9
THE ROLE OF UNIVERSITIES IN THE EVOLUTION OF TECHNOLOGY-BASED ECONOMIC DEVELOPMENT POLICIES IN THE UNITED STATES

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Introduction

By the end of the twentieth century, technology-based economic development (TBED) programs had become a nearly ubiquitous tool for public sector economic development policies in the United States. TBED programs are not limited to federal policies but have become the key element of most state level economic development efforts. In addition, innumerable local public initiatives across the nation are based on promoting technology to foster regional economic competitiveness and growth. Publicly financed TBED programs focus on the attraction, retention, and growth of advanced technology-based firms and industries. Expanded technology-focused policy efforts have fostered growing partnerships between the public sector and institutions of higher education, especially those with expertise in research. Some reports go so far as to say that regional research centers and institutes are “undisputedly the most important factor in incubating high-tech industries” (DeVol 1999; State Science and Technology Institute 2006, p. 13). Unlike anytime in the past, American research universities have developed extensive and formal collaborations with both state and local governments, making them primary partners in local economic development policy in regions across the nation.

Today, virtually all U.S. research universities attempt to build successful technology transfer programs aimed at commercialization of university developed intellectual property, with a goal of generating licensing fees and revenues based on equity appreciation. These efforts are complementary to public efforts broadly geared toward the promotion of entrepreneurship and firm creation. As a result, many university programs are more closely integrated with public efforts promoting regional economic growth than they ever were in the past. This paper traces the evolution of government policies that have facilitated the new and growing role of research
universities in public sector economic development policies. This expanded role of universities results not only from changing priorities within academic institutions, but from deliberate shifts in economic development priorities at both state and federal government levels.

Changing fiscal conditions in higher education have significantly altered the way universities view technology commercialization. The potential for generating private revenue from university-generated research is a relatively recent phenomenon in American higher education. These efforts were catalyzed by the passage of federal Bayh-Dole legislation in 1980 which dramatically shifted the incentives for universities to promote technology transfer of publicly financed research. The new legislation allowed institutions of higher education to benefit financially from the commercialization of publicly funded research in ways they were mostly precluded from previously. Accelerated university-based technology transfer efforts have coincided with a dramatic shift in the focus of economic development programs promoted by all levels of government in the U.S. State governments and, in particular, have moved beyond older ‘smokestack chasing’ programs almost exclusively devoted to attracting manufacturing enterprises. Many of these efforts have been supplanted by a vast expansion of public programs targeting smaller and technology intensive industries.

Research universities are almost always a partner of public TBED programs. Research universities are typically often the largest regional concentrations of research and development, but they play a crucial role in both workforce development and new company formation. TBED programs emphasize the creation of new companies based on advanced technologies, precisely the goal of many university-based programs. After a broad description of what constitutes TBED policies, the paper will describe the independent histories of science and technology policy at the federal and state government levels in the U.S. The paper will then review the impact of Bayh-Dole legislation and the changing role of technology transfer within research universities and how it has changed university attitudes toward commercialization. In conclusion, the paper covers more recent trends in TBED policies and the expansion of local government efforts focusing on technology-based programs.

**Defining technology-based economic development**

What differentiates TBED programs from broader economic development policies of state and local governments? TBED initiatives exist as a subgroup of policy efforts aimed at promoting economic growth. The goals of economic development programs vary but usually concentrate on the promotion of employment and income growth and bolstering public sector tax revenues. TBED efforts are typically implemented by public or nonprofit sectors organizations, or hybrid organizations that incorporate both public and nonprofit characteristics, with the intent of influencing private sector investment.

How TBED policies promote investment varies from program to program. The current focus of TBED efforts has been characterized as ‘influencing, either directly or indirectly, private sector activity specifically in high-tech or technology intensive companies and industries’ (Phillips and Pittman 2002). A myriad of tools has been developed to promote the ultimate goal of increasing investment and economic outcomes: direct marketing can be used to recruit new technology companies into a region; subsidies for technology incubators facilitating firm creation; direct financial support such as loan guarantees can be provided to existing technology companies for expansion; indirectly, local governments can finance specific infrastructure that encourages growth of technology industries.

The specific tools used do not distinguish TBED programs as much as the specific industries targeted. TBED efforts attempt to foster growth in technology intensive industries. The actual
definition of what constitutes “high technology” industries lacks consistent definition. Many programs focus on firms engaged in early stage research and development, regardless of industry. Because this research often starts as university-based research, governments attempt to partner with academic institutions to facilitate the movement of academic research into commercial products and services. These collaborative efforts are almost always characterized as a public–private partnerships (PPP). Typical TBED effort brings together business, government, foundation, and not-for-profit sectors toward the goal of building fast-growing industry clusters.

U.S. federal government’s role in technology policy

The interaction between universities and the U.S. federal government changed dramatically over the twentieth century. Through the nineteenth century, federal government support for institutions of higher education was limited or indirect, such as support for the creation of land grant colleges via the passage of the Morrill Land-Grant Act of 1862. Over the same period, the federal government played little role in funding research activity at academic institutions. Prior to World War II, the bulk of research in the U.S. was directly financed by the private sector. Federal impact on university-based research expanded rapidly during World War II. A National Defense Research Committee (NDRC) was formed in 1940 to organize civilian scientists working on problems of national defense (Bush 1941). From that emerged the Office of Science, Research and Development (OSRD) under the direction of Vannevar Bush, which became the primary mechanism for federal support of university-based research funding. By 1945 over 83 per cent of all support for research in the natural sciences was coming from the federal government (Douglass 1999). After WWII, the federal government continued its role as the dominant sponsor of university-based research, surpassing the private sector as the largest sponsor of research at academic institutions.

The federal government’s new role was by design. Vannevar Bush’s 1945 report, *Science: The Endless Frontier*, called for a permanent centralized role of federal government in science funding. The report, even only partially implemented, was considered a seminal document shaping postwar federal science and technology policy, which led to the creation of the U.S. National Science Foundation in 1950. Federal science policy as envisioned by Bush and others did not emphasize the commercialization of new technologies to promote economic development. During the war, scientific advancement was a tool deemed essential to furthering military efforts that were increasingly technology-intensive.

Greater federal funding of scientific research followed from the expansion of Cold War tensions between the United States and the Soviet Union in the 1950s. Federal efforts to support university research and education accelerated further following the Soviet Union’s launching of the Sputnik satellite in October 1957. The public perception that the United States was losing technological competitiveness with its Cold War rival led directly to several significant new initiatives to improve not only scientific education but research production in the U.S. The National Defense Education Act (NDEA), passed in 1958, was premised with a ‘Declaration of Policy’ that stated: ‘an educational emergency exists and requires action by the federal government. Assistance will come from Washington to help develop as rapidly as possible those skills essential to the national security’ (Forest 2002). The NDEA included support for loans to college students, the improvement of science, mathematics, and foreign language instruction in elementary and secondary schools, graduate fellowships, foreign language and area studies, and vocational–technical training.

Particular regions experienced significant economic impacts as a result of these defense focused expenditures. The concentration of defense and aerospace firms in Los Angeles benefited the
regional economy of Southern California. Massachusetts, and in particular the Massachusetts Institute of Technology (MIT), garnered sizable concentrations of federal research grants, later catalyzing technology driven economic growth along Massachusetts’ Route 128. Sizable federal expenditures in research and development benefited Stanford University and the Silicon Valley area of California.

Nonetheless, the Cold War goals of federal expenditures were focused on scientific outcomes, not regional economic impacts. Where regional economies grew as a result of concentrated federal research expenditures, the result was more incidental than intentional. In the U.S., intentional federal involvement in regional economic development has generally been limited to support of the Tennessee Valley Authority (TVA) and to a lesser extent the Appalachian Regional Commission (ARC). Both of these programs focused on historically underdeveloped areas. Both regions remained minimally impacted by federal science and technology expenditures in the decades after World War II.

Because the primary motivation for increased federal support of academic research was not economic development, it is not surprising that policies did not encourage the efficient transfer of new technology to the private sector. In addition to university-based research, a core of federal labs expanded during the Cold War. These organizations were not charged with facilitating technology transfer into the private sector. As a result, federal labs placed virtually no emphasis on encouraging regional economic growth. Before 1980, it was generally considered illegitimate for federal labs to even try and provide economic support for the regions where they were located (Hill 1994).

Inconsistent federal policies for intellectual property inhibited efforts to move new innovations out of the laboratory. Existing federal law in the decades following World War II required that the federal government retain licensing rights to all research developed with federal funding, whether or not those developments were made in federal labs, universities, or private companies. Partner institutions lacked incentives to pursue the commercialization of research they were producing. As a result, the level of new innovations directly transferred into the commercial sector was minimal. Before 1980 only 5 per cent of government patents were eventually licensed (Schacht 2009).

State and local economic development policies

Regional economic development policies in the U.S. have developed independently from federal policy from the very birth of the nation. For much of the nation’s history, state level economic development policies were dedicated primarily to the promotion of manufacturing industries and were often in direct competition with each other. Federalism as the defining construct of the American political system has inspired economic competition between states dating back at least to 1791. That year, the U.S. Secretary of the Treasury Alexander Hamilton began efforts to locate a new manufacturing corporation in what would later be named Patterson, New Jersey. The new quasi-public entity, named the Society for Establishing Useful Manufactures (SUM), was chartered as a state-favored enterprise, exempted from certain state taxes by the New Jersey legislature. Arguably, SUM was the first public–private partnership in U.S. history. That early tax incentive soon generated complaints from legislators in neighboring Pennsylvania who observed that the “powers, rights and privileges, given to this company would be, in their operation, very injurious to this state as well as other states” (Seneca et al. 2004, p. 2). State economic development programs remained mostly independent of federal policies, and often fiercely in competition with each other, through the next two centuries.
The state of Mississippi accelerated publicly financed competition for commercial investment when it passed the Mississippi Industrial Act in 1936. The act permitted communities in the state to issue Industrial Revenue Bonds (IRBs) to support private sector investment. IRBs were generally offered to firms relocating establishments into targeted regions. The use of public bonds lowered borrowing costs for investors. The use of IRBs and similar publicly funded financial incentives expanded after World War II, but the targets of these industry attraction efforts were almost always existing manufacturing enterprises (Mead 2005).

Major shifts in state level economic development efforts began in the 1980s. Plosila (2004) traces the development of state level economic development policies in the United States. Through the late 1970s, state policies continued to be concentrated on “brick-and-mortar issues,” including: infrastructure development; subsidies for land acquisition and building costs; and property tax abatement and support through regulatory processes. These efforts focused almost exclusively on influencing the site selection or relocation for large industrial facilities. States directly competed against each other for the highest priority projects. The epitome of these practices arguably came in 1975 when the Volkswagen Corporation of Germany announced its intention to build a new automobile manufacturing plant in the U.S. Multiple states engaged in a fierce competition to attract the new automobile manufacturing facility. The Commonwealth of Pennsylvania “won” the site selection decision in 1976. A new plant was built and production began in 1978. The decision was facilitated by a then unprecedented $78 million in tax abatements and publicly funded incentives provided directly and indirectly to the corporation.

Where there was state level science policy during the 1970s, it was generally not focused on economic development efforts. The U.S. Department of Commerce and the U.S. National Science Foundation (NSF) had encouraged states to establish high level science advisor positions in the early 1960s. Again Plosila, who himself served as a senior policy advisor to Pennsylvania Governor Richard Thornburg in the early 1980s, notes that these advisors and foundations were primarily interested in broader scientific issues with little focus on economic development:

Issues about talent, the role of higher education, the building of entrepreneurial cultures and related issues deemed more important today were rarely considered components of state economic development policy and programs through the post-World War II period until the early 1980s. (Plosila 2004, p. 114)

Through the 1980s state economic development programs moved away from what was considered “first wave” economic development policies that emphasized the relocation of manufacturing facilities—policies characterized as “smokestack chasing.” Much of the shift was precipitated by the slow economic growth of the period. Severe national recessions between January and July of 1980 and between July 1981 and November 1982 had concentrated impacts on traditional industrial areas. Older economic development practices focused almost exclusively on attracting manufacturing enterprises were seen as ineffective, given the contraction of the manufacturing sector concentrated in specific regions.

To understand the independence of state and federal economic development efforts it is important to note that the United States broadly lacks structural adjustment policies to deal with major regional economic shifts. Addressing regional economic downturns is mostly left to state and local governments. To deal with the multiple recessions of the 1980s, states developed new programs to promote economic competitiveness. Instead of focusing on attracting large industrial plants in traditional industries, new policies began to focus on smaller firms in emerging growth sectors. States were most interested in attracting firms in emerging
technology-based industries. New emphasis was also placed on growing new firms and encouraging entrepreneurial activity. These new policies broadly constituted what has been called the “second wave” of economic development policies (Eisinger 1988).

Despite little experience in leveraging technology, states rapidly shifted economic development efforts. In January 1981, the state of California proposed a $23 million program focused on small innovative companies. That same year the Ben Franklin Partnership program was authorized by the state of Pennsylvania. In February 1982, the new Ben Franklin program evaluated applications from seven proposed consortiums to establish regional Advanced Technology Centers. At its inception, the program had four major project thrusts: Research and Development, Entrepreneurial Development, Workforce Training, and University-based Centers of Excellence. Research and Development projects focused on new product/process development or the improvement of existing products and processes. The majority of these projects had a university partner that performed the actual research and then transferred the knowledge or prototype to the private sector for application (Ben Franklin Technology Partnership 2013). Other states soon followed with similar programs, including the New Jersey Advanced Technology Centers and the Thomas Edison Program in Ohio. Most of these emerging programs emphasized product development from applied research taking place within existing research institutions, typically universities.

A fundamental difference between emerging state-level TBED efforts and older economic development programs was an emphasis on smaller firms, including those at the earliest stages of formation. To encourage new company formation, states engaged for the first time in direct financial support for seed, venture, and working capital programs supporting private sector enterprises. These efforts were aimed directly at encouraging the commercialization of research likely to be generated at existing research institutions. This directly translated into greater cooperation between local governments and research focused universities.

By 1983 there were at least 153 state-level technology programs that were intended to stimulate the growth of existing technology-dependent businesses and new businesses (United States Office of Technology Assessment 1984). The attraction of technology-based initiatives stemmed from the perception of continuing growth and potential for employment and job creation. These policy efforts focused on investments in applied research and development, venture capital, science parks, and business incubators (Rosenfeld 2002). New state policies evolved including expanded use of research and development tax credits. The state of Minnesota adopted what is considered the first state level Research and Development tax credit in 1982. The new program was enabled by the federal Research and Experimentation Tax Credit authorized in the Economic Recovery Act of 1981. Over forty states offered similar tax credits over the subsequent thirty years (Miller and Richard 2010).

State interest in TBED programs accelerated just as the federal government shifted the legal framework for commercialization of publicly financed research. Almost all of these new programs were focused on taking advantage of university-based research originally funded in large part by federal research initiatives. The dramatic shift in state and local policies could not have taken place without the enactment of new federal legislation which encouraged the commercialization of publicly financed research for the first time.

Universities and Bayh-Dole legislation

The lack of effective federal policies promoting technology development became a growing political issue by the end of the 1970s. Through the 1970s critics found limited cohesion to federal technology policies and a general disinclination to support the commercialization of
technology (Feller 1992). Some of the largest roadblocks to technology commercialization were federal rules constraining the ownership of virtually all intellectual property resulting from federal funding. Slowing national economic growth through the 1970s motivated new legislative efforts to facilitate faster commercialization of technologies being developed at U.S. federal labs, or at universities with federal funding (Stevens 2004).

U.S. Senators Robert Dole and Birch Bayh led legislative efforts to redefine the federal government’s role in technology transfer. Their efforts resulted in the passage of the Bayh–Dole Patent and Trademark Act of 1980. The act gave institutions receiving federal grants the right to retain title to the inventions that resulted. The new legislation had pronounced impacts on how academic institutions managed research activities. This reassignment of intellectual property rights fundamentally changed the role of universities in the process of commercialization of new technologies. The new legislation enabled universities, industries, and individual researchers working on publicly funded projects to benefit financially from their inventions. The Bayh–Dole Act hastened the entry of many American universities into patenting and licensing activities that most formerly avoided as a matter of policy (Mowery and Ziedonis 2000). The bill may have assisted the geographic spread of university–industry knowledge transfers and contributed to commercialization of research products and establishment of new start-up firms (Balasubramanian and Sakakibara 2005).

In addition to the passage of the Bayh–Dole Act, other legislative efforts attempted to further open federally funded research, including research generated within federal labs. In 1983, a federal Laboratory Review Panel chaired by David Packard, Chairman and Co-founder of the Hewlett Packard Corporation, concluded:

> The United States can no longer afford the luxury of isolating its government laboratories from university and industry laboratories. Already endowed with the best research institutions in the world, this country is increasingly challenged in its military and economic competitiveness. The national interest demands that the federal laboratories collaborate with universities and industry to ensure continued advances in scientific knowledge and its translation into useful technology. The federal laboratories must be more responsive to national needs.  

*(Gross and Allen 2003, p. 23)*

Through the decade, federal policy promoting technology transfer was dramatically altered by a series of new legislation. The 1980 Stevenson–Wydler Technology Innovation Act mandated the creation of a technology transfer office in federal agencies and required federal laboratories to facilitate the transfer of federally owned and originated technology to state and local governments and the private sector. In 1982, the Small Business Innovation Research (SBIR) program was established. The National Cooperative Research Act of 1984 encouraged U.S. firms to collaborate on generic, precompetitive research by establishing a rule of reason for evaluating the antitrust implications of research joint ventures. The 1986 Federal Technology Transfer Act amended the earlier Stevenson–Wydler Act authorizing cooperative research and development agreements between federal laboratories and other entities, including state agencies. The 1988 Omnibus Trade and Competitiveness Act established the Competitiveness Policy Council to develop recommendations for national strategies and specific policies to enhance industrial competitiveness. The act also created the Advanced Technology Program and the Manufacturing Technology Centers within the National Institute for Standards and Technology to help U.S. companies become more competitive. The 1989 National Competitiveness Technology Transfer Act further amended the Stevenson–Wydler Act to allow government-
owned, contractor-operated laboratories to enter into Cooperative Research and Development Agreements (CRADA) with the private sector (Heisey et al. 2006).

Collectively the broad set of new legislation shifted the relationship between the federal government and educational institutions. While the Bayh–Dole Act itself has been called “one of the most enlightened pieces of economic legislation of the 20th century” (Economist 2002), its adoption in 1980 was not without critics. Early criticism centered around the perception that publicly funded assets were being “given away” to the private sector. Those criticisms have quieted over time, but arguments continue over the impact of commercial ventures within academic institutions. The emphasis on protecting intellectual property is considered by some antithetical to the norms of open science. And while some consider any commercial focus inappropriate for academic institutions, others actively seek to expand the role of universities in creating economic relevance for the communities they serve, to the point of calling economic development a “fourth mission” for universities after teaching, research, and outreach (Geiger and Sá 2009).

**University attitudes toward technology transfer**

Spurred by the Bayh–Dole Act and other factors, the attitude within American universities toward commercialization of research has shifted dramatically since World War II when participation in federally funded projects was seen as a wartime exigency. Even some of the most significant inventions resulting directly from university-based research were rarely patented. For example, when Jonas Salk developed an effective vaccine for polio in 1946, the new medicine was not patented.

Even when university researchers wanted to commercialize their research, opposition within academic institutions often prevented collaboration with the private sector. At one extreme, university attitudes bordered on disdain for commercial efforts, even those spawned from academic research. One early example comes from the history of the ENIAC project at the University of Pennsylvania. The project was responsible for the development of the first digital computer during World War II. Following the war, the two engineers most responsible for the ENIAC, electrical engineers J. Presper Eckert and John Mauchly, saw the commercial potential for digital computing and sought to extend their research within the university. Senior academics argued at the time not only against the commercialization of computers, but against the continuation of the digital computing project at the university (Lasar 2011). That rejection prompted Eckert and Mauchly to independently found the Eckert-Mauchly Computer Corporation (EMCC) in 1947, which after being acquired by the Remmington Rand Corporation, went on to produce the first UNIVAC, the world’s first successfully marketed commercial computer in 1951 (Ceruzzi 1999).

Despite a vast expansion of federal research expenditures after World War II, the linkage between universities and regional economic development efforts remained limited. Berman (2012) has traced the broad history of academic science and its interaction with economic development policies. Most telling is the experience of Otto Kerner, the Governor of Illinois in 1961, who asked the University of Illinois that year to study its impact on economic development within the state in 1961. The university was mostly confused by the request, replying that “certain basic factors are far more important in attracting industry and in plant location decisions, and therefore in stimulating regional economic growth, than the advantages offered by universities.”

University–industry partnerships began to evolve in the late 1970s. An experimental National Science Foundation effort incentivized the collaboration of engineering focused universities with specific industries. Programs at the California Institute of Technology, Carnegie Mellon
University, Rensselaer Polytechnic Institute, and the University of Delaware started and met with varying levels of success (Berman 2012). State governments soon became partners in the growing collaboration between universities and industry. One of the earlier efforts came in 1978 in Arizona. That year advanced technology firms based in the state approached then Governor Bruce Babbitt with a plan to collaboratively strengthen engineering education at Arizona State University. The impetus for the plan was a need for more technology workers. The effort reflected an early shift toward workforce development in economic development policies.

University–industry collaboration produced a new revenue stream for universities. Many universities were receiving millions of dollars in licensing fees based on university research by the end of the 1980s (Dill 1995). Revenue generation from university-based technology transfer programs are increasing and have the potential to become much more significant in the future. Revenues accrued to universities result from research performed years earlier. In December 2012, a lawsuit brought by Carnegie Mellon University (CMU) against the Marvell Technology Group resulted in a $1.17 billion verdict in favor of the university. The litigation alleged infringement of integrated-circuit patents derived from research at the university completed in 1996. The potential award could reach beyond $3 billion.

**Continuing evolution of TBED policies**

From 1980 forward the expansion of public TBED programs has been unabated. At the state level, aggressive strategies continue to be pursued to attract technology ventures by offering various types of incentives including financial support. One particular focus has been efforts to grow clusters of biotechnology or life science–based industry clusters. By 2001 it was estimated that forty–one of fifty U.S. states had state-level policies focused on the promotion of biotechnology and life sciences alone (Biotechnology Industry Organization 2001).

One of the most noteworthy aspects of state level TBED programs in the United States remains how independent state efforts remain from both federal programs and each other. The absence of federal leadership in early TBED efforts was not seen as a disadvantage at the state and local level. By the 1990s, a consensus among state policy makers was that the federal government should not take a lead in emerging technology-based economic development efforts and instead should play a supporting role to state, local, and regional efforts (Thornburgh 1998). In 1992, the Carnegie Commission on Science, Technology, and Government reaffirmed the decentralized role of states in promoting a national innovation system. The commission did not encourage any greater federal role, instead encouraging states to work together to establish an interstate compact identifying the “policies [that] work best in a decentralized and variegated nation” (United States President’s Council of Advisors on Science and Technology 2004).

Into the twenty-first century, the federal role in local economic development efforts remains minimal and legacy efforts have diminished. One of the first federal agencies focused on regional economic development, the Economic Development Administration (EDA) formed in 1965 has been described as a “shell of its former self” (Markusen and Glasmeier 2008; Singerman 2008). That criticism may reflect a transition period for federal involvement in local economic development. Ongoing programs at the federal level focus increasingly on entrepreneurial programs including greater incentives for collaboration with research universities. The Small Business Administration’s Small Business Innovation Research (SBIR) program, first authorized in 1982, continues with an allocation of over $1 billion in federal funds in 2010. A complementary Small Business Technology Transfer (SBTP) program coordinates with eleven different federal departments and agencies. The National Science Foundation’s Partnerships for Innovation competitive grant program fosters collaboration between academia, government,
and the private sector. The EDA also supports an Advanced Technology Education program and the Industry–University Cooperative Research Partnership program promoting collaboration with technical colleges. The Department of Commerce runs federal innovation programs such as the Manufacturing Extension Program (MEP) designed to leverage existing resources from government, business, or academic institutions. Other ongoing cooperative efforts between federal and state agencies include the National Association of State Development Agencies, the State Science and Technology Institute (SSTI), the National Association of Manufacturers, and various universities and community colleges (Schacht 2011).

American federalism was once described by U.S. Supreme Court Justice Louis Brandeis as implementing “laboratories of democracy.” The phrase has come to epitomize the execution of state and local economic development policies in the United States (Osborne 1988). This independence has fostered continuous change in the types of programs used to promote economic growth. Similarly, state TBED programs continue to evolve new tools for advancing their goals. One of the more creative funding mechanisms for state TBED programs resulted from the 1998 Tobacco Master Settlement Agreement (MSA), a consent decree between forty-six state attorney generals and the four largest tobacco companies operating in the United States. The agreement provided funding as redress for tobacco related illnesses and health care costs incurred by the states. While the uses of tobacco revenues varied across the states, many dedicated the new funding directly into TBED initiatives. The state of Pennsylvania, in particular, used the money to create several dedicated “Life Science Greenhouses” promoting biotechnology focused research and development in collaboration with local universities and corporations.

TBED efforts are not limited to any one technology and have adapted both their industry and geographic focus. In Pennsylvania, new TBED efforts include the Pennsylvania Initiative for Nanotechnology, which began in 2005 (Sá et al. 2008). TBED efforts have also expanded into local programs. Through the 1990s, TBED efforts devolved further, becoming central to programs limited to specific metropolitan areas or even smaller areas. These efforts put even greater emphasis on the role of research-based universities in regional economies. Universities in particular are key to hiring “stars” in targeted research fields that have been shown to be critical to attracting federal research funding, increasing corporate sponsored research and promoting state initiatives that leverage both corporate and federal funds (Innovation Associates 2005). As a result, these efforts took on new priorities including the attraction and retention of the professional workforce seen as crucial to technology development.

Local public sector TBED programs continue to expand (State Science and Technology Institute 2012). TBED efforts have been more and more devolving to local efforts as cities and counties also attempt to implement TBED programs focused on more specific geographic areas, some programs even designed to benefit specific neighborhoods within municipalities. Examples of programs being implemented at the local level include direct grants offered by the St. Louis Arch Grants program to promote startup companies in the St. Louis metropolitan area. In the Wake County/Research Triangle Park region of North Carolina, $1 million set-aside for attracting workers into key advanced technology industry clusters was ongoing in 2013.

Older tools of economic development policy are being repurposed to support TBED efforts at the local level. Tax Increment Financing (TIF), a widely used tool to provide public financing of local development efforts, use anticipated tax revenue to subsidize investment in specific projects. Typically, development bonds are issued by a public entity to raise money for these projects. The bonds themselves are guaranteed by the higher property tax revenues anticipated to be generated once the project is completed. Typically used to finance construction projects, recent use of TIFs have been more focused on TBED focused projects. In Chicago a 2012 TIF provided $3.7 million to support a biotech lab for a company that tests pharmaceutical
A new innovation for the Chicago project is a formal profit-sharing arrangement between the company and the City of Chicago, once certain profit thresholds are met. In effect, the TIF investment has been described as venture capital financing, with the City of Chicago as the investor (Wang 2012).

Conclusions

Public efforts targeting technology-based industries to foster regional economic development have not been limited to the U.S. However, U.S. TBED efforts are distinguished by the scale of sub-national competition that defines them. Much like what was happening in the U.S., Japan’s Ministry of International Trade and Industry (MITI) proposed a “technopolis” program in the early 1980s designating fourteen cities for focused investment (Glasmeier 1988). The efforts were intended to spark economic growth in less developed regions. Also like efforts in the U.S., the program was designed to take advantage of existing concentrations of university-based research and development. While the program was designed to have a larger degree of local autonomy than was typical of other economic policies in Japan, it still was far more centralized than the emerging TBED efforts across the U.S. (Bass 1998). In the U.S., state and local economic development efforts are definitively not driven by top-down mandates, and have broad independence from federal efforts, often operating in direct competition with each other.

Competition and change will undoubtedly continue to be core characteristics of economic development policies at the state and local level in the United States. Factors impacting regional economic competitiveness are less and less tied to particular regions. The result has been a magnified interest in promoting industry clusters based on advanced technology firms. The public sector continues to search for new mechanisms to incentivize technology investment. Often the most innovative approaches have evolved first at the state and local level, only to be adopted by federal programs.7

TBED policy has also expanded with greater emphasis on human capital formation, attraction, and retention. The earliest TBED programs at the University of Arizona and in North Carolina both were spurred by shortages of workers needed by advanced technology industries. These shortages are likely to be exacerbated into the future. This will likely force further evolution of TBED efforts to promote workforce skills and expanded worker attraction policies. These new priorities are consistent with increasing research documenting the important role of “star scientists” in catalyzing research activities (Zucker and Darby 2006; Tripple and Maier 2011). Where competition once focused more on bringing financial capital into regions, those goals are now often secondary to strengthening human capital, particularly when the goal is attracting advanced technology industries.

Early TBED efforts in the United States were catalyzed in part by state efforts to respond to rapid declines in the manufacturing sector. The legacy of those early TBED efforts in the American “Rust Belt” continues. In many ways TBED programs have come full circle with new efforts again focused on promoting manufacturing industries in formerly manufacturing-centric regions. Often the focus remains on manufacturing industries, though most successful manufacturing firms have been forced to adopt technology on par with the most advanced technology firms. In 2012 a $30 million grant was made to promote manufacturing-based enterprise development at the National Additive Manufacturing Innovation Institute. The institute was located in the TechBelt Initiative region spanning Cleveland, Ohio; Youngstown, Ohio; and Pittsburgh, Pennsylvania, regions once considered the core of the American Rust Belt (Bagley 2012). Additive manufacturing includes the growing application of three dimensional printing in the production process for rapid prototyping and other applications. The one project brought
together federal funding with state and economic development agencies to work with universities in promoting an emerging technology. Where such technology-focused public–private partnerships were once considered novel, they have long since become routine.

Notes
1 Plosila himself spent eight years working in the administration of Richard Thornburg, governor of Pennsylvania 1979–1987, serving first as a policy advisor and later as the state’s Secretary of Commerce and Industry. Osborne (1987) has described Plosila’s seminal role in changing the economic development paradigm: “Plosila dreamed up 90 percent of Thornburg’s economic development initiatives.”
2 For a compilation of the interdisciplinary debates surrounding the impact of Bayh-Dole legislation see McManis and Noh (2011).
3 Whether Salk and his sponsors, the University of Pittsburgh and the National Foundation for Infantile Paralysis, wanted to patent the vaccine remains a matter of debate. Smith (1990) notes that the institutions at least analyzed the potential for patenting the vaccine and concluded it could not be patented.
4 Berman provides a longer list of UIRCs that came into existence in both the 1970s and 1980s.
5 The final disposition of the case was ongoing in early 2013, but the initial jury verdict recommended the $1.17 amount which was affirmed by the judge early in 2013. Appeals of the case were expected. For more see Bloomberg News: “Marvell to Seek to Void $1.17 Billion Patent Verdict,” December 27, 2012.
6 The use of TIFs in TBED efforts is not entirely new. In 1983 the City of Pittsburgh began a multi-decade effort to redevelop the former LTV steel works on 48 acres near downtown Pittsburgh. A $7.5 million TIF was used to supplement state and local funding to redevelop the site into the Pittsburgh Technology Center, intended to be an incubator of technology-based firms. Funding for the site brought together private sector investment and at least four different public funders, including the local water and sewer authority (Urban Redevelopment Authority, Western Pennsylvania Brownfields Center).

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