerging science-based technologies are crucial factors in shaping the economic winners and losers of the first half of the 21st century," according to the report. "To create international comparative advantage in a knowledge-based economy, clustering innovative activity is imperative."[34]

As this review of state policies in the US indicates, most state governments have placed tremendous importance on policies and funding with the assumption—and hope—that Maskell and Kebir are wrong. The rising tide of new state-based initiatives as an investment in S&T to drive economic growth assumes that technological innovation fuels sustainable economic expansion, generating higher wages, exports, and productivity in a globalizing economy. Further, and as noted, a growing HT sector is viewed as key to economic competitiveness, and, ultimately, to determining quality of life; indeed, there is growing evidence that both public and private sector investment in the US leads to personal income gains, as well as overall state economic growth.

One study of the US economy states that more than three-fourths of personal income growth can be tied to increases in technology output. Another study indicates that states that do not invest significantly in R&D (less than 1 percent of GSP from all sources, public and private) have low average incomes. Of the thirty-two states with R&D investment of over 1 percent of GSP, all have above average rates of per capita income.[35]

The stakes are high, but the true influence of this relatively new wave of state policies on the already growing HT sector will not be known for many years. They are investments in the future. In the case of the US, what we do know, however, is that the entrepreneurial university has been a productive partner in promoting economic growth, having developed programs (like CONNECT) and managerial structures and investments to promote patents and licensing, encourage faculty start-ups, and sometimes to create venture funds out of their own endowments.[36]

States have long been active agents in shaping regional economic activity, beginning in earnest after World War II.[37] But beyond simply funding the enrollment growth of higher education institutions, states have focused, until recently, largely on relatively small and specific programs and funds to promote HT R&D and university-business partnerships. The *Second Stage* includes a more broad-based effort, linked to statewide strategies for economic development and with high political stakes. A number of concluding observations on this nascent trend follow.

A Process of Devolution

In Europe, one sees the rise of the European Research Area and an attempt under the so-called 7th Framework to adopt some of the mechanisms that have long characterized US federal policies. The ERA offers a potential watershed in the evolution of EU science and technology policy, seeking “a common strategy on science and technology in the service of society” and represents a new construct within the European Union. ERA had a budget of 17.5 billion euros for the years 2002 – 2006 and funding represents, so far, only about 4 to 5 percent of the overall R&D expenditures in EU member states.

The European Commission plans to more than double its funding for R&D to member states in coming years and promote policies under the “7th Program Framework” (PF7) as a catalyst for the EU to spend 3 percent of GDP on R&D by 2013, both private and public, with a substantial role for universities in helping make the EU the world’s most innovative economic region.[38]

In the US, there is an apparent process of “devolution”—essentially, new policy initiatives are coming from the states as part of the *Second Stage*. Federal policy remains relatively unchanged with a promise of increased funding in the physical sciences, an actual flattening of funding for the health sciences, the extension of existing federal tax credits, and marginal programs in funding and potential impact intended to improve the quality and productivity of science education largely in the schools. States are the relatively new arena for policymaking and investment, and the majority of state initiatives appear to come from lawmakers and HT entrepreneurs, or from others such as Richard Lerner (a wealthy and savvy patients’ rights advocate) and Robert Klein, and not from university leaders.

Indeed, it is unclear how important the higher education community is in influencing policies that often directly affect their academic programs and priorities. In part, one can attribute this phenomenon to a long campaign waged by the higher education and scientific community on the importance of public funding of research universities for economic growth, starting with studies in the late 1970s by the National Science Foundation and by organizations such as the American Association for the Advancement of Sciences.

One cause of devolution was a significant decline in federal funding for academic research after the surge in the 1960s and a new sense that research universities ought to mobilize and more fully articulate the importance of science and innovation. This campaign and, of course, the growth of the computing and life sciences, and related HT businesses created a new milieu that popularized and politicized this *Second Stage*.

Science and technology, in essence, is now too important to leave either to academics or to the business sector alone—a perception shared globally. In the US, academic leaders generally appear to welcome this trend and certainly are not opposed, for it means additional funding in research areas that universities want to build and fits into a long cultural history of serving regional economies, accompanied by rather minor concerns over the growing private-sector influence. In an era of declining general funding (on a per-student basis) for public institutions, which enroll about 80% of all students in the US, state initiatives are one more source of funds to leverage.

Interstate Competition

An important shift is accompanying the process of devolution, and this is an increased sense among lawmakers of interstate competition. This explains in part the influx of initiatives. While there are important differences among the states in their approaches (stem-cell research being a glaring example), there are also many similarities that reflect the agreed-upon tripartite formula of university and business collaboration, combined with benevolent and strategic state government investment. Lawmakers, the HT sector, and political and savvy promoters like Richard Lerner are engaged constantly in surveying the activities of their competitors and seeking useful best practices.

On the other hand, Americans are generally not looking across the Atlantic or Pacific, or across their borders, for ideas on HT policymaking. Lawmakers and other policymakers are concerned about being competitive in the global marketplace, but the US remains largely isolationist in its leanings despite the fact that the HT sector is increasingly an international endeavor. The focus of government and much of the business sector is on protecting or expanding foreign markets, intellectual property rights and tax incentives, buttressing venture capital markets, and reducing restrictions on immigrant/visitor visas.

The US retains a sense that this nation remains the most productive and innovative home for science and technology, and that, for instance, the cure for cancer or the breakthroughs promised by stem-cell research will be homegrown. Thus far, this seems to ignore the significant knowledge centers in Europe and emerging S&T centers in countries like China, India, and other parts of the world.

The debate over stem-cell research is a case in point regarding America's isolationist perspective. Promoters of state initiatives and of modifications in federal policy have portrayed a failure to generate increased investment in research and have promoted the idea that the world stands to gain innumerable cures if the US invests—a selling point encouraged by the scientific community.

For the consumption of domestic politics, however, beating foreign competitors has *not yet* emerged as a major reason for state initiatives. This may soon change. For now, the attention of policymakers in the US is largely on interstate rivalries, with occasional efforts at multi-state programs such as the nanotechnology initiative involving Maryland, Virginia, and the District of Columbia.

In the postmodern world, competition breeds indices and rankings. The increased interstate competition and the emergence of a growing HT managerial and professional class, along with more academic researchers, have led to increasing efforts to rank or classify the "climate" within each state for HT business growth.[39] The problem for now is that most state-based initiatives are relatively young. More meaningful assessment using these and other indices will need to wait perhaps four or more years. This assumes that state initiatives and public investment will be sustained—a big assumption, since lawmakers often shift priorities for both practical and frequently political reasons.

Signs of Overall HT Vitality

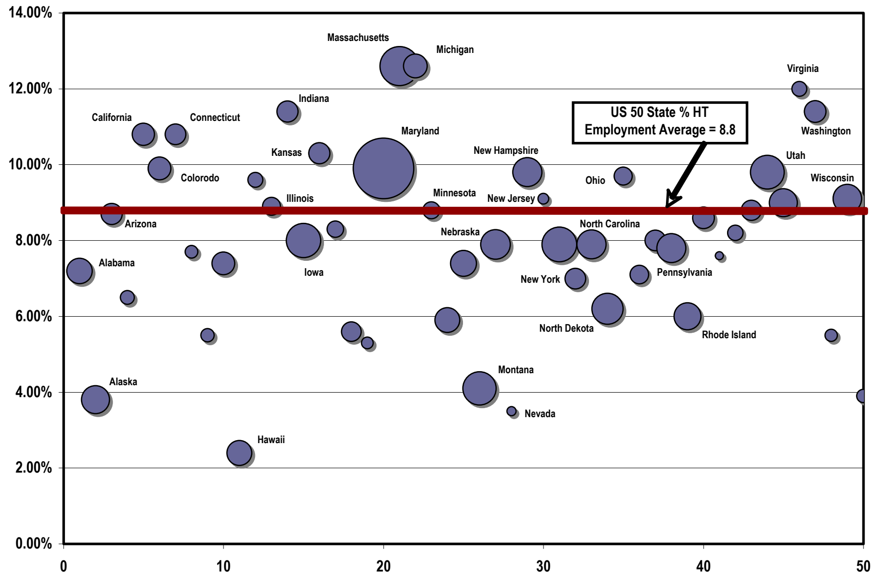
There are problems with using states as a unit of analysis to gauge the overall vitality of the US S&T sector. As noted previously, a number of variables influence the role of HT in the economy, including the geographic and population size of a state (for example, California has over 35 million people, Massachusetts has 6.4 million), urban versus rural population, the concentration of research universities and their quality, the amount of R&D as well as its source (public versus private) and focus, the economic mix of a state (service versus agriculture, versus HT), and the type of HT ("blue sky" versus more applied, purpose-driven research).

Immigration and other demographic factors are also important. In assessing the economic activity of California, one could divide the state into five or more quadrants: the San Diego area; Los Angeles; the Bay Area; the Central Valley, which is dominated by agriculture; and sparsely-populated northern California.

Still, states are an extremely important player in terms of setting laws, funding education, and leveraging federal funding. State governments and agencies also regulate and fund public universities. Recent data indicates that increased competition between the states and, most importantly, the long-term investment in science and technology by both the federal and state governments since the 1960s have created a vital HT sector in most states.

As shown in Figure 3, while there are only three states where the percentage of employment in HT sectors is above 12% (Massachusetts, Michigan, and Virginia), most states have reached at least 7%. One question is whether there will be greater or less disparity between the states in the future.

Figure 3. 50 State Comparison: HT as a Percentage of All State Employment and Relative Size of University R&D Per $1,000 of Gross State Product, 2000



Source: US Office of Technology Policy, State Science and Technology Indicators, 2004.

While there are regional concentrations of HT, Figure 3, with states listed in alphabetical order, indicates the widespread geographic nature of the HT sector. There are significant pockets of HT business activity throughout the US, which was not always the case. In the 1960s, for example, R&D was heavily concentrated in a few major states, correlating with defense and aerospace-related industries.

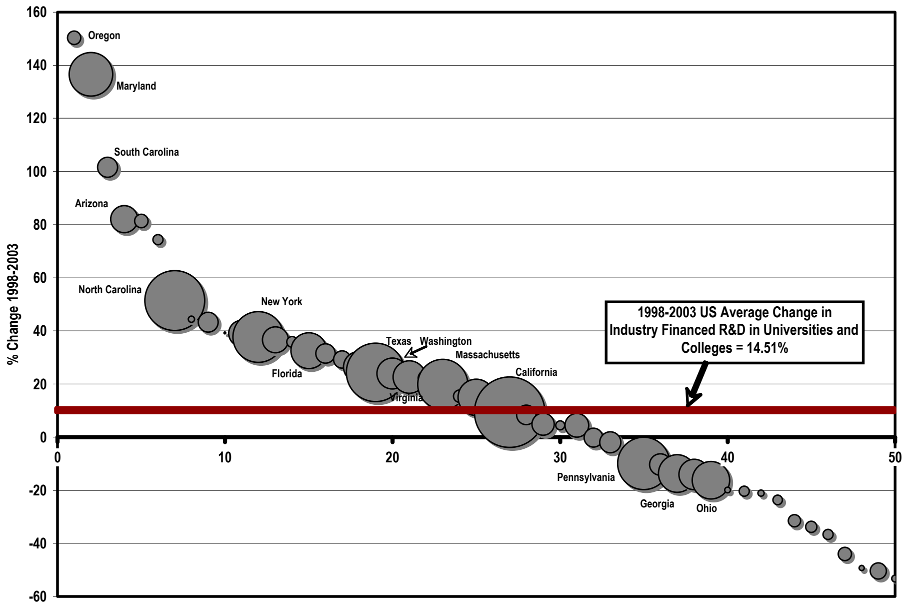
There is also evidence that some leading HT states, like California, are losing their market share of HT exports as other states become more competitive. A study of US information technology exports notes a general decline in these products since 2001, but the decline was more pronounced in California, in part because of competitor states—in particular Texas, Tennessee, Colorado, Arizona, Oregon, and Massachusetts.[40]

Figure 3 also provides the amount of university R&D per $1,000 of GSP in each state, an indicator of the relative importance of university based research—or, perhaps more accurately, a state's relative dependence on public universities to help bolster their S&T sectors. Large states with a high percentage of HT employment, as in California, also have very large and growing private sector R&D and diverse and robust economies.

In the case of Maryland—a state with a relatively small population, federally funded R&D, a number of major non-profit research centers, and a relatively small private HT sector—university R&D is much more significant. This chart deemphasizes the amount of total R&D (relative to other states) or its quality and emphasis (such as biotech), but it illustrates that states with sizable university research expertise and capability could, with sustained effort, reposition themselves relative to other state competitors. This is, of course, the focus of much of the discussion and flurry of initiatives by lawmakers.

Another indicator of a general vitality across the various states in developing university-industry collaborations is the increased industry-financed R&D performed by universities and colleges. Figure 4 provides recent data on the percentage change in industry funding between 1998 and 2003, in the order of greatest change, and by the relative size of the funding provided in 2003. This ranges from some $251.4 million in California to a mere $10 million in Oregon.

Figure 4. 50 State Comparison: Change in Industry-Financed R&D Expenditures in US Universities and Colleges and Relative Size of Funding, 1998-2003



Source: National Science Foundation/Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, FY 2003

Oregon grew the most in terms of percentage, but it started in 1998 with a relatively small funding base of only $4.2 million. Yet the chart also illustrates that most states have had healthy growth in industry-based funding for their universities—on average, an increase of 14.51% over a six year period—and this, again, even with the downturn in certain sectors of the HT economy.[41]

An important and largely unresolved question is how effective the great array of state initiatives—partially described in this article—will be in influencing HT economic growth and, perhaps more importantly, the relative position of each state. The US experience indicates that high quality research and university-industry collaborations can happen almost anywhere.[42]

A Policy Disjuncture: Depth Versus Breadth

While states have focused on creating HT clusters and funding university-business collaborations in specific fields such as biotech and nanotechnology, seeking depth and a market position, many states have not made a similar investment in what might be a more important long-term source of discovery and innovation (breadth): bachelor degrees and graduate programs in public universities and colleges. Many studies point to the problems in the US (a problem shared by European counterparts) with production of scientists and engineers. The number of bachelor degrees awarded in engineering, for example, peaked at more than 77,000 in the mid-80s. During the 1990s, and while the demand for technical positions soared, the number of all engineering degrees awarded dropped to 63,000.

One major problem facing American higher education is that states are in a process of long-term disinvestment in their public universities (relative to the rising costs of a still labor intensive sector dependent on highly educated professionals), causing rising fees and efforts to find other funding sources—in other words, the process of privatization. In some ways this relatively new budgetary environment is good, forcing universities to be leaner and meaner and to become more entrepreneurial. But few public institutions are able to recover from steadily declining state funding and the rising cost of operation, particularly in science and technology related programs.

On the supply side, many major universities and university systems are increasing student-to-faculty ratios, particularly in growing states like California, Texas, and Florida. Some are tightening admissions requirements. The declining quality of secondary schools and the further bifurcation between rich and poor school districts are also influencing production rates of bachelor degrees. While private colleges and universities play a vital role in science and innovation and in graduate education, public higher education is the bulwark of most state educational systems.

Of the over eleven million students in colleges and universities in the US, nearly nine million are in public institutions (nearly 80%). Public universities produce 75% of all doctoral degrees and 70% of all engineering and technical degrees. They also conduct the majority of the nation's academic R&D. When compared with other industrialized nations within the OECD, the United States now ranks only thirteenth in the percent of the population that enters postsecondary education and then completes a bachelor's degree or higher.[43]

A key strategy for states should be to seek increased efficiencies in their higher education systems. But there is also a general need to provide greater general funding—to focus on the general vitality of the system and key universities by providing adequate levels of support. This is a conclusion that Irwin Feller, Paul M. Romer, and other economists have supported. Feller warns, "States that are either unable or unwilling to provide the financial support necessary to maintain competitive higher education systems are likely to fall behind in longer-term efforts to develop nationally competitive knowledge-based production."[44]

Romer comes to a similar conclusion, saying essentially that both the federal and state governments over the past two decades have been too focused on initiatives to expedite the process of developing and commercializing technological innovation, such as increased spending on R&D and R&D tax incentives, and too focused on increased demand without considering the availability of the scientists and engineers required to support that demand.[45] In other words, the spectacular promise of HT and the race by states to enact industry- and field-specific initiatives has partially blinded states to what is perhaps the greater need for a holistic approach that includes more aggressive efforts to improve local schools and fund and nurture public higher education institutions.[46]

Being Left Behind

Does HT growth lift all socioeconomic boats? The US scientific community and academic leaders have engaged in a long campaign to portray science and technological advancement as a salvation for postmodern economies, and policymakers have come to embrace this concept warmly. Strategic and sustained investments in HT clusters and infrastructure will drive economic development, raising wages and benefiting the general standard of living, including a reduction in poverty.

There is evidence that some version of this predicted future is correct, but there are also indicators that the story is complicated, Current patterns of targeted investment by state governments may exacerbate one major problem facing the US: the growing disparity between a rich and highly skilled sector of the population and a growing pool of unskilled and low-income Americans.

Figure 5. Educational Attainment, HT Labor Pool, Employment and Poverty Rates: Sample of Twelve States

SAMPLE OF LARGE STATES	California		Texas		Michigan		New York		Illinois		Florida	
> 12.5 Million People	#	Rank	#	Rank	#	Rank	#	Rank	#	Rank	#	Rank
Employment in HT Businesses in 2000	1,397,776	1	703,206	2	514,017	3	513,472	4	491,433	5	339,093	9
% of Employment in HT in 2000	10.8	6	8.8	20	12.6	1	7.0	37	8.9	18	5.5	44
% of Population Completing High School	80.20	41	78.10	50	86.50	26	83.70	35	85.90	29	83.30	36
% of Population with Bachelor's Degree	27.90	15	26.20	5	22.50	39	28.80	13	27.30	16	25.70	25
% Bachelor's Degrees Granted/Pop 18-24	3.56	42	3.37	46	4.82	22	5.38	12	4.55	28	3.80	39
% S&E BS Degrees Granted/Total BS	18.20	18	17.00	33	19.70	7	15.80	41	17.30	27	14.80	47
% S&E Graduate Students/Pop 18-24	1.58	14	1.28	27	1.65	11	2.18	3	1.97	6	1.19	33
Computer Specialists/10,000 Workers	205.00	8	188.00	14	130.00	29	179.00	17	185.00	15	143.00	27
Life & Physical Scientists/10,000 Workers	24.90	16	20.20	25	130.00	35	20.90	23	13.10	42	13.70	39
Engineers/10,000 Workers	101.30	8	96.10	10	94.90	11	63.00	26	62.80	27	54.10	35
% Population Above Poverty Line	86.90	39	85.90	41	90.30	17	85.90	41	89.80	22	88.00	31
Per Capita Personal Income	32,898	10	35,708	5	30,222	18	35,708	5	33,320	8	29,559	22
% of Workforce Employed	93.30	45	93.90	37	93.80	41	93.90	37	93.50	44	94.50	25

SAMPLE OF MIDSIZED STATES	Ohio		Pennsylvania		Massachusetts		North Carolina		Washington		Wisconsin	
< 12.5 Million People	#	Rank	#	Rank	#	Rank	#	Rank	#	Rank	#	Rank
Employment in HT Businesses in 2000**	484,110	6	394,786	7	388,928	8	268,284	12	258,234	13	200,932	14
% of Employment in HT in 2000	9.7	13	7.8	30	12.6	1	6.2	39	11.4	5	9.1	15
% of Population Completing High School	87.30	22	86.10	28	86.50	26	80.10	43	90.40	5	86.80	23
% of Population with Bachelor's Degree	24.50	31	26.10	24	34.30	4	22.40	40	28.30	14	24.70	30
% Bachelor's Degrees Granted/Pop 18-24	4.71	25	5.88	8	7.26	3	4.29	30	4.03	35	5.27	14
% S&E BS Degrees Granted/Total BS	15.90	40	17.60	24	16.80	36	18.10	19	16.60	38	18.20	17
% S&E Graduate Students/Pop 18-24	1.50	16	1.64	13	3.43	1	1.29	25	1.01	42	1.45	19
Computer Specialists/10,000 Workers	144.00	26	149.00	24	304.00	3	167.00	19	245.00	6	135.00	28
Life & Physical Scientists/10,000 Workers	14.40	38	23.00	19	39.10	4	28.00	11	33.00	9	17.30	34
Engineers/10,000 Workers	79.30	16	68.40	25	117.40	2	56.10	34	139.90	1	69.60	23
% Population Above Poverty Line	89.20	29	90.80	16	89.80	22	87.10	37	89.60	27	91.40	12
Per Capita Personal Income	29,317	25	31,663	15	39,044	3	27,566	34	32,661	12	29,996	21
% of Workforce Employed	94.30	30	94.30	30	94.70	22	93.30	45	92.70	48	94.50	25

Source: US Office of Technology Policy, State Science and Technology Indicators, 2004.

Returning to our sample of six large states, while California, Texas, Michigan, New York, and Illinois constitute the top five states in total HT employment in 2000 (before the full effects of the dot.com bust), California and Michigan had relatively high rates of HT employment in relation to their total employment (12.6% in Michigan and 10.8% in California).

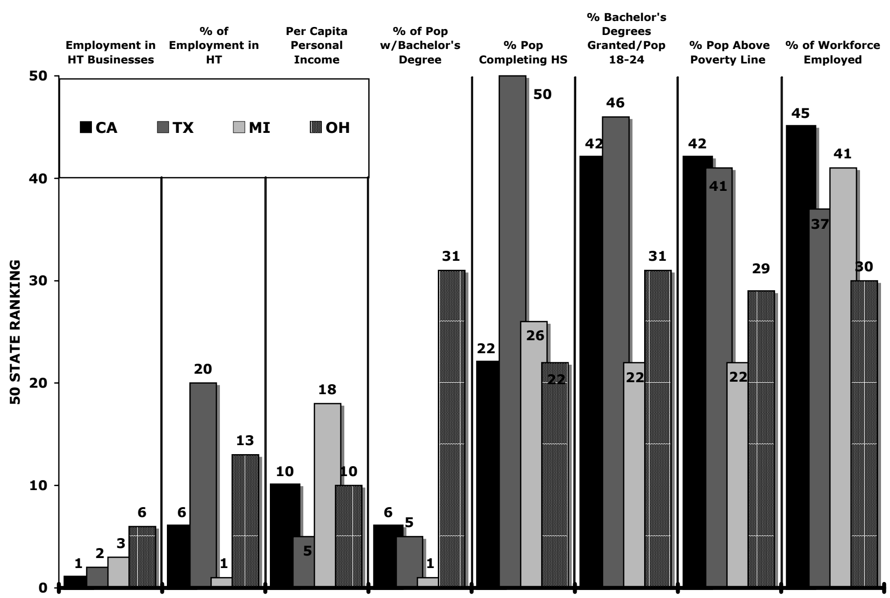
Each of these states also had relatively high poverty and unemployment rates when compared to other states (see Figures 5 and 6). At the same time, the HT sector is a contributor to high average per-capita personal income: Texas and New York are tied at fifth, Illinois ranks eighth, California tenth, and Michigan eighteenth.

Another indicator of economic and social bifurcation in HT-intensive states is the dichotomy between educational attainment levels and skilled HT workers. California is now among the bottom ten in the production of bachelor degrees among eighteen-to-twenty-four-year-olds. This is a dramatic turnaround from earlier patterns. Throughout most of the twentieth century, California led the nation in college-attendance rates and undergraduate degree production relative to population.

Texas is ranked even lower, and Florida, Illinois, and Michigan are ranked thirty-ninth, twenty-eighth, and twenty-second, respectively. New York is considerably higher, but this reflects in part a large influx of out-of-state students to the state's large collection of private institutions. Yet California and most of these other states have a relatively high percentage of their population with bachelor degrees and a high percentage of computer scientists, engineers, and professionals and skilled workers in the life and physical sciences as well.

Most HT-intensive states are importing the skilled professional workers they need from other states and other nations. With the lack of a national policy to expand access aggressively to higher education in general and not just to science and engineering fields, and with the continued lack of general investment by states in public higher education systems, one might imagine that HT-sector growth has certain limits and, further, that under certain conditions HT growth would exacerbate the division of rich and poor.

Figure 6. National Ranking of Educational Attainment, HT Labor Pool, Employment and Poverty Rates: California, Texas, Michigan, and Ohio



Source: US Office of Technology Policy, State Science and Technology Indicators, 2004.

If this dichotomy of rich versus poor and a highly educated native labor force versus a relatively uneducated one persists, one could imagine international implications. For one, the US economy would be highly dependent (more so than now) on skilled HT labor from other countries—essentially continuing to benefit from the “brain drain” from countries like India.

This raises the question of what should be the strategy of state governments—and their public universities—for pursuing a competitive edge in S&T and for bolstering their HT economic sectors. Thus far, that investment of political interest and money has been heavily toward the types of initiatives discussed in this paper, and less so for the general infrastructure of an educational system that will produce the talent, native and foreign, and the long-term base for economic competitiveness.

There is growing evidence that tertiary access rates in the US are flat and possibly declining, particularly among younger age groups and in states with large populations. And while the US retains relatively high access rates compared to other OECD countries, it now ranks only about 13th in the percent of the population that enters postsecondary education and then completes a bachelor’s degree or higher. That ranking, it appears, will likely slide in coming years unless there are more concerted efforts by states and the federal government, and largely public universities and colleges, to stem the tide.[47]

Whither America’s S&T Advantage?

While the states and the US national government have shown relatively little concern—beyond rhetorical exclamations—for growing global competition in science and technology, there are major changes occurring in the world. America remains the single largest producer of scientific labor and innovators—of whom nearly one-third are immigrants. The US employs nearly one-third of the world’s scientific and engineering researchers, spends 44% of all R&D, and remains among the most competitive economies.[48]

Arguably, however, America’s hegemony in S&T excellence has ended, if it ever truly existed to the extent imagined by the American public, lawmakers, and even much of the scientific community. The new global environment is characterized by a changing market for talent, the rise of greater geographic dispersion of centers of science and technological prowess (similar to that shown in the US, as discussed previously), and, in turn, the prospect of an altered flow of talent, venture capital, and corporate investment to places outside of the US.

As emerging knowledge centers mature and become more widespread throughout the world, the influx of talent necessary to sustain America’s HT model will likely shrink. Science and technological expertise is becoming more dispersed, subject increasingly to a highly mobile and competitive global market and facilitated by the ubiquitous power of internet communications—sometimes called the “death of distance”—as a condition for building productive S&T communities.[49] While much attention is on the emerging economies of Brazil, Russia, India, and China (dubbed “BRIC” by economists), the developed economies in Europe are arguably a more immediate competitor in advanced HT sectors. In 2005, for example, Europe surpassed the US for the first time in the number of biotech companies going public: 23 in Europe and 13 in the US.[50]

The US will undoubtedly remain a leader in HT and will continue to draw talented graduate students and scientists to its unmatched network of research universities. Already the initial negative influence of the Patriot Act has ebbed and foreign applications to US graduate schools have begun to increase once again, although perhaps the numbers will grow at a slower pace than in previous decades.[51] However, because of other nations' investment in education in science and technology programs at universities and the corresponding growth of S&T sectors, America's once dominant competitive advantage will diminish.

An emerging body of research largely produced by the scientific community and economists describes this prevailing trend. A congressionally requested report by a pre-eminent committee of scientists and S&T leaders chaired by the former CEO of Lockheed Martin Marietta, Norman Augustine, recently argued that "a comprehensive and coordinated federal effort is urgently needed to bolster U.S. competitiveness and pre-eminence in these areas."[52] The political traction of such analysis, however, has proven marginal, thus far.

Labor economist Robert Freeman has observed that a diminished comparative advantage in high-tech will "create a long period of adjustment for US workers, of which the off-shoring of IT jobs to India, growth of high-tech production in China, and multinational R&D facilities in developing countries, are harbingers." The US will need to adjust by developing "new labor market and R&D policies that build on existing strengths" and that recognize scientific and technological advances in other countries.[53]

As of this writing, America remains a nation mired in a protracted and expensive occupation in Iraq and Afghanistan. Rising deficits, a growing trade imbalance, and Republican control of both houses of Congress and the White House has placed a low priority on increased funding for domestic programs by the federal government. As noted previously, the American Competitive Initiative recently announced by the Bush administration offers a welcomed increase in funding for the physical sciences, but it is arguably a relatively minor additional investment relative to the problem—a small blip in allocation of federal funds.

The H&T sector has long been one of the bright spots for the US in trade—one of the few sectors with an actual trade surplus. If scientific expertise and talent are a declining strategic advantage for the nation, what other structural aspects of the US system give it a leg up in the global economy?

As noted, there is also the prospect of altered flows of corporate investments towards newer centers of research expertise. International corporations such as IBM and Nokia are placing an increasing percentage of their R&D investment in parts of the world with growing S&T capabilities *and* that represent emerging markets for their products. Costs are often cheaper than in the US, but perhaps more importantly there is the prospect of being closer and more knowledgeable with respect to the needs and foibles of the local market. Relationships with these universities are also often more flexible and less bureaucratic than with mature and often demanding universities in the US.

Yet the US remains a productive environment for S&T and will remain so in the short run. The excellence of its research universities and the growth of new business sectors like biotechnology is not the only reason. There is also the availability of venture capital, relatively high rates of R&D investment, and tax incentives and legal precedents that, thus far, are not yet matched in other economies.

On average, American companies spend three times as much as those in Europe on R&D; they have access to some ten times as much debt financing. This is one reason why many S&T firms in Europe and other parts of the world set up offices in the US—not to gain access to scientific expertise, but to its capital markets. Because of the high cost for an initial public offering on the stock market, many international firms are merging with existing, and often fledgling, US firms.

The question is how long this advantage will remain. Individual countries, such as England, are growing significantly in their R&D abilities, in part via government policies and in part because of expanding investment by the private sector. The European Research Area and the emerging 7th Framework are intended to boost significantly R&D investment *and* to help shape tax policies and the availability of capital.[54] What is clear is that national, supranational, and regional entities (like state governments in the US) ought to assess the larger international market changes to inform policymaking. Current state policy initiatives may be a good partial answer to this changing global environment, but not adequate in themselves.

Conclusion: Strategy and Sustainability

Reflecting on this cursory review of the *Second Stage* in US S&T policy, two questions emerge. First, are the various states pursuing productive strategies? And second, what is the sustainability of the myriad initiatives, some briefly described in this essay?

Regarding the first question, strategies differ between the states. As noted, many states with inadequate access to venture capital have attempted to create their own sources, targeted largely toward university spin-offs and university-industry collaborations; states with relatively small HT sectors seek tax incentives and seek to form research clusters to lure businesses from other states; and states with more liberal constituencies and higher concentrations of biotech firms are more favorable toward supporting stem cell research. Most states seek expanded or new university-business collaborations in targeted areas related to existing university and business strengths—biotechnology and nanotechnology in a state like California, with more emphasis on robotics in mid-west economies linked to the auto industry.

Few if any states seem to focus their strategies on bolstering the development of science and technology talent. Many states have been cutting funding for their public higher education systems, and few if any states have put a priority on expanding their science and engineering graduate programs. In the wake of the Patriot Act, states remain ambivalent (and sometimes even hostile) to the notion of pursuing policies intended to attract foreign talent to university graduate programs or to help fill HT employment needs.

More generally, few states have made a conscious link between the primacy of increasing the educational attainment level of their native populations and the long-term health of the HT sector, and their economies in general. No state, it seems, has taken account of the changing global climate for HT or the possible advantages of encouraging stronger ties with emerging science and technology centers in other countries.

Addressing these market opportunities may characterize the future evolution of the "second stage."

Yet there remain questions regarding the sustainability of state sponsored initiatives. Are they now a permanent part of America's HT political and economic environment? Tax incentives and state TBED offices seem a long-term policy reality, simply an extension of general state strategies for business development. State sponsored research centers and initiatives such as California's stem cell initiative (Proposition 71), on the other hand, are funded in part to fulfill a perceived inadequacy in the private sector or in the research and behavior of universities. Among the factors that may influence the longevity of such initiatives are the following considerations.

- As private sector investment in such university-business collaborations and in university basic research presumably grows, there appears to be the intention to withdraw state support and to assume that such centers will become self-sustaining and that grant programs will no longer be necessary.

- Many initiatives have been funded using temporary sources, including dollars received from recent legal settlements with tobacco companies and bonds, and within a relatively improved economic climate.[55] What will happen as the fortunes of state budgets shift and as new political priorities arise?

- What is the actual effectiveness of such initiatives and how will state TBED strategies change? Will priorities shift from, say, field-specific initiatives (e.g., nanotechnology) to human capital development (e.g., broader support for graduate education)?

- What is the relative role of the federal versus state governments in funding both basic research (for example, on stem cells) and fields relevant to S&T?

- What shifts will occur in science and technology research that will open new opportunities for university-business collaborations?

- How will the global market for S&T labor, products, and research change?

- Initiatives sponsored by a political party or politician in one era are often not supported in a succeeding era as the political winds shift.

Each of the variables in this incomplete list in some way relates to a much larger question of political economy: what is the short and long-term role of government in promoting and influencing the private sector? Further, what is the proper role of state governments in providing incentives and programs to encourage university collaboration with the business sector and, indeed, to encourage universities to act more like private sector entrepreneurs?

A political consensus has clearly emerged, in part informed by past successes, but also by significant rhetoric about S&T and the nature of the postmodern global economy, and it is a consensus that is reflected throughout the developed world—and beyond.

In the United States, state lawmakers justify current initiatives as a means to fill a gap unfilled by either the HT sector or universities—in the words of the governor's conference, "current practices in commercializing technology from public-funded research are not keeping up with the needs of the states and the nation." Even if universities and the business sector were to eventually "keep pace," it seems unlikely that states will desist from their relatively new interventions as national and, perhaps more importantly, global competition intensifies.

NOTES

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[35] Maine State Planning Office, "30 and 1,000: How to Build a Knowledge-Based Economy in Maine and Raise Incomes to the National Average by 2010," November 2001, <http://www.state.me.us/spo/sp/>.
[36] The University of Alabama at Birmingham, along with a handful of other universities—often in parts of the country, like the Midwest and Southeast, where venture capital is scarce—have set up their own venture-capital fund to develop campus companies and attract private sector investors. See *Chronicle of Higher Education*, 26 May 2000, <http://chronicle.com/weekly/v46/i38/38a04401.htm>.

[37] John Aubrey Douglass, "Earl Warren's New Deal: Post-War Planning and Higher Education," *Journal of Policy History* 12.4 (2000).

[38] FP7, the EU's chief instrument for funding scientific research and technological development over the period 2007 to 2013, is one of the most important elements in pursuing the Lisbon agenda (2002) for growth and competitiveness. Much like the early development of US science policy in the wake of World War II and then Sputnik, the ideal is to promote and further support the science and technology prowess of member states of the EU. See European Commission, "Building the ERA of Knowledge and Growth", 2005; European Commission, "Creating an Innovative Europe: The Aho Group Report," 2006.

[39] DeVol and Koepp, *California's Position in Technology and Science.*

[40] John D. Haveman and Howard J. Shatz, "Recent Trends in Exports to California's Information Technology Products," *California Economic Policy* 1.2 (April 2005).

[41] National Science Foundation/Division of Science Resources Statistics, "Survey of Research and Development Expenditures at Universities and Colleges, FY 2003."

[42] This is an affirmation of the strategy promoted by the World Bank in its report, *Constructing Knowledge Societies: New Challenges for Tertiary Education* (Washington, DC: The International Bank for Reconstruction and Development/World Bank, 2002).

[43] The Organisation for Economic Co-operation and Development, *Education at a Glance 2002*.

[44] Irwin Feller, "Virtuous and Vicious Cycles in the Contributions of Public Research Universities to State Economic Development," *Economic Development Quarterly* 18.2 (2004): 138-150.

[45] Paul M. Romer, "Should the Government Subsidize Supply or Demand in the Market for Scientists and Engineers?," National Bureau of Economic Research, *Innovation Policy and the Economy* (2001).

[46] Hence, the building of HT clusters and an entrepreneurial environment may be best achieved by developing and supporting high quality universities that attract both talented undergraduates and graduate students as well as faculty. See David Huffman and John M. Quigley, "The Role of the University in Attracting High Tech Entrepreneurship: A Silicon Valley Tale," *Annals of Regional Science* 36 (2002): 403-419.

[47] John Aubrey Douglass, "The Waning of America's Higher Education Advantage," Center for Studies in Higher Education, Research and Occasional Papers Series, CSHE 9.06, <http://cshe.berkeley.edu/publications/publications.php?id=226>.

[48] Richard B. Freeman, "Does Globalization of the Scientific/Engineering Workforce Threaten US Economic Leadership?" Working Paper 1147, Cambridge MA,National Bureau of Economic Resaerch, June 2005, 3.

[49] *Constructing Knowledge Societies,* 7 - 22.

[50] Andrew Pollack, "U.S. Finance Pulls Biotech Across Seas," New York Times, 12 July 2006.

[51] Council of Graduate Schools, "Findings from the 2006 CGS International Graduate Admissions Survey," March 2006.

[52] Committee on Science, Engineering, and Public Policy, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (New York: National Academies Press, 2006).

[53] Freeman, "Does Globalization Threaten US Leadership?"

[54] A recent EU report states that Europe's lagging R&D intensity results from structural characteristics, including tax incentives and an improved environment for

entrepreneurship among small firms, not underinvestment in R&D by individual and usually large European firms. See Petro Moncada-Paternò-Castello et al., "Does Europe Perform Too Little Corporate R&D? Comparing EU and non-EU Corporate R&D Performance," European Commission Joint Research Centre, Institute for Prospective Technological Studies (IPTS), Seville, 2006.

[55] States that are using tobacco settlement funds as a key component in their TBEDs include Arkansas, Connecticut, Georgia, Michigan, Missouri, North Carolina, Ohio, Oklahoma, Pennsylvania, and Virginia. "State Tobacco Settlement Funds & TBED: Where Are They Now?" *State Science & Technology Institute Digest*, 29 August 2005.