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BEYOND TECHNOLOGY TRANSFER: US STATE POLICIES TO HARNESS UNIVERSITY RESEARCH FOR ECONOMIC DEVELOPMENT

ABSTRACT. This paper examines the recent history of State-level policies in the United States for knowledge-based economic development, and identifies an emerging model based on technology creation. This new model goes beyond traditional investments in technology transfer and prioritizes cutting-edge scientific research in economically relevant fields. As research-intensive universities are indispensable for technology creation, these policies have yielded substantial new investments in university science.

INTRODUCTION

Knowledge creation and technological advancement are central to economic competitiveness. In the past decade, science and technology (S&T) policies have become vital to development strategies of the United States and the other member countries of the OECD.[1] Today, in one way or another, most such government efforts to promote innovation require the active participation of higher education institutions.

In recent years, scholars have generated a growing literature on university–business partnerships, technology transfer, systems of innovation, and the economics of university research.[2] In the United States, policy making in this area has been almost completely redefined. Although American universities have long had close

[1] Organization for Economic Co-operation and Development, *OECD Science, Technology, and Industry Outlook 2002* (Paris: OECD, 2002).

[2] On technology transfer in the USA, see Gary W. Matkin, *Technology Transfer and the University* (New York: Macmillan, 1990), and Roger L. Geiger, *Knowledge and Money: Research Universities and the Paradox of the Marketplace* (Stanford: Stanford University Press, 2004), 180–231. For innovation systems, see Richard R. Nelson, *National Innovation Systems: A Comparative Analysis* (New York: Oxford University Press, 1993).

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relations with industry,[3] the Second World War brought a new relationship between the Federal government, academia, and industry.[4] During the last two decades, leading American States have taken up an active role as well. Indeed, a 1998 report to Congress by the House Committee on Science recognized the special opportunities they present:[5]

> 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 their efforts.[6]

This article examines State-level policies aimed at fostering economic development by leveraging university expertise to promote technological innovation. The first section describes the opportunities and limitations faced by States in mobilizing university expertise for economic development; the second, reviews State patterns of wealth, R&D, and academic research; the third, examines four current approaches to the stimulation of research; and the fourth, discusses some implications of these policies, and their dependence upon the participation of high quality institutions.

These policies form part of a larger body of State programmes dedicated to 'technology based economic development' (TBED). These transcend previous efforts to stimulate collaborative research and knowledge transfer, and focus intently upon fields with significant economic relevance. In so doing, they emphasize basic university research as well as assist those who commercialize discoveries. Taken together, they constitute a kind of natural experiment, in which different States are devising different strategies to achieve similar ends.

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3 For industry, university research, and innovation during the twentieth century, see David C. Mowery and Nathan Rosenberg, *Paths of Innovation: Technological Change in 20th Century America* (Cambridge and New York: Cambridge University Press, 1998); and David C. Mowery *et al.*, *Ivory Tower and Innovation: University–Industry Technology Transfer Before and After the Bayh-Dole Act* (Stanford: Stanford University Press, 2004).

4 See Roger L. Geiger, *Research and Relevant Knowledge: American Research Universities since World War II* (New Brunswick, NJ: Transaction Publishers, 2004 (1993)).

5 House Committee on Science, *Unlocking Our Future: Toward a New National Science Policy. A Report to Congress by the House Committee on Science* (Washington, DC: 24 September 1998).

6 *Ibid.* Chapter III, Section A, 'State-based partnerships'.

STRENGTHENING UNIVERSITY–INDUSTRY INTERACTIONS

The economic rationale for government involvement in university–industry relations starts with the role of R&D in industry. Firms engage in R&D to acquire competitive advantage in the form of improved products or processes. In this sense, research-based innovation is a beneficial social outcome, generating economic returns to producers (through competitive advantage) and consumers (cheaper/better goods). Firms are constrained, however, in their ability to invest in basic research for two reasons. First, returns from basic research are long term and carry a high degree of uncertainty. Second, their results tend to become generally known, and are thus difficult for any single firm to appropriate.[7] For these reasons, firms in competitive markets tend to invest less in research than would be optimal from a national point of view. Therefore, a case can be made for public subsidies to lower research costs and increase industrial participation.

At present, American universities perform one-half of all the basic research that is done in the United States. The universities also enjoy a special relationship with industrial research. Academic research rarely produces marketable goods, but rather serves as an input to enhance the value of industrial R&D.[8] For this reason, its tangible value cannot be precisely determined. Nevertheless, its contribution can be critical in gaining comparative advantage. University research therefore provides a strategic point for government intervention.

Beginning around 1980, Federal and State policies began to subsidize university–industry research relationships in the expectation that they would foster 'technology transfer', and thereby strengthen the competitiveness of American industry. The Federal initiatives were intended to stimulate innovation in existing industries, regardless of location. Their chief instrument was the subsidized university centre for collaborative research. Some States followed with policies to encourage collaboration. However, the States faced constraints not unlike those confronting industry. The long-term results of subsidized research are uncertain – hence difficult to defend

[7] Manuel Trajtenberg, Rebbeca Henderson and Adam Jaffe, 'Ivory Tower versus Corporate Lab: An Empirical Study of Basic Research and Appropriability', Working Paper No. 4146 (Cambridge, MA: National Bureau of Economic Research, 1992). See also Nathan Rosenberg and Richard R. Nelson, 'American Universities and Technical Advance in Industry', *Research Policy*, 23 (3), (1994), 323–348.

[8] Geiger, *op. cit*. note 2, 194–196.

politically. States also faced the problem of appropriability – i.e., how to ensure that the economic benefits, or 'spillovers' from research, will be captured within the economy of the State itself.

Initially, States responded by subsidizing university research in fields relevant to local industries, and by targeting special programmes for small business. Small firms have long been of special concern because of their local importance (and political influence), as well as because of their economic contribution. However, small firms typically have difficulty using the results of research. Most lack internal research capacity, or are focused narrowly upon product development. In either case, there is little prospect of enhancing internal R&D by contacts with universities. Small firms may also lack the capacity to solve their own technological problems. States have developed policies to remedy these weaknesses. 'Technology development programmes', such as Pennsylvania's widely imitated Ben Franklin Program, subsidise small firms to commission research from local universities. At the same time, 'technology assistance' helps firms overcome their difficulties.

During the 1980s, policies to encourage university–industry interaction took three forms: (1) supporting technology development, by adding university research capacity in areas relevant to local industry; (2) making provision for cooperative research in university–industry centres and (3) establishing programmes to give smaller firms access to university research. After peaking in the late 1980s, such policies generally lost political support. Tangible economic benefits were difficult to show. From the late 1990s, however, State S&T policies revived – but with a different spin. The earlier preoccupations remained, but a new emphasis was placed upon (1) high technology industries; (2) industrial and academic 'clusters' and (3) start-up firms. Above all, new policy focused upon *technology creation*.

Virtually all States wish to attract or develop high-tech industries. The example of Silicon Valley, and the literature spawned by its fabulous growth, has drawn special attention to the role of 'agglomerations'.[9] The distinctive clustering of similar high-tech

[9] See Ian R Gordon and Philip McCann, 'Industrial Clusters: Complexes, Agglomeration and/or Social Networks?', *Urban Studies*, 37 (3), (2000), 513–532; and Hans Weiler, 'Proximity and Affinity: Regional and Cultural Linkages between Higher Education and ICT in Silicon Valley and Elsewhere', in Marijk van der Wende and Maarten van de Ven (eds.), *The Use of ICT in Higher Education* (Utrecht: Lemma Publishers, 2003), 277–297.

industries creates a social and economic infrastructure in which economic 'spillovers' are captured by local firms. Innovations and ideas are thus quickly communicated, creating a greater collective 'intelligence', and technological opportunities are translated into start-up firms. Since success is driven by the production of advanced, science-based technologies, the local research university becomes an indispensable partner.[10]

Technology creation policies involve the establishment of new laboratories in cutting-edge fields, such as biotechnology and nanotechnology,[11] which have commercial potential and which will spawn patents, licences, and start-up firms. The latter require additional policies to assure their viability – business incubators, venture capital, and management assistance. The educational component provides scarce human capital.

The Federal government has long fulfilled the role of stimulating research through grants and other incentives. The difference now is that States have begun to take up the task, with the explicit intention of capturing and retaining as many economic benefits as possible for themselves. Increased Federal research funds come as part of the payoff. At the same time, corporations have also shown willingness to share costs so as to have privileged access to intellectual property. Intellectual property also provides the basis for start-up firms. The combination of specialized university laboratories, high-tech corporations, and local start-ups will, it is argued, create thriving 'clusters' of economic activity.

Differences Among States

The fifty States of the Union reflect huge differences in scientific capabilities, industrial base, and economic vigour. State policies for economic development reflect these differences. Although general

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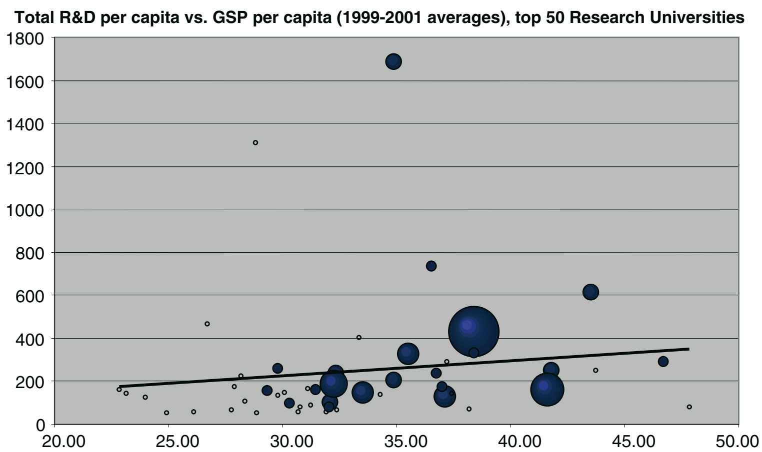
[10] Universities make numerous contributions to the economy: see Michael I. Luger and Harvey A. Goldstein, 'What is the Role of Public Universities in Regional Economic Development?' in Richard D. Bingham and Robert Mier (eds.), *Dilemmas of Urban Economic Development* (London: Sage Publications, 1997), 104–134.

[11] Irwin Feller, 'Virtuous and Vicious Cycles in the Contributions of Public Research Universities to State Economic Development', draft ms. (17 May 2003). 'Homeland security' is the latest target, the attraction of which is not scientific promise but government spending.

trends can be discerned, S&T policies have been implemented in accordance with local conditions.[12] University R&D expenditures comprise a small proportion of total American R&D (12 per cent). From the data that form Appendix A, we can see that the R&D expenditures highly skewed. California, for example, stands out with more than 20 per cent of national R&D expenditures compared with 13.5 per cent of GDP and 12 per cent of the US population. The top ten States account for almost 60 per cent of the total R&D spending and the bottom ten, just 1.2 per cent. Significantly, the 'top fifty research universities' are located in the twenty-four States that have the largest expenditures on academic R&D.[13]

These fifty universities are determined by a combination of measures of academic quality, publication productivity, and research expenditure. The relationship between State wealth, total R&D, academic R&D, and the presence of one or more of these 'top-50' is set out in Figures 1 and 2. The number of universities in this category is indicated by the size of the circles in the figures below. Cal-

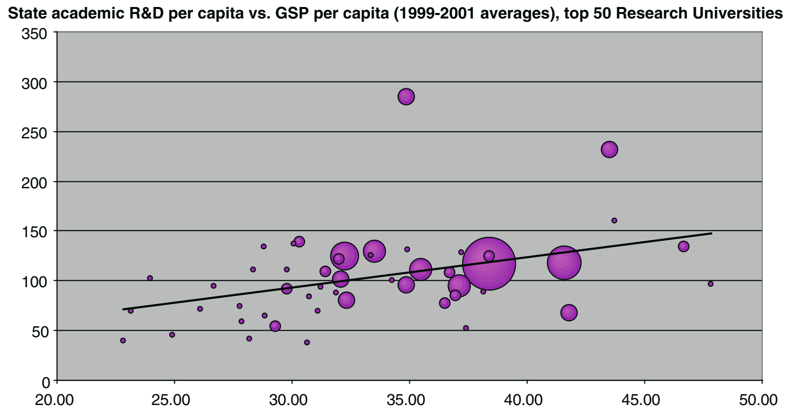
Figure 1.



[12] Irwin Feller, 'Federal and State Government Roles in Science and Technology', *Economic Development Quarterly*, 11 (4), (1997), 283–295.

[13] The top fifty American research Universities were determined by a composite of relative attainments in expenditure for research, number of publications, and NRC academic ratings, compiled by Roger L. Geiger and Nancy Diamond. Medical universities were not included.

Figure 2.



ifornia leads with eight; twenty-eight States have none. Both plots show positive correlations between R&D per capita and per capita gross State product (GSP), but the relationship between per capita GSP and academic R&D is stronger.[14]

These findings suggest that positive effects flow from university research into State economies. One would expect a high degree of randomness in this association, since the differences among States are affected by geography, urban–rural mix, and other factors unrelated to research. But economic standing does appear to be positively associated with university quality and research spending.

State Policies

Most of the new policies in this domain have been introduced place since 2000. Interest in supporting quality research has led to the creation of 'centres of excellence', and interest in generating 'clusters' has spawned support of 'corridors'. And despite the fact that, since 2000, most States have endured financial difficulties, New York and California have made large investments in scientific

[14] Academic, Total R&D and GSP per capita were calculated as three-year averages (1999–2001) of the related research expenditures and GSP, divided by the State population in 2000. Sources: National Science Foundation, 2000 Census. The bivariate correlation between Academic R&D per capita and GSP per capita was statistically significant ($r = .400$, $p = 0.004$), whereas that between Total R&D per capita and GSP per capita was weaker and non-significant ($r = 0.137$, $p > 0.05$).

capacity; Florida, Iowa, Kentucky, Maryland, Ohio, Kansas, and South Carolina have also announced new programmes.

However, not all States are moving in this direction. Alaska, Michigan, New Jersey, and Texas, for example, have reduced their commitments. States currently initiating or refining their policies face two choices. The first focuses upon *technology creation*, which entails direct investment in universities in carefully targeted fields. This seeks to build research and encourage rapid commercialization. The alternative, representing the older technology transfer approach, may be called *facilitation*. By emphasizing collaborative research aimed at specific technological developments, they aspire to achieve immediate goals. It is useful to consider examples of both strategies, and also of reliance on private sector initiatives and policy reduction or termination.

Technology Creation and Research Infrastructure

Georgia is an example of a State that has pioneered *technology creation*. In the 1990s, the Georgia Research Alliance (GRA), a private non-profit group representing universities and industry, assumed the responsibility for technology transfer. The GRA sought to use State appropriations to leverage private funds for strategic investments in research capacity. These investments totalled over $300 million in the 1990s. In a project dubbed 'Yamacraw', a group of industry, academic, and government leaders devised an ambitious plan to make Georgia a leading centre for the development of broadband telecommunications systems, devices, and chips.[15] The State committed an investment of $100 million dollars over seven years to create academic positions and infrastructure at public universities. These funds directly linked technology creation with job creation.

The new university positions were intended for both technology creation and the training of graduates for industry. To gain access to the technology, companies paid a nominal membership and promised to create a specific number of jobs. Both objectives seem to have been met. In three years (2000–2002), sixty-four academic positions were created, plus an additional 200 academic research posts; industry created 1,000 jobs and pledged another 2,000. The entire project has since received a permanent name and home. Now

[15] Geiger, *op. cit.* note 2, 210–213.

called the Georgia Electronic Design Center, it is located in a new Georgia Tech building complex that combines university research and business education units with State-related units for economic development. The striking feature of this project is its direct connection between technology creation and commercialization. Inventions emerging from GEDC laboratories are regularly presented to member firms, who are invited to acquire, patent or license them. The Georgia pattern has captured all the salient features of the new policy – technology creation, agglomeration, the production of human capital, and the facilitation of new firms.

In 2000, the State of California implemented a major initiative to capitalize upon the research prowess of the University of California. California Institutes for Science and Innovation (CISI) were designed to generate and capture knowledge in three fields: electronics and computing, biotechnology, and nanotechnology. The State committed $300 million over four years in four institutes, with the requirement of receiving 2:1 matching funds from other sources.[16] Each of the four institutes is based on partnerships between industry and individual campuses of the University of California.[17]

Several other States have also embraced *technology creation*. New York has earmarked $250 million for new laboratories in biotechnology and other fields.[18] Such 'Centres of Excellence' have been established at the State University of New York branches at Buffalo, Stony Brook, and Albany, and at the Universities of Rochester and Syracuse.[19] South Carolina – a State with middling capacity in S&T (ranked 29th in academic R&D and without a 'top-50' research university) is also adopting the 'Centres of Excellence' model to endow professorships in areas relevant to the State's economy.[20] Kansas, which has long encouraged technology

[16] The institutes are: the California Nanosystems Institute; the California Institute for Bioengineering, Biotechnology and Quantitative Biomedicine; the California Institute for Telecommunications and Information Technology; and the Center for Information Technology Research in the Interest of Society.

[17] See a portal for the institutes: http://www.ucop.edu/california-institutes/about/about.htm

[18] 'NY Makes Record $520 Commitment to TBED', *State Science and Technology Institute (SSTI) Weekly Digest,* 24 May 2002.

[19] The New York State Office of Science, Technology and Academic Research has a number of programmes to advance technology transfer, attract faculty, and stimulate university–industry liaison, in addition to supporting research. See: http://www.nystar.state.ny.us/default.htm

[20] See 'SC Commits $30 Million to University R&D', *SSTI Weekly Digest*, 27 June 2003.

transfer, has adopted a comprehensive new plan for TBED that includes research infrastructure and sixty new academic appointments in the biosciences over ten years.

Facilitation Policies

Facilitation policies aim chiefly to encourage technology transfer, and these seem to be prevalent in States having an average or less R&D activity. In 2000, for example, Kentucky, passed an Innovation Act, authorizing investment of $53 million in several programmes.[21] This created an R&D Voucher Fund that provides a maximum of $100,000 per year in matching funds to encourage firms to pursue R&D with universities in the State. This approach places the initiative with industry R&D labs (for technology development) rather than with university scientists (for technology creation). The Kentucky Science and Engineering Foundation supports research mainly in the Universities of Kentucky and Louisville, with grants typically under $100,000. The relatively small size of all these awards suggests an orientation toward small business, which may be appropriate to the economic circumstances of the state. Other less wealthy States are typically seeking to encourage tech-based industries without committing much in funding. They resort to such measures as R&D tax credits, incentives, and subsidies, and rely heavily upon non-profit associations.

In general, there seems to have been a falling-off of in interest in technology transfer *per se*, despite increasing interest in TBED. Where these States do support university research, the emphasis is on the biosciences – an area likely to pay off in research funding and possible commercialization. Many of these approaches reflect new policy choices. However, whereas *technology creation* involves fairly large, focused investments with explicit provision for commercialization, *facilitation* are focused upon direct aid to industry.

Reduction and Termination of State S&T Programmes

In the early 2000s, deepening budget deficits created an incentive for States to scale back their S&T initiatives. Alaska is a telling case in point. In 2003, the State government abruptly terminated the Alaska

[21] See 'Kentucky Innovation Act Calls for $53 Million S&T Investment', *SSTI Weekly Digest*, 18 February 2000.

Science and Technology Foundation (ASTF), transferring the balance of its endowment ($87 million) to general funds. The ASTF had been in existence since 1988, when it received a $100 million endowment and a $6 million appropriation. Income from the endowment supported a number of initiatives, including the investment of $35 million in matching funds for technology projects. During its fifteen years of operation, the foundation helped the State invest a total of $120 million in science-based economic development, and supported several councils and associations related to R&D and manufacturing.[22] The State governor and his aides justified their decision to terminate on the grounds that the foundation had failed to deliver. The governor's chief of staff further argued that 'funding entrepreneurship is not an essential function of government'[23] – a view certainly at odds with S&T policy in other States. The foundation may have been loosely run, but these arguments gave a sufficient rationale for confiscating the ASTF endowment.

In 1999, Michigan started what it called the 'Life Sciences Corridor', planning to use the proceeds from its tobacco settlement to allocate $50 million annually to boost State competitiveness in the life sciences and biotechnology.[24] The 'corridor' involves Michigan's research universities – the University of Michigan, Michigan State University, and Wayne State University – and the Van Andel Institute. Most funds were targeted for basic academic research or cooperative university–industry research. The balance was intended to finance start-up companies. However, despite receiving complementary investments – including $70 million to build facilities at the participating universities, a $60 million private gift to establish the Van Andel Research Institute, and $100 million pledged by the University of Michigan to build a Life Sciences Institute – the State reneged on its commitment. Facing a large budget shortfall, the governor reduced the programme to $25 million, diverting tobacco funds to

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22 See 'Alaska Abandons Bid for Tech Future with ASTF Demise', *SSTI Weekly Digest,* 16 May 2003.

23 *Ibid.* See akso Richard Richtmyer, 'Proposal Takes Aim at Foundation', *Anchorage Daily News* 7 March 2003, and the opinion piece by the governor's Chief of Staff Jim Clark, 'ASTF Can't Go On in its Present Form', *Anchorage Daily News*, 4 May 2003, G2.

24 On the founding of the Life Sciences Corridor, see 'Michigan Commits $1 Billion to Life Sciences R&D & Biotechnology Commercialization', *SSTI Weekly Digest,* 20 August 1999; and Alka Agrawal, 'Michigan Spends $1 Billion on "Life Sciences Corridor"', *Nature Biotechnology,* 17 (10), (October 1999), 947–948.

homeland security and automotive technology.[25] Michigan had hoped to challenge Massachusetts and California by creating a flourishing cluster of pharmaceutical firms, start-ups, and academic laboratories, but it now seems doubtful that these lofty goals will be met.

Another cutback has taken place in New Jersey. The New Jersey Commission on Science and Technology was typical of a 1980s S&T programme. Beginning in 1985, it supported Advanced Technology Centers at New Jersey universities, and in 1997, added an R&D grant programme for small businesses. In 2002, an official inquiry was conducted into its 'management, ... effectiveness, and efficiency'. Outright termination was threatened, but in the end, its budget for FY 2004 was instead slashed from $15 to $8 million. The State's need to balance its budget was a consideration – $100 million was simultaneously cut from university appropriations. The State seems to have lost confidence in the Commission. However, in a step indicative of the trend favouring biomedical research, New Jersey separately allocated $18 million for cancer research, and has begun funding a stem cell research institute.[26]

The decision to rescue S&T policies from budget cuts, or to invest in new initiatives, has depended far more upon the priorities of governors than those of legislatures. Thus, New York's governor pushed through a new science programme, but the governor of Texas summarily terminated a research-support scheme.

Reliance on Private Sector Initiatives for S&T Policy

Large investments in research infrastructure are by no means limited to public sources. In 2001, the California Institute of Technology received two private gifts – announced as the largest private donations ever given to an institution of higher education – totalling $600 million.[27] In policy terms, such acts constitute an 'intervening factor' that enhances a State's comparative advantage.

[25] See Jonathan Knight, 'Biotech Project in Turmoil as Michigan Balances Books', *Nature,* 422 (13 March 2003), 102; Battelle Institute, *Laboratories of Innovation: State Bioscience Initiatives 2004* (Columbus, Ohio: Battelle Institute, 2004), 223.

[26] http://www.state.nj.us/scitech/home.htm. See 'NJ Governor Shifting State TBED Priorities', *SSTI Weekly Digest,* 14 February 2003.

[27] Half of the total amount came from Intel cofounder Gordon and Betty Moore, and half from the Gordon and Betty Moore Foundation: http://pr.caltech.edu/media/Press_Releases/PR12193.html

Philanthropy has always been a feature of American higher education, and an important component of State policy as well.[28] However, some universities rely more than others on private gifts.

The State of Massachusetts exemplifies a high degree of reliance upon private universities for scientific excellence and TBED. A 2003 report documented how the eight research universities in the Greater Boston area contributed to economic activity.[29] The institutions – Boston College, Boston University, Brandeis University, Harvard University, Massachusetts Institute of Technology, Northeastern University, Tufts University, and the (public) University of Massachusetts, Boston – spent $1.5 billion on research, and another $1 billion on research through affiliated hospitals and institutes.[30] Of the total research expenditure in Massachusetts, the State provided only 0.4 per cent and the universities themselves just 2.7 per cent. The bulk of the funds – more than 80 per cent of the total – came from the Federal government. The eight universities contributed an estimated $7 billion to the regional economy, including capital investments, employment, business development, and research spending.[31]

Massachusetts has relied upon private initiatives to fulfil functions met elsewhere by public policy. As an example of building capacity for technology creation, a recent donation of $100 million to Harvard University and the Massachusetts Institute of Technology stands out.[32] This gift brought the two universities together to establish the Eli and Edythe L. Broad Institute, which will apply genome research to medicine. The Institute began operation in 2003, in partnership with MIT's Whitehead Institute for Biomedical Research (an earlier, highly successful, private investment in research capacity) and Harvard's affiliated hospitals. The two universities are expected to raise an additional $200 million in private support for research, the results of which should be available for 'scientists around the world'.[33]

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28 In fact, many of the largest gifts to universities are intended to strengthen research and academic quality: see, http://chronicle.com/stats/big_gifts.html

29 *Engines of Economic Growth: The Economic Impact of Boston's Eight Research Universities on the Metropolitan Boston Area* (New York: Appleseed, 2003) at: http://www.masscolleges.org

30 *Ibid.*, 5.

31 *Ibid.*, 6.

32 Andrew Pollack, '$100 Million Dollar Donation Helps to Establish a Genome Institute', *The New York Times*, 20 June 2003, Section A, p. 21, col. 1.

33 'Philanthropists Eli and Edythe Broad of Los Angeles Give $100M to Create Institute with MIT, Harvard, and Whitehead to Fulfill Genome's Promise for Medicine':– http://www-genome.wi.mit.edu/broad/

The Broad Institute augments the already powerful biomedical research complex in the Boston area. Given the dominance of the private sector in Massachusetts, a question arises whether State policies for TBED are even needed. A recent report, *MassBiotech 2010*, has argued that, despite the prominence of biotechnology in the State, Massachusetts has had a poor record of capturing economic benefits from the development of the biotech industry. California was identified as a stronger performer, along with North Carolina.[34] The crux of the report was that extraordinary research productivity has not been translated into manufacturing jobs. This concern recognises that knowledge 'spillovers' will not be captured locally without special effort. In this case, the Boston Consulting Group, the authors of the report, stop short of recommending specific programmes, and rather outline a series of steps that would improve the business climate, reduce regulatory burdens, and establish public–private organizations to coordinate and promote the industry – a policy, in other words, appropriate for reliance upon the private sector. The 2003 report on economic growth took a similar stance. It gave only a single paragraph to the suggestion that 'strategically targeted state investments', such as those in other States, 'could help ensure that Massachusetts universities can maintain their contribution to the state's competitiveness'.[35] It is clear that Massachusetts receives substantial economic benefits from its private sector at virtually no cost to its taxpayers. On the other hand, such programmes have little commitment to retaining knowledge 'spillovers'.

Technology Creation Policies: Their Implications

Since the late 1990s, the conviction that academic research can be mobilized for economic benefit has worked to the advantage of the research universities. State programmes have helped expand research capacity. On the other hand, the withdrawal of support in the face of budgetary cutbacks casts doubt on their long-term viability. What are the implications of this policy model for States and universities?

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34 See *MassBiotech 2010: Achieving Global Leadership in the Life Sciences Economy*, produced by the Boston Consulting Group and the Massachusetts Technology Council: http://www.massbiotech2010.org

35 *Engines of Economic Growth*, *op. cit*. note 29, 100.

The most conspicuous aspect of the new policies has been their commitment to science-based technologies, just as their characteristic feature has been their faith in cutting-edge science. The largest commitments are concentrated in the thirteen States that conduct most American academic research (Table I). This fact has

TABLE I

Technology Creation Policies in States with Largest Academic R&D

R&D Rank	GSP Rank	State	Program	Tech Creation
1	1	California	4 California Institutes for Science and Innovation	Yes
2	2	New York	Centers of Excellence; Gen*NY*sis for biosciences	Yes
3	3	Texas	Texas Excellence Fund (TEF), University Research Fund (URF), Advanced Research Program (ARP)	?
4	6	Pennsylvania	Life Sciences Greenhouse, biotech	Yes
5	16	Maryland	Private and Federal partnerships	N/A
6	11	Massachusetts	Private sector initiatives	N/A
7	5	Illinois	Leveraged investments for science at U. of Illinois, Urbana	Yes
8	12	North Carolina	Mature programs (research triangle, biotech consortium); Centennial Campus, NC State	Yes
9	9	Michigan	Life Sciences Corridor; now Michigan Tri-Technology Corridor	Yes
10	7	Ohio	10-year/$500 m. for collaborative research facilities; eminent scholars	Yes
11	4	Florida	3 Centers of Excellence @ $10 m.; Scripps East Coast Laboratory	Yes
12	10	Georgia	Georgia Research Alliance; Ga. Electronic Design Center	Yes
13	20	Wisconsin	Leveraged investments at U. of Wisconsin	?

interesting implications. First, these States apparently possess the very high levels of expertise that make such investments productive. Scientific expertise is the *sine qua non* for establishing a significant position in high-profile, competitive fields. Cooperating firms seek to gain advantages that only cutting-edge discoveries can achieve. Second, insofar as these fields are economically relevant, they can be expected to be the engines of academic R&D. Hence, these policies tend to solidify the advantage of established research leaders.

Expenditures for academic R&D correspond closely to the size of State GSP. Still, some States are 'overachievers' (Academic R&D rank > GSP rank), while others are 'underachievers'. North Carolina, a conspicuous 'overachiever,' has had S&T policies in place for decades – beginning with the Research Triangle – and has recently focused upon biotechnology. In addition, the Centennial Campus of North Carolina State University, and a second similar campus for biotechnology, represent an innovative approach to university–industry collaboration, achieved in this case through State assistance rather than through direct investment.[36] Other 'overachievers', including Massachusetts and Maryland, rely heavily upon private universities and, in the case of Maryland, Federal laboratories as well.

Florida appears to be the most egregious 'underachiever'. Its 'centres of excellence' programme is a partial acknowledgement of its deficiency. Originally budgeted at $100 million, however, the State's commitment was scaled back to $30 million. A proposed $20 million addition would still leave it far short of its original aspirations. Florida is handicapped by having the lowest amount of R&D per capita of any large State (see Appendix), only one 'top-50' research university, and long-running difficulties over its higher education governance structure. Perhaps to compensate, State and local governments in 2003 combined to pledge the largest TBED investment in Florida to date, inducing the Scripps Institute to locate its East Coast Facility there.[37] However, there are concerns that the high costs of the operation may not translate into as many jobs as initially projected.

Owing to budgetary shortfalls, three of the States listed in Table 1 – Texas, Michigan, and Wisconsin – have substantially reduced (although not abandoned) commitments to universities for

[36] Geiger, *op. cit.* note 2, 207–210.

[37] 'Florida Slowly Discovering the True Costs of Landing Scripps', *SSTI Weekly Digest,* 14 June 2004.

technology creation programmes. On the other hand, programmes in California, Ohio, and New York have been stoutly maintained. In the latter two, the respective governors believe that technology stimulation is crucial to the long-term revitalization of the State economy.

Support may be difficult to sustain in the face of budgetary pressures. However, S&T investments have often come from other sources. For example, many States have relied upon what might be called 'windfall financing'. In some cases (Michigan, Ohio, and Pennsylvania), 'windfalls' came from the settlement of lawsuits against the tobacco industry. Some States earmarked the proceeds from lotteries (a throwback to a colonial practice!), while others (such as California) took such decisions when the State's coffers were overflowing. It made good sense to allocate non-recurring revenues towards investments likely to produce future wealth. The inspiration to spur economic development through advanced S&T occurred at a propitious moment. But such extraordinary funding has protected only a few. The Alaska Foundation, itself a product of an earlier 'windfall', was looted; Michigan changed its mind about the use of its tobacco settlement. It may be asked whether such cutbacks are part of the inevitable economic perturbations that take place across fifty states; or whether they represent the ending of a 'virtuous cycle'.[38] Currently, however, there are few signs of disillusionment with the underlying ideology (Alaska excepted). In fact, Ohio committed an additional $100 million to existing S&T programmes for 2005.[39]

The stratum of States below those listed in Table 1 (Academic R&D rank 14–24 in Appendix), presents a more negative picture. Colorado, Virginia, and Arizona have been among the most niggardly in providing regular appropriations for their universities. Washington and Missouri have shackled their universities with crude performance measures. New Jersey and Connecticut have looked to the private sector for research support. Only Indiana, Iowa, and lately Minnesota have been supportive of university S&T policies.[40]

[38] Feller, *op. cit.* note 11, 3–11.

[39] 'Ohio Injects Another $100 Million into Third Frontier Programs for FY2005', *SSTI Weekly Digest*, 14 June 2004.

[40] Indiana's large-scale programme is again investing in universities after a temporary freeze; Iowa's programme focuses upon business development and assistance. Minnesota announced a biotech plan in 2003, as soon as wrestler-governor Jesse Ventura left office. In 2003–2004, New Jersey has been contemplating a reorganization of its public universities and S&T policies. Missouri in 2003 passed legislation to use one-quarter of its tobacco settlement funds for technology creation policies in bioscience, beginning in 2007.

Economist Irwin Feller has cautioned States against directing university investments towards potential economic return, while neglecting their general support. In fact, the prevailing trend since 2000 might well be described as 'disinvestment'. The cases in this study bear this out. A few States – California and North Carolina – deserve high marks for supporting their public universities even in adversity (at least so far). But New York, Texas, and Illinois seem more interested in gathering the economic golden eggs than in feeding the university goose. And Virginia expects its appropriations-starved universities to garner funds for the Virginia Institute for Defence and Homeland Security. More generally, 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 economies'.[41]

The scale of technology creation efforts is another factor. The most significant investments in technology creation are being made by the largest states, with California and New York leading the way. In other cases, what appear to be well-designed programmes may not be large enough to have much impact. Both Florida and South Carolina, for example, have committed $30 million to centres of excellence, but the Florida investment hopes to stimulate a State economy four times as large as that of South Carolina.

A number of smaller States have adopted facilitation policies. Although generally small in size, their scale may well correspond to the level of opportunity present in their local economies. Where there are few inventions being made, start-ups or technology-based firms are likely to be few. Even in such cases, facilitation policies have the potential to make only incremental contributions. By instituting policies for technology assistance, development, and business incubation, the small States are essentially trying to catch up. They model themselves on programmes that have been proven or are assumed to be effective in larger States. Their universities may welcome such programmes, but technology assistance and development tend to be marginal to the permanent enhancement of university research.

Conclusion

The fundamental question – whether States should invest in research linked with private entrepreneurship – has been raised

[41] Feller, *op. cit.* note 11, quotation on 9.

in Alaska, but apparently not anywhere else. Instead, since 1980, there has emerged a tacit consensus that State programmes produce, on balance, public benefits that are commensurate with their expense. Not that these benefits have been satisfactorily measured. In fact, when quantitative measures are applied to R&D decisions, they seem stacked against basic (or university) research.[42]

Clearly, the economic contribution made by universities extends far beyond the production of economically relevant research. Their greatest contribution continues to lie in the formation of human capital. But universities are also major actors in creating and sustaining knowledge-intensive industries.[43] Such outcomes are, however, relative to the quality of the university. Technology creation policies aim to bolster quality by enhancing research infrastructure. This promises to bring academic benefits and additional support, but whether or not they succeed in boosting employment or spawning high-tech industries will not be known for some time, if ever.[44]

In recent years, State governments have accepted a new framework – one based on the inexorable transformation of the United States into a 'knowledge-based economy'. Indeed, virtually every major State has produced a semi-official document outlining its present position, weaknesses, options, and recommendations.[45] When the problem is framed in these terms, a research university becomes an indispensable tool.

Nonetheless, the dominant actors in the 'knowledge-based economy' remain knowledge-intensive firms, especially the major corporations. Start-up firms, which assume great risk to translate knowledge into commercial products, are smaller complements of a much larger process. The role of the universities lies in their capacity to produce new knowledge. In fiercely competitive industries, privileged access to cutting-edge knowledge is uniquely valuable. The role of State policies is to weld these components together, and to lubricate the process.

Policies for technology creation have thus become a new instrument in the policy toolbox. Once *ad hoc* investments, they have now become a national trend that has touched almost all the largest States. The fruits of these policies may be a long time in

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42 Nathan Rosenberg, 'Why Do Firms Do Basic Research (with Their Own Money)?', *Research Policy*, 19 (2), (1990), 165–174.

43 Luger and Goldstein, *op. cit.* note 10, 113–115.

44 For the complexity of this issue, see Michael E. Porter, 'The Economic Performance of Regions', *Regional Studies*, 37 (6–7), (2003), 549–578.

45 References and links can be found in the *SSTI Weekly Digest*.

coming. But their impact upon American science is already apparent. The influx of leveraged State funding has enabled American universities to expand their capacities in the most lucrative, competitive, and scientifically fecund fields. While their ultimate economic consequences lie uncertainly in the future, their immediate beneficiaries are clearly, and unequivocally, the American research universities, and American science in general.

APPENDIX

State Share (%) of Gross State Product (GSP) and Per Capita (PC) of GSP; Proportion of all State Research and Development Expenditures (R&D) and Academic Research and Development Expenditures (AR&D); and Number of 'Top-50' Research Universities in each state in 2000

State	*(%) GSP*	*GSP (PC)*	*(%) R&D*	*R&D (PC)*	*(%) AR&D*	*AR&D (PC)*	*Top50 RU*
California	13.53	3.97	20.80	16.27	13.52	12.77	8
New York	8.04	4.21	5.10	7.14	7.64	12.78	5
Texas	7.47	3.56	4.40	5.54	6.80	10.53	2
Florida	4.75	2.95	1.80	2.92	2.84	6.13	1
Illinois	4.70	3.76	4.80	10.28	3.90	10.21	3
Pennsylvania	4.06	3.29	3.70	8.01	5.17	13.58	4
Ohio	3.75	3.28	2.90	6.75	3.06	8.74	2
New Jersey	3.65	4.32	5.00	15.61	1.89	7.22	2
Michigan	3.27	3.27	7.10	19.01	3.32	11.08	2
Georgia	2.98	3.62	1.10	3.42	3.09	11.89	3
Massachusetts	2.87	4.49	4.90	20.48	4.96	24.54	2
North Carolina	2.83	3.50	1.90	6.27	3.47	13.84	3
Virginia	2.63	3.69	1.90	7.16	1.96	8.41	1
Washington	2.21	3.73	4.00	17.84	2.14	11.83	1
Indiana	1.93	3.16	1.20	5.35	1.70	9.30	2
Maryland	1.87	3.51	3.30	16.30	5.03	30.94	2
Minnesota	1.86	3.76	1.60	8.74	1.39	9.40	1
Missouri	1.80	3.20	1.00	4.62	2.05	12.04	1
Tennessee	1.79	3.14	0.80	3.62	1.35	7.34	0
Wisconsin	1.74	3.23	1.00	5.02	2.21	13.40	1
Colorado	1.69	3.90	1.60	9.83	1.82	13.12	1
Connecticut	1.60	4.68	1.80	14.35	1.56	14.47	1
Arizona	1.57	3.05	1.20	6.06	1.55	9.76	1
Louisiana	1.39	3.08	0.20	1.40	1.33	9.44	0
Alabama	1.21	2.70	0.70	3.89	1.43	9.75	0
Kentucky	1.19	2.93	0.30	2.14	0.91	7.07	0
Oregon	1.19	3.47	0.80	6.18	1.15	10.63	0
South Carolina	1.14	2.83	0.40	2.81	0.98	8.74	0
Oklahoma	0.92	2.66	0.20	1.91	0.84	7.29	0
Iowa	0.90	3.06	0.40	3.48	1.40	14.93	1

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