Building State Economies by Promoting University-Industry Technology Transfer

By

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FOREWORD

SUMMARY

Technology-based companies are accounting for the majority of regional and state economic growth in the "new economy," and these companies are partnering with research universities for talented people, new knowledge, and innovative technology. Nationally, universities have significantly increased the volume of their research and technology transfers in just a few decades. Universities can play a major role in economic development, and university-industry technology transfer can be a stimulant, precursor, or complement to building a high-skills, high-wage state economy. However, newly trained graduates, licensed technologies, and commercialization opportunities could migrate to states with preexisting assets in research and development-intensive industry. Consequently, states need to focus on the "economic geography" of technology transfer and craft economic development strategies that are technology-focused.

During a thirty-year period, universities have increased the volume of their research nearly ten-fold, and the volume of their formal technology transfer through patenting and licensing has more than doubled in the past six years.[1] The incorporation of academic science into new products and processes is increasing, particularly in fields such as biotechnology and medicine. Not all states are appropriating the benefits of this new information economy. There is persuasive evidence that people and technology are migrating to states with strong research and development (R&D) bases.

For university-industry technology transfer to thrive, it must rest on a foundation of effective university-industry research partnerships, appropriate staffing, flexible policies, and a supportive culture and mission orientation. For technology transfer to have a positive impact on state and local development, it must be oriented toward fostering state-based, university-industry R&D partnerships and licensing arrangements and toward commercialization through local start-up companies.

To take advantage of and promote technology transfer, states must understand how the process works and how it works most effectively. They must then develop strategies to increase the scope and impacts of technology transfer. States can:

- encourage university-industry partnerships involving state-based companies, particularly through funding programs.
- invest in entrepreneurial support organizations, such as incubators, that are linked to universities;
- enable private-sector investment in new technologies and technology-based companies, for example, by changing tax laws and increasing the availability of capital;
- remove legal barriers to university-industry technology transfer, including ethics and procurement laws that impede commercialization through start-ups;
- champion the role of universities in economic development by communicating this message in speeches and involving industry leaders in economic development planning;
- attend to human resource and quality-of-life issues that are important to technology-based companies and workers, such as education, recreation, and the environment; and
- monitor federal programs and policies affecting technology transfer.

States will face several challenges in promoting university-industry technology transfer to build state economies. Most critical technology transfer activities occur deep inside universities and are not very amenable to the usual state policy and program levers. Research universities have a well-developed tradition of self-governance and academic freedom, and they will bristle at "external pressure." In many institutions, administrators and faculty are divided on the desirability of the university playing an active

role in economic development. The most formidable challenge for states is mastering the economic geography of technology transfer so the high-quality jobs and fast-growing companies it fosters benefit state citizens.

WHAT THE NEW ECONOMIC ENVIRONMENT LOOKS LIKE

Why should Governors care about university-industry technology transfer? Until recently, states seldom recognized state universities as major assets in economic development, aside from these institutions' historic role in workforce preparation and in the mostly localized impacts of their spending. However, several trends are spurring policymakers to rethink the role of universities in building state economies:

- knowledge and new technology are driving a new global economy;
- university science and new knowledge is increasingly involved in this new global economy; and
- university-industry technology transfer is giving birth to new industries and products.

Not all states are positioned to realize the benefits from the new global economy, and people and technology are migrating to states with preexisting assets in research and development-intensive industry.

THE KNOWLEDGE ECONOMY

Increasingly, R&D-intensive firms that are exploiting new knowledge and technologies are leading the transformation of U.S. businesses. The significant role being played by the computer and information technology industries are particularly noteworthy, though there are comparable developments in biotechnology and medicine. Looking closely at the recent phenomenal growth of the stock market, a large fraction is accounted for by companies that are primarily selling technology-based products or are embedding new technologies (e.g., information systems) in their delivery of traditional services and products. During the second quarter of 1999, more than 80 percent of corporate profits "came from companies in New Economy industries."[2] National and industry trends also translate to the state and local levels. A recent analysis estimates that high-technology performance explains 60 percent of the differential in job growth among metropolitan areas.[3]

Another feature of the emerging economy is globalization, often based on advances in underlying knowledge. This includes the development of new technologies, the movement of people and ideas, and the international exploitation of intellectual property through patenting and licensing. During the past decade, technology-based companies such as pharmaceuticals and chemicals have shown the most dramatic increases in international market share.[4]

THE GROWTH AND IMPORTANCE OF UNIVERSITY SCIENCE

Prior to World War II, the scope of university-based research was quite modest.[5] As recently as the late 1930s, no more than twenty universities performed any significant amount of funded R&D, and most research money came from a few companies and foundations. Federal agency funding was virtually nonexistent by today's standards, though the die was cast for a significant post-war expansion. Toward the end of World War II, the Carnegie Institution's Vannevar Bush called for a massive, ongoing federal investment in the development and application of science in his 1945 report to President Franklin D. Roosevelt, *Science: the Endless Frontier.*[6]

Between 1960 and 1997, expenditures for academic research rose from $2.8 billion to $21.1 billion (measured in constant dollars). During this period, the proportion paid for by the federal government never went lower than 58 percent, reaching as high as 73.5 percent in 1966.[7]

Federal funding of academic R&D is confined to a few agencies. From 1971 to 1997, the combined R&D spending of the National Institutes of Health (NIH) and the National Science Foundation (NSF) increased from 52.9 percent to 71.3 percent of total agency funding of universities, and the NIH share alone rose to 56.5 percent of the total during this period.[8] The U.S. Department of Defense is the third most prominent funder of academic R&D, followed by the National Aeronautics and Space Administration, U.S. Department of Energy, and U.S. Department of Agriculture.

In addition to federal spending on academic research, state appropriations for colleges and universities totaled $41.9 billion in 1993–1994. Parents and students spent another $48.6 billion on tuition at public and private institutions.[9]

Along with the development of this massive science resource, there has been an increase in the scope of R&D interactions between universities and industry. Between 1965 and 1979, the industry share of total academic R&D support hovered between 2.4 percent and 3.7 percent and averaged just less than 3 percent. By 1981, the first full year after the passage of Bayh-Dole, landmark technology transfer legislation, this share increased to 4.3 percent, and it remained around 7 percent throughout the 1990s.[10]

Formal transfer of university intellectual property through patenting and licensing also began to accelerate during the 1980s. This paralleled another trend of states playing a more significant role in fostering university-industry linkages through partnership programs. Most of the state technology programs currently in operation date to this period, and most of these programs aim to promote university-industry ties.[11]

THE GROWTH AND IMPACTS OF FORMAL TECHNOLOGY TRANSFER

At an aggregate level, there is no question that a vigorous university research base contributes significantly to economic growth. Often this occurs through people-embedded knowledge transfer as new graduates move into the workforce. It also occurs in many informal ways, such as faculty consulting, seminars, publications, and conferences, as well as through formal technology transfer. Formal technology transfer involves the licensing of legally protected intellectual property.

Formal university-industry technology transfer took off after the passage of Bayh-Dole. By the late 1980s, virtually every major research university had its own professionally staffed technology transfer office. Based on national statistics, the growth in all measures of formal technology transfer performance has been remarkable, given that it started from essentially nothing in 1980.[12] During fiscal 1997, universities responding to the Association of University Technology Managers (AUTM) survey reported $698.5 million in gross income from 6,974 licenses and options yielding income. They also reported a 21-percent increase in new licenses and options from the previous year.

Nonetheless, there are still great disparities among institutions in performance, and less than 50 percent of universities realize enough royalty revenue to cover the costs of running their technology transfer office.[13] These disparities seem to be a function of some institutions getting into the game later and trying to play catch-up.[14]

There is a growing recognition that what happens in the university affects industry growth and product development. In fiscal 1997, 333 start-up companies, at least partially based on university technology, were formed, an increase of 34 percent from the previous year. Moreover, a recent national analysis of predictors of metropolitan growth cited technology as the primary factor explaining differences among metropolitan areas, and "research centers and institutions are undisputedly the most important factor in incubating high-tech industries."[15]

Economic analyses confirm that especially in some industries, such as pharmaceuticals, the proportion of new products with a direct link to university research is quite high.[16] Determining estimates of broader economic impact, such as by examining sales revenue from products that involve licensed technology is more difficult; these data are typically proprietary and are not available on a license-by-license basis across universities. However, various analyses have attempted to reason backward by applying a multiplier to aggregate royalties.[17] Using this approach, it has been estimated that in fiscal 1997, formal technology transfer accounted for $24.5 billion in product sales and another $4.2 billion in preproduction investments.

Unfortunately, there are no good estimates on the economic impact of informal technology transfer (i.e., situations in which no intellectual property, in a legal sense, is developed or transacted). For example, quantitative data on the scope or economic impacts of consulting are rare, though both are probably considerable.

THE ECONOMIC GEOGRAPHY OF TECHNOLOGY TRANSFER

If university research is related to industrial growth, what can be said about the economic geography of these public and private investments? Do economic benefits accrue where these investments are made? Of course, for states, the optimal outcome would be if a large fraction of graduates, new knowledge, and new technologies from their state-based universities would "stick to the ribs" of state-based companies. Unfortunately, there are good reasons why this is not the case nationwide.

The United States entered the relatively recent era of technology-intensive economic growth with gross disparities among states in their stock of R&D-intensive industry. One telling statistic is the proportion of gross state product (GSP) that is accounted for by industrial R&D. GSP ranges widely, from highs between 3 percent and 5 percent to lows of 1 percent or less.[18] A state's chances to assimilate the output of its university system would higher if the state started out more technology-intensive.

Technology-based companies, and the highly skilled people who work in them, are more "footloose" " than in other sectors and also locate in a community for qualitatively different reasons than do traditional companies and workers. For example, in a recent study of companies founded by Massachusetts Institute of Technology (MIT) graduates, the primary criteria for company location were, in order: "quality of life," "access to skilled professionals," and "proximity to principal markets."[19] Some states may be at a relative disadvantage in attracting and retaining highly skilled people, new technologies, and fast-growth companies. There is evidence of a considerable imbalance across states in the interstate migration of highly skilled people, commonly referred to as the "brain drain." In a fifty-state analysis, the Southern Technology Council found that some states enjoyed a highly significant and positive balance of exchange, both retaining their own recent science and engineering graduates and attracting those from other states.[20]

This migration of people is paralleled by a migration of technology transfer deals. Other studies by the Southern Technology Council indicate that depending on the state or institution, between 80 percent and 90 percent of new university-developed technology in the South is licensed to companies outside the state or region where it was originally developed, and these patterns are relatively stable over time.[21] Unless there is perfect reciprocity in the geography of these exchanges, then many states are gradually bleeding away their technology stock.

These patterns related to the migration of people and migration of technology transfer deals also seem to hold at the community level. A study of 125 metropolitan areas found that the amount of university research was related to industrial R&D and product innovation. The strength of this relationship varied widely and seemed to be a function of the "concentration of high-technology production, presence of business services employment, and relative importance of small firms in the metropolitan area economy."[22] Communities and states seem to do better in terms of realizing the benefits of universities in the knowledge economy if they have already achieved some threshold level of development of their own technology-based industries.

WHAT STATES NEED TO KNOW ABOUT TECHNOLOGY TRANSFER

States interested in promoting the transfer of technology to build a high-skills, high-wage state economy must first understand how university-industry technology works. The term "technology transfer" is incomplete. It is better to think of formal technology transfer as part of a more complex innovation process. This innovation process includes not only formal technology transfer procedures, but also information exchange and industry partnership mechanisms. State policy must address formal technology transfer (e.g., patenting and licensing and the associated law, policies, and procedures), and the precursors and accompaniments to make the technology transfer work more effectively (e.g., robust university-industry partnerships, cultural rewards, and incentives).

STEPS IN FORMAL TECHNOLOGY TRANSFER

The formal transfer of new, innovative technology from university to industry involves three steps:
• legally disclosing and protecting the invention;
• choosing a commercialization path; and
• implementing the commercialization path.

Legally Disclosing and Protecting the Invention. After the inventive act occurs, the first step for the faculty inventor is to file an invention disclosure with his or her technology transfer office.[23] In this filing, the invention is described, evidence for the date of the invention is provided, the funding source is identified, and the inventors are named. Laboratory notebooks, data, and drawings can be attached as evidence. An invention disclosure begins to establish a legal right to the invention. Under U.S. law, title to a faculty invention developed under federal government sponsorship is owned by the university that employs the faculty inventor, though the inventor shares the proceeds from any technology transfer deals.

After receiving the invention disclosure, the technology transfer office must quickly decide whether the invention can be legally protected and whether the university should spend resources to do so. Typically, the office will conduct patent searches and preliminary market analyses. If the office determines that the invention lacks commercial potential, the university may turn the title to the invention back to the inventor, who may pursue its protection and commercialization with his or her own time and money.

If the technology transfer office determines that the invention can be legally protected and that the university should spend resources to do so, the university will move legally to protect the invention, often by applying for one or more patents. An initial, low-cost step is to file a provisional patent application, which must be followed by a formal application within a year.

Under U.S. law, an invention can be patented so long as it is a process, a machine, an article of manufacture, or a composition of matter.[24] An invention must also satisfy the criteria of having novelty and never having been disclosed or made or sold in commerce; being nonobvious to a person "skilled in the art"; and having utility. Sometimes professors may prematurely disclose an invention prior to pursuing protection because of the university norm of free dissemination of knowledge.[25]

Securing a patent involves a complex, often lengthy and expensive, legal interchange with the U.S. Patent and Trademark Office and is best handled by specialized patent attorneys.[26] Once this interchange is successfully consummated, the university will have one or more patents, with various "claims" upheld. Patents are valid for twenty years from the date of formal application, not the date of provisional application.

Another form of protecting inventions is the copyright, which protects the expression of an idea through authorship. Although copyrights traditionally have been used to protect books, music, and artwork, they also have been extremely important in protecting software. Software has been legally construed as a "writing," though the use of patent protection for software is growing. Other types of intellectual property, such as a distinctive name that can be used in commerce, may be protected through trademark law. Some inventions may be protected through a mix of patents, copyrights, and trademarks; software is an excellent example.

Choosing a Commercialization Path. Once legal protection of the invention is obtained, the technology transfer office and the faculty inventor must decide on a commercialization path. The basic transaction involves licensing the intellectual property (e.g., the patent) to a business, but there are several options. For example, are there multiple licenses? What is the mix of exclusive licenses and nonexclusive licenses?

The commercialization path has very important implications for a state's economic development. Critical decisions are whether to license the technology to an established, often large national company or commercialize the technology through a new or start-up company that is apt to be based locally.

A "straight licensing" path will most likely to be used when the invention is an incremental improvement to a well-established product, when an established corporate structure is an advantage (e.g., mass marketing), and when development and production costs could be quite large. Straight licensing is a tried-and-true approach and demands less investment of the university's time and money. However, there are limits on the opportunity for gain. Royalties and research funds are typical returns, and these are likely to be modest.

From the perspective of state government, the geography of a straight licensing deal is important. If the licensee company is from another state, in-state economic outcomes derived from advanced development, manufacturing, marketing, and sales will be negligible. Universities should not be faulted for using this technology transfer path. Fiscal exigencies, such as the attraction of sure royalty revenues, and general risk evasiveness are powerful institutional motivators.

For the institution, technology transfer through a start-up company is inevitably culture-perturbing and staff-intensive, and it usually defers financial returns until an uncertain future time. It also usually stretches existing state policies and sometimes state laws. For example, start-ups are frequently cash-poor, and the university will often need to take an equity share in the company in lieu of front-end payments. For the faculty inventor, being involved in a start-up, even in a nonmanagerial role, demands a temporary or permanent career shift. The start-up approach to technology transfer is also most likely to arouse the ire of other faculty, particularly those not involved with inventions and intellectual property.[27]

Technology transfer through a start-up company can bring rewards to states and communities. Nearly 84 percent of university-linked start-ups set up shop in the state and/or community in which the university is located.[28] This has the potential to anchor the benefits of economic development, at least in the short term.

RAMIFICATIONS OF BAYH-DOLE

Little university-linked technology transfer occurred prior to 1980, when Congress enacted Public Law 96-517, the Bayh-Dole Act.[29] Before Bayh-Dole, the primary funders of university research—federal agencies—had legal title to any inventions derived from that research. However, these federal agencies had a woeful track record of licensing or commercialization. Of interest to universities and faculty, key provisions of the legislation include the following.

- Nonprofit contractors (e.g., universities) can retain title to inventions produced under federal support, with appropriate notification of the federal government.
- Universities can patent and license those inventions.
- Universities must share royalties with inventors and use some of their institutional share to improve research facilities.
- Universities must give small companies and U.S.-based companies first preference as licensees. Any resultant product that will be sold in the United States must be manufactured domestically, though the law includes a waiver of this provision if certain conditions are met.[30]

PRECURSORS TO, AND ACCOMPANIMENTS OF, FORMAL TECHNOLOGY TRANSFER

Formal technology transfer does not generally flourish in universities that lack skills in fostering and managing other types of industry partnerships. For example, many license deals include follow-on consulting arrangements with the faculty inventor and money for academic research. Many licensed faculty inventions evolve from a prior industry-sponsored research project in which the company sponsor has a first right of refusal to negotiate a license. These quick and friendlier deals do not happen if the university is not flexible and adaptive in terms of industry-sponsored research contracts, particularly regarding issues of intellectual property.[31]

Much industry-sponsored research never results in a faculty invention or formal technology transfer but leads to follow-on R&D within the company and subsequent economic value. In 1997 more than $1.5 billion in industry-sponsored university research was conducted, and analyses of patent applications of “prior art” citations indicate that an increasing share—up to 50 percent in pharmaceuticals—is referencing university academic science. U.S. industry inventors are relying more on the U.S. academic science base.[32] However, unless a state has an R&D-intensive industrial sector, the companies with which universities partner will be based elsewhere.

Industry is quite clear about its reasons for partnering with universities, and formal exchange of intellectual property is only one of them. In a study of companies founded by MIT graduates, the respondents were asked why they contacted MIT or other universities.[33] Faculty consulting was cited as the most important reason. This was followed, in order, by professional education, recruiting, joint R&D, and technology licensing. Similar views were expressed in a survey of life science companies.[34]

Companies work with universities in different ways, and many of these activities complement the formal technology transfer function. State and institutional leaders can improve the performance of the formal technology transfer function only if they also encourage a variety of university-industry relationships, hopefully with state-based companies.

WHAT WORKS IN UNIVERSITY-TECHNOLOGY TRANSFER

Technology transfer rests on a strong foundation of university-industry research partnerships. To thrive, a technology transfer office must have appropriate staffing, a clearly articulated mission, a customer-friendly orientation, clear policies and procedures, and a supportive university culture. Other elements critical for success are an entrepreneurial staff, links to business and economic development activities, and access to capital.

Consider the following fact-based but fictional parables.

The Best of Times. Assistant Professor B at Hip State University has been doing research in materials science, supported by federal grants along with some industry money. The findings suggest two real-life applications. One is the processing of dielectric materials for storage batteries; the other is an adhesive with uses in cosmetic surgery. Dr. B files an invention disclosure with his university technology transfer officer, Mr. X, who speedily carries out patentability and market analyses. The analyses confirm the uniqueness and commercial potential of the technology and its applications. The university begins patent applications, which will ultimately yield both U.S. and international patent protection. It also launches a two-pronged technology transfer strategy.

The university approaches two battery manufacturers in the state, both with ties to Dr. B's program, as possible licensees. It eventually licenses the battery application to Alwaysbright, Inc., in exchange for up-front cash, ongoing royalties on product sales, and $1 million in research support for Dr. B. The university's patent costs will also be paid as part of the deal. Product development and manufacturing will be based in Alwaysbright's in-state facilities, resulting in significant employment opportunities.

For the adhesive application, the university determines that the new technology might best be exploited through a start-up company. It agrees to license Dr. B's invention to a newly formed company, GluzRUs, which will involve Dr. B as a scientific consultant and be located in a university-affiliated business incubator. A local entrepreneur is tapped as the chief executive officer. The deal will involve little up-front royalties, though the university will take equity in the company. GluzRUs' development strategy is eased through a federal Small Business Innovation Research grant and $200,000 in applied research funding from a state program.

Five years later, both commercialization approaches are doing well. Based on Dr. B's technology, Alwaysbright launched a new line of high-performance batteries for hand-held tools, electronic appliances, and flashlights. Annual sales this year will top $500 million worldwide. A new local manufacturing plant has been built, employing 200 workers. Annual university royalty payments are in six figures, as is research support for Dr. B's lab. Every year, Alwaysbright hires several graduating students.

After some struggle, GluzRUs has become a $10-million company and left the incubator; it now has twenty-five employees. The transition to second-stage capitalization is eased through an "angel network," a loose-knit group of local venture capital investors. Within two years, GluzRUs will probably organize an initial public offering, at which point the university should realize a handsome gain.

The Least of Times. Dr. H. is a professor of microbiology at Hapless State University. His research interests lie in the bioengineering of commodity crops so they can express and produce useful proteins, such as cancer drugs and industrial enzymes. Dr. H. has early success in expressing an antibody for a virulent gastrointestinal disease from a bioengineered peach he has developed. This development has great potential as an edible vaccine for Third World countries. Dr. H. knows enough to fill out an invention disclosure, having done his postdoctoral work at Hip State University, and sends it to his university's understaffed technology transfer office. Months pass. In the meantime, Dr. H's department is pressuring him to publish his results and urging him to abandon his technology transfer aspirations. (His department chair asserts that universities are "not about profit.") Wrongfully assuming that a prepublication speech will not jeopardize international patent protection, he agrees to present his findings at a regional professional meeting. Dr. H. makes his presentation to a small audience and hands out copies of his overheads. A French scientist asks several incisive questions. One month later, a European company has filed for patent protection in several key international markets for the technology. Dr. H. and his university technology transfer office decide not to challenge the move because of a lack of funds for litigation and the fact that Europe operates under first-to-file rules. Dr. H. also wants to move on to other research interests.

Five years later, a French-German joint venture is marketing Vacco-Peach fruit throughout Africa and is sublicensing root stock to major orchards.[35] State-based peach growers write letters of protest to the Governor and the university president. However, no one can determine the past chain of events because the technology transfer office has gone through two changes in leadership in the past five years, remains understaffed, and has poor case records.

KEY ELEMENTS OF EXEMPLARY PRACTICE

Data on technology transfer performance metrics—typically patents, licenses, and royalties—suggest which universities do well at this activity.[36] Detailed study of these best-in-class institutions, or practice benchmarking, also has yielded a picture of what works in internal policies and procedures.

Appropriate Staffing. A technology transfer office must be staffed appropriately, qualitatively and quantitatively. This means an office, led by a full-time manager, with other professional staff appropriate to the size and disciplinary emphasis of the university research portfolio. Well-staffed offices generally have one full-time-equivalent position for every $15 million to $25 million of research expenditures. Professional staff will usually have advanced degrees in a scientific or engineering discipline and comparable degrees and/or experience in business or law. The role of state government in technology transfer office staffing is limited, unless the state wants to get into the political minefield of the internal budgets of state universities. However, there may be a special, short-term opportunity for states to beef up the technology transfer staff of universities that are late starters. Institutions that try to increase their transfer activities after years of neglect will typically encounter a backlog of demand for services and a commensurate delay in royalty revenues to pay for the additional staff needed to provide those services. States can help by providing short-term (e.g., up to five years) capacity-building support.

Clearly Articulated Mission. The importance of technology transfer should be acknowledged among the goals of the university, and the highest leaders of the institution should champion this message to internal and external audiences. It is probably more persuasive to articulate this mission in terms of applying and disseminating knowledge rather than making money. There is little state governments can do with respect to institutional mission other than use the bully pulpit to communicate that state universities are economic development assets. States would be ill-advised to attempt to pack boards of regents with appointees more supportive of technology transfer.

Customer-Friendly Orientation. Effective technology transfer offices operate with a business mentality and a customer-friendly orientation as well as within a clear but flexible organizational framework. For example, better offices use external patent counsel effectively, often selecting attorneys from several firms with particular areas of expertise, rather than choosing a local attorney with political ties. Similarly, viable technology transfer offices have the flexibility to negotiate without excessive micromanagement, and they treat licensee firms and inventors as respected customers. This includes periodic information outreach, such as involving faculty in workshops about patenting, licensing, and intellectual property.[37] Customer friendliness also pertains to industry-sponsored research, which is often a precursor to, or accompaniment of, formal technology transfer. Most of these issues are internal, institutional management issues and, consequently, are beyond the reach of state government.

Clear Policies and Procedures. Effective technology transfer offices have institutional policies and procedures that enable their work. This includes flexible consulting and conflict-of-interest policies, a clearly stated intellectual property policy that is accessible to faculty, step-by-step procedures on how internal and external customers can work with the office, and clear forms and manuals. AUTM publishes, and continually updates, an excellent and voluminous manual of professional policies and procedures drawn from its member institutions.[38]

Supportive University Culture. Perhaps most important, but least tangible, is the underlying "culture" of the university. Is it supportive of technology transfer and industry partnerships?[39] For example, is industry money considered second class when it comes to faculty tenure evaluation? Are there acknowledgement programs or opportunities for positive media exposure for faculty who are successful in some technology transfer relationship? Is there an oral history in the institution that recounts tales of faculty technology transfer heroics?

OTHER ELEMENTS CRITICAL FOR SUCCESS

If the university becomes involved in start-ups based on its innovative technology, other elements are critical for success.[40]

Entrepreneurial Staff. The staffing of the technology transfer offices will need to be "richer" and include individuals who are experienced in launching a business. Some offices will add an individual who has been personally involved in a successful technology start-up. These deals take more staff time and expertise, particularly in downstream "due diligence" as the new company evolves.

Links to Business and Economic Development Activities. The university will need to align itself with various business and economic development activities, either as an operator or a partner. These activities include technology business incubators, which typically provide lower-cost space and core office services and, most importantly, broker a variety of specialized business expertise (e.g., legal and accounting work).[41] Recent evaluation research indicates that incubators produce a relatively high rate of firm survival, new jobs at a modest per-job public subsidy cost, and firms that tend to remain in their local communities after they "graduate" from a program.[42]

Access to Capital. Access to early-stage financing mechanisms is extremely important for technology start-ups. This includes seed-level investment capital or applied research funding in the form of grants. Universities that are more active and effective in fostering start-ups based on faculty inventions will tend to develop alliances with community-based financing programs. Some universities have redirected some of the institutional share of their royalty income to small internal grants to investigators who are trying to develop a working prototype. Other institutions have become actively involved in managing funded projects and helping companies apply for federal Small Business Innovation Research funding.

Start-ups are a major arena for innovative policies and programs. Interestingly, many universities that are involved in early-stage capitalization, business incubations, and other approaches to nurturing start-ups are doing so in collaboration with state and local economic development organizations and as part of a larger university vision vis-à-vis the industrial community.[43]

WHAT STATES CAN DO TO PROMOTE TECHNOLOGY TRANSFER

If university-industry technology transfer is to have a positive impact on state and local development, it must be oriented toward fostering state-based, industry R&D partnerships and licensing as well as promoting commercialization through local start-ups. However, many university-industry technology transfer actions occur in the bowels of institutions, places that have been relatively immune to state scrutiny or direct policy and program intervention. Research universities fiercely guard their organizational autonomy, particularly when it pertains to an internal staff function such as technology transfer. Consequently, in promoting university-industry technology transfer, states should *not* force change through line-item budgeting of technology transfer activities, which is likely to enrage the larger academic community; force change by intruding into the selection processes for deans and other high-level officials to secure candidates friendly to technology transfer; and criticize university officials at annual appropriation hearings on their failure to contribute to the local and state economies.

Yet states can take several steps to promote university-industry technology transfer in the interest of building state economies. They can:

- encourage university-technology partnerships;
- invest in entrepreneurial support organizations;
- enable private-sector investment in new technologies and technology-based companies;
- remove legal barriers to university-industry technology transfer;
- champion the role of universities in economic development;
- attend to human resource and quality-of-life issues; and
- monitor federal policies and programs affecting technology transfer.

ENCOURAGE UNIVERSITY-INDUSTRY R&D PARTNERSHIPS

Formal technology transfer (e.g., patenting and licensing) rarely works well in institutions unless other types of interactions with industry are robust. These include industry sponsorship of academic research as well as informal relationships, such as consulting, conferences, student internships, and personnel exchanges.

Support University-Industry Research-Funding Programs. University-industry research-funding programs exist in several states and have been successful in, for example, Arkansas, Georgia, New Jersey, Ohio, Oklahoma, and Pennsylvania. A common approach is to support projects that include a state-based company and a faculty researcher. State money is typically matched by industry in cash and/or in-kind, though some programs also support basic research in which direct industry involvement is minimal. Generally, there are rules or expectations that follow-on commercialization will occur within the state. Such programs also help shift the culture of the university and gradually make industry-funded research projects almost as valued as those funded by federal agencies. They need to be large enough to attract the attention of academics, because it is often easier for professors to submit good ideas to traditional federal funding agencies without having to nurture a working relationship with a company. State programs differ on the extent to which they broadly or narrowly target specific industries or technologies. These relationships are excellent precursors to formal technology transfer and make faculty more sensitive to the needs and priorities of industry.

Some of the more recently established efforts are quite large and have made novel use of windfall money. For example, as an investment strategy for its tobacco settlement money, Michigan is establishing a Health and Aging Research and Development Initiative. During a twenty-year period, $50 million will be allocated annually to life science research performed in the state's research universities. Of this total, $20 million will be allocated for basic science, $25 million for applied research and industry collaboration, and $5 million for technology commercialization support.

Maintain R&D Facilities. State higher education budgets often neglect the nonbuilding capital needs of a first-class academic R&D enterprise. In many states, university laboratories are poorly maintained, have out-of-date equipment, and are not on a par with those in technology-intensive companies. To enable industry partnering and technology transfer, capital needs must be given a higher priority in education budgets. For example, the New York legislature recently approved the creation of the New York Office of Science, Technology, and Academic Research (NYSTAR). Among its responsibilities, NYSTAR will manage a capital facilities program valued at more than $95 million per year. The Georgia Research Alliance is investing heavily in facilities at the Advanced Biotechnology Core (ABC), located at Georgia State University, which will be available for academic and industrial users.

Leverage Proximity. Getting faculty members and their industry counterparts to speak to one another and work in close physical proximity often produces unexpected technological partnering. A common economic development strategy is to develop research parks adjacent to universities that include academic and industry tenants. Some of the older and larger parks (e.g., in Madison, Wisconsin, and Research Triangle Park, North Carolina) have been very successful in fostering informal partnering relationships as well as in changing the culture of the university.

An innovative feature of newer research parks is to mix academics and industry types in the same building. The Centennial Campus at North Carolina State University is an excellent example. It is organized into buildings that represent areas of technology, and each building has academic and industry tenants. The potential for interaction in the halls, luncheon areas, and parking lot is tremendous. Recognizing this potential and the university's quality telecommunications research, Lucent Technologies recently decided to move 500 engineers and scientists to the Centennial Campus.[44]

INVEST IN ENTREPRENEURIAL SUPPORT ORGANIZATIONS

To realize a greater regional impact from technology transfer, universities need to be more active and adept in local start-ups. Unfortunately, start-up companies often require a great deal of hand-holding early in their history. This assistance is beyond the capacity of most universities, so it often falls to local entrepreneurial support organizations to help start-ups. These organizations include small business development centers, mentoring programs of local chambers of commerce, private business service companies, and investors. Technology-based business incubators are particularly effective entrepreneurial support organizations.

Business incubators "accelerate the successful development of entrepreneurial companies through an array of business support resources and services, developed or orchestrated by incubator management, and offered both in the incubator and through its network of contacts."[45] They also provide space at modest cost. Moreover, in the case of new, technology-based companies, they offer access to specialized services, such as intellectual property management, regulatory compliance advice, and R&D partnership brokering. An incubator is a highly effective partner for a university getting involved in start-up companies.

Some universities have experienced great success as a result of their partnerships with, or operation of, technology-based business incubators. Rensselaer Polytechnic Institute (RPI) has a very active incubator that is contiguous with the campus. RPI's program has served more than 120 entrepreneurial companies, two-thirds of which have spun out of the university. The University of Alabama-Birmingham (UAB) has expanded its incubator facility. In recent years, UAB has been a benchmark institution in the South in terms of start-ups, many emanating from its medical complex. Iowa State University has an incubator in its research park; the incubator and research park have contributed to the university's excellent technology transfer outcomes in royalties and start-ups. The Maryland Bioprocessing Center is adjacent to Johns Hopkins University.

Some states have adopted an incubation program as a major component of their state technology strategy. For example, the Kansas Technology Enterprise Corporation has a network of innovation and commercialization corporations that are collocated with universities around the state. A network of technology-oriented incubators also is a component of the Ben Franklin program in Pennsylvania.

Most university research is in the life sciences, so it is notable that a recent report of the Biotechnology Industry Organization (BIO) made only one "programmatic" (i.e., not dealing with capitalization) recommendation among its 1999 state legislative priorities. BIO wants to encourage "all states to assist biotechnology firms access incubators and/or shared manufacture facilities."[46]

ENABLE PRIVATE-SECTOR INVESTMENT IN NEW TECHNOLOGIES AND TECHNOLOGY-BASED COMPANIES

A large proportion of university technology finds its way to new or small companies, and these enterprises are typically undercapitalized. Consequently, technology-oriented investment capital is critical to growing university-industry technology transfer. However, states or other government organizations are not the best investment decisionmakers. Moreover, the supply of early-stage venture capital is not evenly distributed across the nation. State governments can take several actions to enhance the supply of capital or provide incentives for others to do so.

Change Tax Laws. There are several tax options, and a recent report from BIO is a good source of information.[47] For example, states can develop R&D tax credits emulating the federal credit, with carryforward provisions, because many technology-based start-ups have little revenue to tax in their early years. BIO recommends fifteen-year, net-operating-loss provisions as an offset against future taxable income, as well as tax loss transferability to other taxpayers in exchange for funds to be used for R&D. In addition, an investment tax credit could be deployed for the purchase of research equipment, as well as a sales or use tax exemption on R&D purchases.

Increase the Availability of Capital. Several states have taken action to foster venture funds by providing seed funding coupled with private-sector investment partners and management. In addition, a few states, including California and Massachusetts, have relaxed provisions governing state pension funds to enable investments in the state's technology companies. An incentive approach is to selectively reduce capital gains taxes when the investments involve state-based ventures in technology enterprises. Recently, North Carolina State University, in partnership with the North Carolina Technological Development Authority, established a $10-million seed-stage venture fund, Centennial Venture Partners Inc., to help commercialize university technologies.

REMOVE LEGAL BARRIERS TO UNIVERSITY-INDUSTRY TECHNOLOGY TRANSFER

To best exploit their technology assets, universities need to be involved in a variety of intellectual property deals; some of these deals will strain the boundaries of what has previously been considered normal practice. For example, professors and/or universities may want or need to take equity positions in new companies. If faculty members are considered state employees and universities are considered state agencies, such relationships may be explicitly or implicitly prohibited by law. It may also improve the general industry partnering culture of the university if faculty can easily consult with companies and engage in industry-sponsored research. Unfortunately, in several states, there is a residue of well-intentioned statute and constitutional law that creates barriers to formal and informal technology transfer. Many of these provisions are an outgrowth of populist traditions and ethics laws intended to prevent private companies from unduly gaining advantages from public expenditures. Two examples are instructive.

In 1998, with leadership provided by Oklahoma Governor Frank Keating, several state legislators, and the business community, a statewide vote significantly changed language in the state constitution. Stakeholders supporting the changes included the Oklahoma Academy for State Goals, the Oklahoma City Chamber of Commerce, and the state chamber of commerce. The two initiatives—State Questions 680 and 681—removed legal prohibitions against state employees (e.g., faculty members at public universities) and state institutions participating in start-up companies based on faculty inventions and in using campus facilities to foster these activities. These constitutional changes were also anticipated in the Technology

Transfer Act of 1998, which the legislature passed prior to the statewide referendum. Based, in part, the "brain drain" issue and the need for better-paying jobs in the state, 73 percent of voters said "yes" to the two questions. Subsequent to these legal changes, the Oklahoma State Regents for Higher Education drafted a new technology transfer policy that includes a model policy "to be adapted by the governing board of each institution active in technology transfer or the commercial development of knowledge."[48] All of the research-intensive institutions in the state have made major changes in the staffing and mission support of technology transfer.

Similarly, in Mississippi during the 1980s, very little technology transfer was occurring in the state's research universities. Technology transfer was blocked by a state ethics commission that tended to discourage any activity in which there was a potential conflict of interest. Faculty were effectively prohibited from having any financial interest in companies commercializing university technology, which precluded their involvement in start-ups. As state agencies, state universities were also prohibited from holding an equity interest in companies. State lawmakers, with the assistance of a university task force, drafted the Mississippi University Research Authority Act. This legislation places university-related conflict-of-interest situations under the purview of a new agency, the Mississippi University Research Authority (MURA). Faculty members disclose potential conflicts to MURA, which reviews each case and has the authority to permit the faculty-company relationship. Under the act, universities can also hold equity positions in companies commercializing faculty inventions.

The challenge for state executive and legislative leaders is to identify barriers to fostering technology-based economic development and leveraging the assets of state-based universities. They especially need to examine ethics and procurement laws that restrict universities' ability to commercialize technology through start-ups.

CHAMPION THE ROLE OF UNIVERSITIES IN ECONOMIC DEVELOPMENT

In championing the economic development mission, it is important to focus on the legal and procedural aspects of university-industry technology transfer as well as the corresponding state program and policy options that could increase the scope and impacts of technology transfer. Moreover, the bully pulpit and organizational innovations can be used to focus the university's attention on economic development. Often the informal organizational culture and incentive systems of the university are at odds with a robust effort in technology transfer and commercialization. Yet Governors and other elected officials can, over time, have an impact on these internal subtleties. If a prominent and repetitive theme of speeches or other forms of advocacy focuses on the importance of the university in state economic development, university leaders will eventually get the message. Governors can also convene the leaders of state-based institutions and use them in various advisory or symbolic roles. As states bring university leaders into the fold of economic development planning and program design, the new roles and responsibilities will migrate into these leaders' stewardship of the internal technology transfer function.

The importance of championing has relevance to another challenge confronting Governors: How can the assets of state-based private universities be leveraged? Most states are home to top-100 private research universities; however, because of their corporate status, these institutions are often beyond the reach of state law and policies. Nonetheless, policymakers must find ways to champion the important role that these institutions can play in state economic development. In addition, state technology programs (e.g., applied research support) should be crafted so that money can flow to such institutions. The leaders of private universities should also be brought into the economic development planning and program design processes along with their publicly funded peers. States need to realize that some resistance within the university system is likely, particularly from disciplines not traditionally associated with business.

ATTEND TO HUMAN RESOURCE AND QUALITY-OF-LIFE ISSUES

Technology-based economic development is led by talented, entrepreneurial people who build products and services around knowledge and innovation. In contrast to previous economic eras, traditional economic development tools such as tax and regulatory relief are less persuasive to these new economy leaders. These leaders also are quite footloose and, as interstate migration data attests, they move themselves and their companies to more attractive places. Site attractiveness is increasingly being defined in terms of access to highly skilled people, great science, and a high quality of life. The emerging "tech cities" not only have the requisite intellectual and human capital and a friendly business environment, but also are great places to live.[49] They are communities where elementary, secondary, and postsecondary education is good, the environment is being protected, crime is lower, and cultural and recreation opportunities abound. Ironically, as Governors become more interested in building high-technology economies, the "old" agenda of social betterment is reemerging.

MONITOR FEDERAL PROGRAMS AND POLICIES AFFECTING TECHNOLOGY TRANSFER

State monitoring of the federal research-funding agencies demands an understanding of the federal policy and program context. The primary federal agency supporters of academic basic and applied research have been NIH, NSF, and a few others. Unfortunately, there is still no consistent and coordinated interagency strategy or structure to address university technology transfer and commercialization, particularly its relationship to state economic development. Perhaps the only exception is the congressionally mandated Small Business Innovation Research (SBIR) program, which has often served as a backdoor, early capitalization resource for university-linked small companies. However, most SBIR grants have gone to companies in a handful of states, particularly California and Massachusetts, that are already R&D-intensive.

Although the federal science establishment will take some credit for the economic largesse bestowed by the technology-intensive new economy, the intellectual argument is primarily in terms of trickle-down. For example, over the years, NSF has taken great pains to describe its programs as supporting fundamental basic science that might be of interest to industry. NIH has been similarly circumspect about its extramural funding programs that, while intended to solve the scientific puzzles surrounding important diseases, are careful about directly encouraging commercialization or technology transfer. However, in its intramural research program, NIH has been the leading federal agency on technology transfer and licenses from its in-house investigators.

One of the few exceptions to this trend has been some of the Experimental Program to Stimulate Competitive Research (EPSCoR) programming located in NSF and other research-funding agencies. EPSCoR was established more than twenty years ago to address the basic research funding gap across states through the various state research strategy and planning efforts, start-up research funding for promising but underfunded academic investigators, and interinstitutional partnership. Realizing the challenge of sustaining improvements in academic performance without viable, technology-based economies in the EPSCoR states, the program has been more willing to support infrastructure such as incubators.

Ironically, the two federal agencies that have supported much of the brick and mortar behind the national network of 600 or more incubators—the Economic Development Administration and the Appalachian Regional Commission—are primarily economic development agencies; they are not deep in scientific and technological expertise among their program staff. These agencies have made only very limited investments in technology-based economic development programs and projects.

The White House Office of Science and Technology Policy has been primarily concerned about "big science" and scientific issues related to the missions of the various federal agencies, particularly the U.S. Department of Defense. The Technology Administration in the U.S. Department of Commerce has had both a programmatic and a policy role, but it has had limited resources. Its Experimental Program to Stimulate Competitive Technology seeks to increase the technology capacities of EPSCoR states but also has been resource-constrained, and university-industry technology transfer is only one of its interests.

The relatively nonaggressive posture of the federal research-funding agencies on technology transfer is, in part, a residue of the industrial policy debates of the 1980s, which questioned whether any government should pick winners and losers among industries and technologies and invest accordingly. It also is a reflection of the prevailing sentiments within the current Congress. For example, a 1998 report from the House Committee on Science is fairly clear on the respective roles of states and the federal government. "The federal government has an irreplaceable role in funding basic research. States, on the other hand, are far better suited to stimulating economic development through technology-based industry within their borders ... through their support of college and research universities and by facilitating interactions between these institutions and the private sector."[50]

Legislative issues pending in Congress could negatively affect university-industry technology transfer, and states should carefully monitor congressional action. For example, language in a recent appropriations bill (P.L. 105-277) requires university research performers (as an amendment to OMB Circular A-110) to make "available to the public ... all data produced under an award." Although this language was drafted to address scientific fraud, it could have serious implications for public disclosure of inventions. Similarly, the Advanced Technology Program of the National Institute of Standards and Technology, which funds technology partnership projects, has incorporated roles from its authorization language that has effectively barred universities from retaining ownership of inventions deriving from such work. This, in effect, contradicts Bayh-Dole. Although U.S. patent law continues to evolve, both in terms of underlying statutes and judicial decisions, no developments suggest that the mandate given universities under Bayh-Dole would be seriously undermined.

Continuing efforts under recent trade agreements seek to harmonize patent laws in the United States with those in the rest of the world, but that agenda is moving relatively slowly.[51] Governors should focus on the patent harmonization discussions because the fixes could have implications for economic development. Notwithstanding these issues, the congressional agenda in the area of university-industry technology transfer seems to be limited to possibly supporting the continuation of SBIR and making the R&D tax credit a permanent feature of U.S. tax code.

WHAT CHALLENGES STATES WILL FACE

University-industry technology transfer—formal and informal—is important in building high-skills, high-wage economies. Technology drives the new economy, and universities provide critical feedstock in terms of talented people, new knowledge, and innovative technology. For states, universities can be major assets in economic development, but there is a danger that the value-added potential of those assets will migrate elsewhere, particularly if states have less preexisting R&D-intensive industry. Mastering the economic geography of university-industry technology transfer is the most formidable challenge for states.

Another challenge for states is to make a difference with few policy and program levers at their disposal. Research universities have a well-developed tradition of self-governance and academic freedom. To play an active role in economic development, changes must occur inside these institutions. Yet states and communities can play complementary roles, particularly in nurturing entrepreneurial technology companies, talented and inventive people, and the culture and environment in which they both can thrive.

ENDNOTES

[1]Association of University Technology Managers, *AUTM Licensing Survey: FY 1997* (Norwalk, Conn.: Association of University Technology Managers, 1998).
[2] M. Mandel, "Commentary," *Business Week*, 16 August 1999, 37.
[3] R.C. DeVol, "Metro Growth: How Dependent on High-Tech Success?" *Regional Special Study (Summer 1997),* WEFA, Inc.
[4] U.S. Department of Commerce, Technology Administration, Office of Technology Policy, *The Global Context for U.S. Technology Policy* (Washington, D.C., 1997).
[5] For a good brief historical background, see Chapter 2 of G.W. Matkin, *Technology Transfer and the University* (New York: Macmillan, 1990).
[6] Vannevar Bush, *Science: The Endless Frontier— Report to the President of the United States* (Washington, D.C.: U.S. Government Printing Office, 1945).
[7] National Science Board, *Science and Engineering Indicators—1998,* NSB 98-1 (Arlington, Va.: National Science Foundation, 1998) Appendix Table 5-2.
[8] Ibid.
[9] BancBoston, *MIT: The Impact of Innovation* (Boston, Mass.: BancBoston Economics Department, 1997).
[10] National Science Board.
[11] D. Berglund and C. Coburn, *Partnerships: A Compendium of State and Federal Cooperative Technology Programs* (Columbus, Ohio.: Battelle, 1995).
[12] Association of University Technology Managers. *AUTM Licensing Survey.*
[13] D.R. Trune and L. Goslin, "University Technology Transfer Programs: A Profit/Loss Analysis," *Technology Forecasting and Social Change 57*, (1998): 197–204.
[14] For example, if one divides the 132 universities reporting on the most recent Association of University Technology Managers' survey at the break point of having more or less than $100 million in research expenditures, one finds that 49 percent of the larger schools realized in excess of $1 million in gross license income, compared with only
12 percent for the smaller institutions. Interestingly, 77 percent of the larger institutions had established their technology offices by 1990, compared with 59 percent of the smaller schools.
[15] R. DeVol, *America's High-Tech Economy: Growth, Development, and Risks for Metropolitan Areas* (Santa Monica, Calif.: Milken Institute, 1999) 13.
[16] E. Mansfield, "Academic Research and Industrial Innovation," *Research Policy*, vol. 20, no. 1 (February 1991):
1–12.
[17] The logic is that if one can assume an "average" royalty rate as a percentage of licensee product sales, then one can apply a multiplier to aggregate royalties across institutions and get a resultant estimate of aggregate sales across licensees.
[18] R. Bennof and S. Payson, *Science and Engineering State Profiles: 1997.* NSF 98-315 (Arlington, Va.: National Science Foundation, 1998). The statistics cited are derived from state data contained in the report.
[19] BancBoston.
[20] The "brain drain" phenomenon seems to be statistically related to the technology opportunity structure afforded graduates (e.g., technology wages and lower university tuition). See data in L.G. Tornatzky, D.Gray, S. Tarant, and J. Howe, *Where Have All the Students Gone? Interstate Migration of Recent Science and Engineering Graduates* (Research Triangle Park, N.C.: Southern Growth Policies Board, Southern Technology Council, 1998).
[21] L.G. Tornatzky, P.G. Waugaman, and J.S. Bauman, *Benchmarking University-Industry Technology Transfer in the South: 1995–1996 Data* (Research Triangle Park, N.C., Southern Growth Policies Board, Southern Technology Council, 1997); L.G. Tornatzky, P.G. Waugaman, and L. Casson, *Benchmarking University-Industry Technology Transfer in the South:1993-1994 Data* (Research Triangle Park, N.C.: Southern Growth Policies Board, Southern Technology Council, 1995).

[22] A. Varga, *University Research and Regional Innovation.* Norwood, Mass.: Kluwer Academic Publishers, 1998); see pp. 121–6 for a summary.
[23] There is rarely the cartoon character "aha" experience. More typically, inventors gradually come to realize that a pattern of findings in their laboratory has important implications for solving an important problem in the real world in a nonobvious, novel way.
[24] Secs. 101-103 of the U.S. Patent Law, Title 35, *U.S. Code.*
[25] Patents in the United States are based on the principle of "first to invent," while elsewhere in the world the prevailing principle is "first to file." This has implications for the public disclosure behavior of faculty involvement.
[26] P.G. Waugaman, L.G. Tornatzky, and B.S. Vickery, *Best Practices for University-Industry Technology Transfer: Working with External Patent Counsel* (Research Triangle Park, N.C.: Southern Growth Policies Board, 1994).
[27] S. Stralser, "Faculty Attitudes and Perceptions about Technology Transfer" (unpublished Ph.D. dissertation, University of Michigan, Center for the Study of Higher and Postsecondary Education, Ann Arbor, Mich., 1997).
[28] Association of University Technology Managers. *AUTM Licensing Survey.*
[29] An excellent review of this history can be found in H. Etzkowitz and A. Stevens, "Inching toward Industrial Policy: The University's Role in Government Initiatives to Assist Small, Innovative Companies in the United States," C*apitalizing Knowledge: New Intersections of Industry and Academia,* ed. H. Etzkowitz, A. Webster, and P. Healey (Albany, N.Y.: State University of New York Press, 1998).
[30] Given that larger licensee companies tend to manufacture wherever costs are lowest, this waiver further dilutes the economic development impacts.
[31] Government-University-Industry Research Roundtable, *Intellectual Property Rights in Industry-Sponsored Research* (Washington, D.C.: National Academy Press, 1993).
[32] Task Force on Industry Reliance on Publicly-Funded Research, *Industry Trends in Research Support and Links to Public Research* (Arlington, Va.: National Science Foundation, National Science Board, 1998).
[33] BancBoston.
[34] Although 60 percent said they had received benefits in the area of patents and new products—perhaps reflecting the greater reliance on academic intellectual property in this industry—an equivalent fraction indicated that they linked to universities primarily to stay current with important research. See B. Blumenthal, N. Causino, E.G. Campbell, and K.S. Louis, "Relationships between academic institutions and industry in the Life Sciences—An Industry Survey," *The New England Journal of Medicine 334* (1996): 368–73.
[35] Any similarity to an actual trademarked product is unintended and coincidental.
[36] One small issue in performance benchmarking of formal university technology transfer is whether to look at outcomes in terms of raw totals (e.g., numbers of patents or total royalties) or by using ratio measures (e.g., patents per $10 million of research expenditures or royalties as a percentage of total research expenditures). The former approach ends up focusing on institutions such as the Massachusetts Institute of Technology and Harvard; the latter approach, which has come to be used more frequently, enables direct comparisons of small and large institutions.
[37] L.G. Tornatzky and P.G. Waugaman, "Academic Culture and Technology Transfer: Some Change Interventions," *R&D Enterprise Asia Pacific,* vol. 2, no. 2-3 (May/June/July 1999).
[38] Association of University Technology Managers. *AUTM Technology Transfer Practice Manual* (Norwalk, Conn.: Association of University Technology Managers, 1994).
[39] L.G. Tornatzky and J.S. Bauman, *Outlaws or Heroes? Issues of Faculty Rewards, Organizational Culture, and University-Industry Technology Transfer*. Research Triangle Park, N.C.: Southern Growth Policies Board, 1997.
[40] L.G. Tornatzky, P.G. Waugaman, L. Casson, S. Crowell, C. Spahr, and F. Wong, *Benchmarking Best Practices for University-Industry Technology Transfer: Working with Start-up Companies* (Research Triangle Park, N.C.: Southern Growth Policies Board, 1995).

[41] For a “best practice” review of more than fifty technology business incubators, many of which are linked to universities, see L.G. Tornatzky, Y Batts, N.E. McCrea, M.S. Lewis, and L.M. Quittman, *The Art and Craft of Technology Business Incubation: Best Practices, Strategies, and Tools from 50 Programs* (Research Triangle Park, N.C.: Southern Growth Policies Board, 1995).
[42] L.A. Molnar, D.R. Grimes, J. Edelstein, R. DePietro, H. Sherman, D. Adkins, and L.G. Tornatzky, *Impact of Incubator Investments—Report to the U.S. Department of Commerce, Economic Development Administration,* Project #99-06-07414 (Athens, Ohio: NBIA Publications, 1997).
[43] For example, Ohio State’s Technology Partnership Task Force report is notable. Among many recommendations and actions, it proclaims the following: “The Ohio State University will become preeminent in creating, promoting and sustaining technology-based business partnerships that transform knowledge and innovation into new technologies and new companies—putting them to work for Ohio and the nation.” In D.N. Allen, *Turning Great Research into Innovative Products: Strategies for Success in the Age of Transitional Technology* (Columbus, Ohio: The Ohio State University, 1999).
[44] “Lucent Technologies to Light Up Centennial Campus with New Facility,” *NC State: The Alumni Magazine of NC State University* (Summer 1999) 64–5.
[45] Molnar, et al.
[46] Biotechnology Industry Organization, *Encouraging Development of the Biotechnology Industry: A Best Practices Survey of State Efforts* (Washington, D.C.: Biotechnology Industry Organization, May 1999).
[47] Biotechnology Industry Organization.
[48] “The Hot New Tech Cities,” *Newsweek,* 9 November 1998.
[49] Ibid.
[50] U.S. House of Representatives, Committee on Science, *Unlocking Our Future: Toward a New National Science Policy.* Committee Print 105-B (Washington, D.C.: U.S. Government Printing Office, September 1998).
[51] Although somewhat dated in terms of specifics, the broad issues are spelled out well in M.B. Wallerstein, M.E. Mogee, and R.A. Schoen, eds., *Global Dimensions of Intellectual Property Rights in Science and Government* (Washington, D.C.: National Academy Press, 1993).

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