A Strategic Assessment of the Economic Benefits of Investments in Research in Arizona

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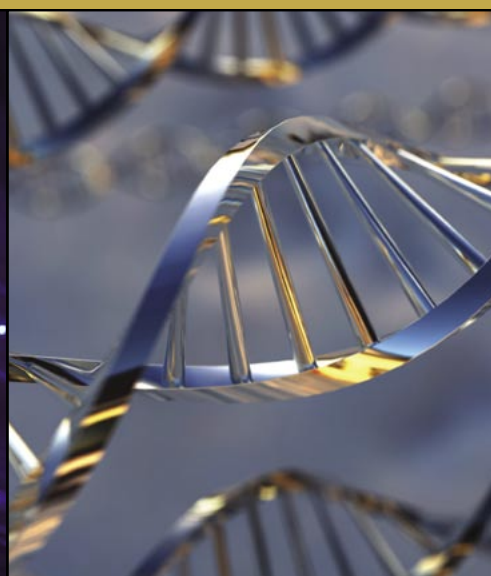

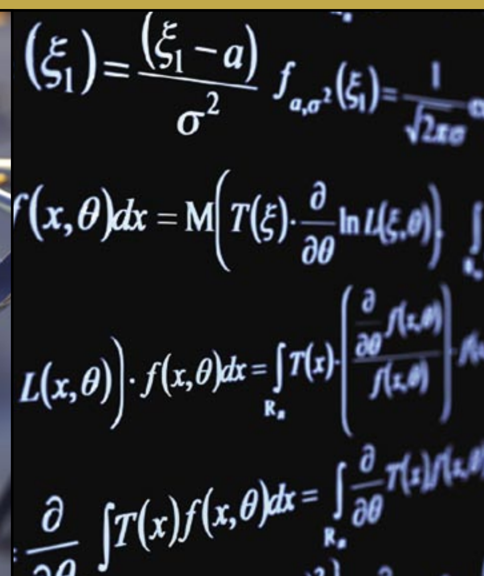

ARIZONA STATE UNIVERSITY

W. P. CAREY SCHOOL of BUSINESS

Eller COLLEGE OF MANAGEMENT
THE UNIVERSITY OF ARIZONA.

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Our intent is to add to this body of literature by investigating the rationale for research investments across the academic literature, examining the assembled empirical evidence on the issue, conducting independent statistical analysis, and surveying what other regions, states and countries are doing to increase the pace of investment in research. The impact of research on productivity and economic activity — how it works, how it's measured — is a fascinating topic that has captured the interest of many authors. This report has clearly benefited from this extensive body of literature. We also acknowledge the broad academic community of scholars and journal editors that provided the basis for much of our analysis.

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Backdrop

A fall 2006 report entitled *The Competitiveness Index: Where America Stands*, from the Council on Competitiveness, paints the picture of a prosperous U.S. economy where overall growth between 1986 and 2005 led the developed world and was responsible for one-third of global growth over the past 15 years. Arizona seems right in step with this performance, ranking among the leading states in overall growth as measured by overall employment growth, population growth or growth in gross state product.

So amid this apparent sea of prosperity, need there be concern about economic progress and prosperity, and if so, in what context? The 2006 report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, produced by the National Academy of Sciences, National Academy of Engineering and the Institute of Medicine, expresses "deep concern that the scientific and technological building blocks critical to our economic leadership are eroding at a time when many other nations are gathering strength." The report prescribes a list of policy actions designed to bolster science education, increase federal investments in research, set targets for education and skill attainment in the workforce, and establish a fiscal/regulatory environment that fosters innovation. Even the ebullient Council on Competitiveness report discussed above notes a number of concerns including: the rapid growth in research and development (R&D) investments diverted to emerging economies; the decline in federal R&D investment as a share of total R&D; the reduction in the share of domestic students pursuing degrees in science and technology; the concentration of venture capital in particular regions of the country; and the lagging performance of the U.S. educational system in terms of both attainment levels and test-score achievement.

The concern can be underscored in the following example. In many developed countries, considerable energy is directed toward ensuring younger workers have the education and skills to meet the global challenge head-on. That is, younger workers tend to have higher educational attainment levels than those 20 years' their senior. Exceptions include Germany, Italy, the United States and, most strikingly, Arizona.

Share of population with Associate's Degree or more

	Age	
	25-34	45-54
Canada	51%	39%
France	33%	19%
West Germany	21%	25%
Italy	12%	11%
Japan	48%	29%
Korea	38%	13%
Mexico	18%	11%
United States	35%	36%
Arizona	30%	37%

Source: Organization for Economic Co-operation and Development (2003) and 2000 decennial census for United States and Arizona

The *2007 State New Economy Index* reveals that Arizona ranks 22nd among the states. While arguably a respectable overall performance, concern may arise over the fact that Arizona is among the states whose ranking has declined the most since the index was first compiled in 1999, and that Arizona's performance is very poor on important measures, including the knowledge component of recent migrants from abroad, the importance of foreign direct investment in the state, and the index of "innovative" entrepreneurial activity within the state.

So questions remain. Are Americans, and Arizonans in particular, achieving maximum levels of economic prosperity today? And even if recent overall performance is strong, are we prepared to compete in the global economy in a manner that maintains or improves future prosperity? The analysis in this technical report, *A Strategic Assessment of the Economic Benefits of Investments in Research in Arizona*, helps inform readers about these issues and builds an understanding about how a science and engineering foundation with an emphasis on research can ensure sustainable economic prosperity.

To better understand these issues, we must first gain perspective on the big issues, which include competitiveness, the role played by productivity in achieving economic prosperity and a strategic analysis of Arizona's economic development plans. We then turn attention to the business plan for Arizona in particular and how, as revealed in this technical report, research investments can fit with the objectives of this overall plan.

Issue Analysis

Understanding Competitiveness

The "C" word elicits emotion. What country or individual does not want to compete — at least on some dimension? But it is important to understand the ultimate goal of an economic competitiveness strategy. Economic competitiveness is not about aspiring to the largest economy nor even the fastest-growing economy. It is about attaining economic prosperity for individuals and businesses that comprise an economy. And, yes, rapidly growing cities can be comprised of poor individuals. According to the 2007 *Pocket World in Figures* published by *The Economist* magazine, the 20 fastest-growing cities in the world are all in Third World countries. Kabul, Afghanistan, is No. 2.

Quoting Michael Porter in the 2006 Council on Competitiveness Report, *Where America Stands*, competitiveness is "not about having a low-cost labor force, the largest share of exports or even the fastest economic growth. It is about creating the conditions under which companies and citizens can be the most productive so that wages and returns on investment can support an attractive standard of living." So the competitiveness challenge for the United States and for Arizona is less about "beating out" other economies in athletic-style "competitions," and more about understanding how the new global marketplace creates new opportunities for raising standards of living and threats to those individuals and businesses who rely on 20th century economic development strategy, markets and skills, a combination that simply may not yield sustainable economic prosperity in the coming years.

There also is a distinction between high-road and low-road competitions, as articulated by Robert Atkinson in his article, *Deep Competitiveness*, published in *Issues in Science and Technology*, Winter 2007. On the high road, winners have the best research infrastructure, the best markets to develop products and innovate, and the best climate for inventors and productive workers. Competition on this level benefits all serious competitors who are able to improve in these dimensions. Battles on the low road are characterized by counterproductive skirmishes that stifle trade, foster protectionism, set up tariffs, and instill the false belief that piracy of intellectual property is acceptable because "everybody does it."

The state and local extension of this low-road competition is manifested in battles over jobs and even local retail sales at all costs. At some point, the competitors need to move beyond competition based purely on taxes and recognize that low-paying jobs can bring more costs than benefits to a region in the long run. Competition on the high road avoids the negative consequences of this low-road engagement.

Productivity, the Key to Sustainable Prosperity

Economic prosperity and productivity are inseparable. Businesses that create high value through labor or capital input are the most prosperous. Individuals who create high value per hour of work earn the highest wages. Competitive economies maintain environments conducive to high rates of productivity growth. Evidence is abundant, most notably from the experiences of countries like Ireland, examined closely in Chapter 4 of *A Strategic Assessment of the Economic Benefits of Investments in Research in Arizona*. Celtic Tiger success is widely known and many have attempted to copy it. A catalyst for this success is a strong leadership position in productivity growth. Ireland's 2006 report of the National Competitiveness Council notes that the rate of productivity growth in Ireland over the last decade is approximately double the rate of the average European Union country and is also considerably higher than that of the United States. Using GDP as a benchmark, Ireland's hourly productivity level has actually eclipsed that of the United States.

So if productivity is the key, what fosters productivity growth? Knowledge stocks imbedded in individual businesses or particular production processes are important. "Know-how," or human capital acquired by experience and educational attainment, is important. Romer's (1990) *Journal of Political Economy* article, *Endogenous Technological Change*, explains how this operates primarily through private investments in R&D and the linkages between R&D investments, inventor innovation, returns on investment and subsequent reinvestment in R&D. Not all the knowledge created in this process is contained within the firm, but rather the benefits of this activity spill over to the surrounding economy and promote widespread productivity growth.

Historically, public investments in R&D have enhanced private sector productivity as illustrated by the downstream impact of high-value-product development that has resulted (e.g. computers, the Internet, laser technology, technologies that support Internet search and batteries that power electronic components of all types). Productivity is the key wealth creator and R&D investments foster productivity growth

Arizona is among our nation's leaders in job and population growth, but lags the nation in output per worker (6.1 percent below the national average) — a rough estimate of productivity — and wages per job (7.5 percent below the national average). According to The American Association for the Advancement of Science (2003, the latest year available), Arizona lags the national averages in total R&D per capita and as a percent of Gross State Product. In contrast, California and Massachusetts are among the nation's leaders in total R&D intensity and output per worker and have wage numbers that exceed national averages by more than 10 percent.

Per-capita personal income in Arizona has declined from approximately 5 percent below U.S. averages in the 1970s to about 14 percent below the U.S. average today. Estimates from the Eller College of Management at The University of Arizona predict deterioration in this performance over the coming decades.

Historically, some have argued that Arizona's cost structure is relatively low so the real purchasing power of wages is not as low as a glance at wage and income statistics might reveal. Recent acceleration in the cost of housing in the state challenges this argument, since the cost to live or relocate to Arizona is clearly much higher today than in prior decades. But rather than puzzle over whether Arizona wages are comparable to U.S. norms or 5-15 percent below, attention should focus on how to achieve sustainable wage increases by increasing the pace of productivity growth in the state. A competitiveness agenda for Arizona must be centered on measures designed to raise the productivity of the Arizona workforce.

Framing the Problem: A Strategic Assessment of Arizona, Inc.

The challenge Arizona faces today is developing a roadmap, a business plan, for the future. Suppose we think in terms of Arizona, Inc. What is our business plan to address future challenges? As part of the plan, can we create an environment that positions the state to couple leadership on overall growth (employment and population) with the aspiration to achieve leadership positions on key individual competitiveness metrics like wages and income per capita?

In terms of current strengths and weaknesses, Arizona is an overall economic growth leader and remains an attractive destination for businesses and individuals seeking employment. We have enviable overall in-migration numbers and overall economic strength that provide Arizona, Inc., the opportunity to make strategic investments that can help ensure future prosperity. But rapid population growth also increases the demand for historically low-wage service employment that requires few advanced skills. The workforce, especially younger workers, has education and skill sets that lag the nation, and a closer look at the in-migration statistics reveals that the net share of young educated in-migrants constitutes a relatively small share of Arizona's total.

As to opportunities and threats, recent overall economic strength provides opportunities that states in the industrial Midwest do not have today. Business and foundation leaders and policymakers are ready to embrace an agenda that aligns with productivity enhancement by placing greater emphasis on education and nurturing an environment conducive to innovation. Perhaps the biggest threat to our state's long-run prosperity is that the rapid, overall pace of growth may mask lagging performance on individual metrics and foster a sense of complacency. Also, Arizona will find the challenge of competing on individual prosperity metrics to be formidable because rapid population growth will continue to increase the pressure for low-wage service jobs — creating a magnet for low-skilled in-migration from all over the world. The result may be that many Arizona workers will be content to live in a pleasant climate with employment at modest means and fail to recognize the imperative for acquiring more knowledge and skills — either for themselves or for their children. If this tendency dominates, businesses may question whether Arizona is the best place to employ high-value knowledge workers. In short, Arizona faces inherent impediments that will create headwinds against progress on productivity growth, so how can these challenges be overcome?

A Strategy for Arizona, Inc.

There are many aspects to an overall business plan for Arizona, Inc., and components include a series of distinct initiatives, business plans in their own right: a plan for increasing education and skills in the workforce — producing employees in Arizona and/or importing skilled workers; a plan for building transportation, energy, water and communication infrastructure; a plan for creating a business-friendly climate with a cohesive, coordinated, economic development strategy that targets high-value, export-based industries; and a plan for nurturing innovation and knowledge-economy pursuits that enhance productivity. This report, *A Strategic Assessment of the Economic Benefits of Investments in Research in Arizona*, articulates a value proposition for strategic investments in research that primarily addresses the last component in the above list and has implications for the development of human capital, as well. In short, the report provides the foundation of a business plan for Science Foundation Arizona (SFAz) — a division of Arizona, Inc., that can prove to be important to our state's success as measured by the economic prosperity of its citizens.

A Business Plan for Science, Engineering and Research Investments in Arizona: Science Foundation Arizona

The recipe for competitiveness and sustainable prosperity has some key ingredients. Investments in research and development promote knowledge creation and innovation. Knowledge and innovation in turn promote human-capital development and help maximize the value of output that can be produced by each hour of input. In the end, research and development investment is perhaps "the key" to productivity enhancement. As a mechanism that fosters research and development, SFAz is an important strategic asset in the overall economic business plan for Arizona, Inc.

The Concept

How does research promote productivity and what role can the public sector, specifically a public-private partnership like Science Foundation Arizona (SFAz), play in fostering a research and development environment? Answers, based on a careful review of the academic literature, are presented in Chapter 1 of *A Strategic Assessment of the Economic Benefits of Investments in Research in Arizona*. Lessons from basic economics reveal that technological change is indeed crucial for productivity gain, that knowledge formation is key, and that knowledge doesn't deteriorate but embodies effects that spill over to benefit other workers and businesses. Private businesses will tend to invest in R&D only if they can retain the direct benefits that accrue. They have no incentive to pay for benefits that might accrue to spillovers, and since they don't retain all spillover benefits, private firms will underinvest in R&D. Hence the role for public research investment arises.

The analysis in Chapter 1 reveals that innovation and research, in advanced countries, are the driving forces of growth in inflation-adjusted, per-person gross domestic product. Two studies of productivity growth in the U.S. economy during the 1990s concluded that technological change and innovation — especially in the areas of information technology, supply-chain management and robotics — accounted for the largest share of U.S. productivity gains over the period.

R&D investments are crucial for knowledge creation. A key characteristic of knowledge is that it is subject to spillover. Because knowledge spillovers are fundamentally a product of human interaction, they also are highly localized. This gives rise to the phenomenon in economic geography of local research networks and innovative clusters. Examples of clustering in commercial research activity include computer operating systems in Washington, word processing and networking in Utah, biotechnology in San Francisco and Boston, industrial applications of optics in New York, and semiconductor design in Silicon Valley.

The analysis in Chapter 1 also reveals the important role that research universities provide for the nation's innovation system and suggests that benefits will likely accrue to the regions where this knowledge creation occurs — including the potential to create an environment that is more conducive to attracting venture capital and/or additional federal research dollar investments. The state of Arizona absorbs only 0.6 percent of U.S. venture capital funds. Colorado, a state that is comparable in size to

Arizona, receives five times more venture capital than Arizona. Scarcity of venture capital may be an impediment to university-driven economic development in Arizona. But evidence from other regions suggests that this hurdle can be overcome if universities and their faculty have a national presence and reputation to attract venture capital from outside the local area.

One of the most important contributions universities make to the national innovation system is the training of industrial scientists and engineers. Much of the country's inventive activity takes place in corporate labs, but these labs are staffed by researchers who learned science and research methods at universities. Availability of scientific labor is a critical location choice consideration for corporate R&D facilities, and there is an advantage to locating in an area with a research university that trains a large number of scientists and engineers. Firms are particular about the institutions they rely on for new researchers, however. Among large firms especially, only the best graduate programs are an attracting factor.

SFAz initiatives can play an important role in the quest for federal research dollars since the program's reliance on independent competitive reviews of research proposals will serve as an excellent "proving ground" for investigators who will eventually need to tap broader pools of research support for their research projects or attempts at commercialization.

Evidence of local economic impacts from university research comes from a variety of sources, including case studies of industries born from the ideas of university scientists and econometric evidence identifying a statistical association between the level of economic activity in an area and the presence of a research university. The evidence shows conclusively that university research programs have local economic impacts, but the size of the impacts varies greatly depending on the university and its location. University research is most likely to generate significant local economic development benefits when the university has highly rated faculty and graduate programs in fields directly related to high-tech industry and when it is located in a large metropolitan area with a concentration of industrial labs and high-tech manufacturers.

The Financials

Public dollars are a scarce commodity, so exactly what types of returns can be expected from investments in SFAz? Chapter 2 examines the literature on returns to public investments, tabulating the direct results of research expenditures; the byproducts in terms of start-ups, licenses, patents produced by the activity, the inducements that occur in the private sector, and the production of human capital and related spillovers. Since the invested tax dollars come from the public sector, the "return" benefits are measured in the results that show up across the economy.

Research expenditures create jobs through traditional ripple effects, but the knowledge created by publicly funded research creates jobs in a variety of ways. University research-related licenses, start-ups and spin-off companies can have a substantial impact on the economy. In addition, the level of university research expenditures substantially influences private-sector research activities, affecting both the level of industrial R&D and industrial patents.

Human capital investments, particularly persons trained in technology, science and engineering, affect the formation of new firms. University research funding also affects overall economic growth or well-being through increases in productivity and wage rates. Research-related innovations and the accompanying jobs occur close to where the research takes place, so an important public policy goal must be to encourage high levels of both public and private research within Arizona.

Including only those components that can be empirically measured, a conservative estimate of the induced returns within Arizona for an annual, hypothetical public investment of $10 million could be as high as an additional $76 million per year. That would be possible even when only a portion of the expected social benefits is included in the calculations. The estimates are linear and the $10 million example is for illustration purposes. Hence, a $100 million investment would have impacts that are higher by a factor of 10.

Is this a "good deal" for Arizona? One is hard-pressed to identify alternative uses for public money that generates economic inducements of this magnitude. The literature also predicts that increased research investments lead to higher earnings per job. Moreover, public expenditures for SFAz can serve as the key catalyst for matching investments from private donors, federal and industry research sponsors, and the research institutions themselves. Finally, the downstream benefits in terms of the products of research, the students produced, the scientists attracted to the state and new research infrastructure yield benefits that can last for generations. So the enabling effect of an investment today by SFAz has the potential to leverage huge returns for the state's economy — returns far greater than estimates.

A Value Proposition for the Regional Economy

If investments in research have benefits that accrue to regions, evidence should be revealed in an assessment of economic statistics. What is the evidence? Have states or regions that have invested the most in R&D truly prospered? While these questions are straightforward, obtaining accurate statistical estimates is a challenge. Indeed, conducting controlled experiments in economies is one of the biggest challenges for empirical economics.

To understand the challenge, consider the Phoenix metropolitan area, where research investments total several hundred million dollars and the local economy approaches $150 billion. The exercise seems akin to dropping a pebble in the ocean and measuring the ripples. A second aspect of the task is establishing causal relationships, e.g., do research investments enhance prosperity or do prosperous regions choose to invest in research?

Chapter 3 of *A Strategic Assessment of the Economic Benefits of Investments in Research in Arizona* examines this question using evidence on research expenditures in local universities and economic performance of 938 urban areas across the past 35 years, applying statistical techniques designed to cope with the statistical challenges outlined above.

After adjusting for cost of living, the average real wage in urban areas with even modest research university activity (in excess of $5 million in 2004) was nearly $3,300 higher than the average of all urban areas. The real per capita income differential was about $2,800 higher in the research university cities. Over the past 35 years, aggregate wages and salaries in urban areas with research universities grew 0.6 percent faster per year than in areas without research universities. While seemingly a small difference, this differential annual growth rate was statistically significant and results in a 20 percent differential over the 35-year period.

In a study of this nature, it may be difficult to disentangle the impact of research universities from the impact of city size, especially when research investments are dwarfed by the size of a city. To mitigate this potential confusion, we focused exclusively on the performance of a sample of 22 urban areas that had very high levels of university research expenditures relative to the size of their economies (greater than 5 percent). Performance of each of these 22 urban areas was compared with the performance of the surrounding region (typically the cities across the rest of the state). The median aggregate wage and salary growth between 1970 and 2005 was 37 percent faster in the research university urban areas than in the surrounding region. Comparing this growth in research-intensive urban areas with cities without research universities over the past 35 years, the median value of the incremental wage and salary gain observed across the 22 areas with high levels of university research expenditures sums to about $736 million annually today. For perspective, this exceeds average annual injections of federal research dollars by a factor of about 5-to-1. A separate analysis revealed that differential patent intensity, induced by the presence of research universities, might be the channel by which the economic impact occurs.

Lessons from Ireland

Arizona controls its own destiny and is clearly capable of charting its own course by setting economic policies that serve the interest of Arizonans. But lessons learned elsewhere can help mitigate risks for an investment like SFAz and help the effort realize its full potential. Ireland's economic success is widely documented. It is due in no small part to the aggressive economic development strategy it has pursued in courting foreign direct investment and positioning Irish businesses to export products. In short, the economic development activities are centrally focused on devising ways to bring capital into the country so Irish citizens can achieve higher levels of prosperity.

The latest addition to this economic strategy is Science Foundation Ireland (SFI). Economic development strategists understand that their historical competitive advantages — low taxes, incentives, and modest labor costs — have been mimicked by others. Most recently these strategists have chosen to compete on another dimension by bolstering the knowledge and science infrastructure of the country in an effort to attract the high-value research and development divisions of relocating companies. The flagship program, Science Foundation Ireland, launched in 2001, is the centerpiece of this new economic development strategy. William Harris, director of SFI from 2001 to 2006, assembled a structure that produced very favorable results. The SFI story is capsulated in Chapter 4 of *A Strategic Assessment of the Economic Benefits of Investments in Research in Arizona.*

According to an international review panel recently convened to review the activities of SFI, the effort has been successful in attracting leading foreign research scientists to Ireland and in attracting distinguished Irish researchers working abroad back to the country. Furthermore, it is directly responsible for the creation of numerous research centers and programs. Recent reports suggest that private-sector research activity has accelerated, with research and development investments by multinationals up 10 percent, and no fewer than 550 companies investing €100,000 (approximately $130,000 in 2007) or more in R&D. Recognizing the early positives, Ireland currently plans to ratchet up investment in this effort.

SFAz achieved an important strategic advantage in attracting Dr. William Harris, an American, to return to his home country and assemble a similar research structure in Arizona. Dr. Harris has the experience (most recently from Ireland but also in his prior position at the National Science Foundation) in assembling external oversight and proposal review boards that ensure financial controls for SFAz and the integrity and accountability in the proposal-review processes crucial to the success of the endeavor. Under his direction, SFAz is not a government initiative designed to "pick winners and losers." It is a public-private partnership that channels research dollars to the best ideas as assessed by independent review panels. Researchers looking for continuing funding will need to demonstrate results.

Indeed, Arizona is unique, but must be willing to establish an aggressive economic development strategy that reflects its independence. The parallels to Ireland are informative. Travel to Ireland and you will find the passion, nationalism and pride the Irish have for their country and their economic system. SFAz, as a key division of Arizona, Inc., can help kindle that same fire of confidence and commitment among Arizonans.

The Competitive Landscape

SFAz is a new venture for Arizona, but certainly we would not be the first state to establish entities or to pass initiatives designed to promote research and innovation. Chapter 5 of *A Strategic Assessment of the Economic Benefits of Investments in Research in Arizona* inventories the initiatives in 36 other states that are attempting to enhance their research and innovation competitiveness.

The initiatives outlined range from small investments to huge multibillion-dollar initiatives. Some provide for single-year funding while others are long-term investment programs scheduled to last 10 to 20 years. The intent of the initiatives varies widely and includes: improving existing research infrastructure at universities and/or other research facilities; establishing new institutes or research centers; building new facilities and laboratories; providing funding to attract top research teams to state universities; commercializing research-driven patents and inventions; and encouraging interactions between universities and state-based companies to drive research and development, commercialization and job creation.

Recent initiatives include: the $3 billion (over 10 years) initiative for California's Institute for Regenerative Medicine (2004); the $200 million (over two years) Texas Emerging Technology Fund designed to improve university research, attract top scientists, help start-up technology firms get off the ground, and move inventions out of the lab and into the market (2004); New York's $250 million for a new High Technology and Development program (2005); and Washington state's $1 billion (over 20 years, to be funded from Tobacco Settlement money) Life Sciences Discovery Fund (2005).

Although these appear to be all new initiatives, substantial public investment in research has a long history in some states. California founded a program in 1985 designed to link entrepreneurs with University of California at San Diego researchers. In 2000, California also provided $100 million to each of four major research centers, focusing on nano systems, information technology, quantitative biomedical research, and telecommunications and information. New York's first Center for Advanced Technology (CAT) was established in 1983 to foster university-industry collaborative research, encourage technology transfer in relevant technologies, and facilitate transfer of technology from New York's top research universities into commercially viable products produced in the private sector. There are now 16 CAT programs at universities across New York state.

Despite these efforts, New York found its share of available federal dollars shrinking while California and Massachusetts increased theirs. As a result, the New York Office of Science Technology and Academic Research (NYSTAR) was established in 2000. NYSTAR is responsible for development and oversight of eight Strategically Targeted Academic Research (STAR) Centers and five Advanced Research Centers (ARCs) through its capital-projects fund. These centers are intended to expand high-tech research and provide state-of-the-art facilities and equipment to foster the development of new technology-based jobs and business programs. NYSTAR is also responsible for a statewide network of cooperative research and development centers among private universities, private industry and state government, and oversees a network of centers that provide business planning, access to venture capital, product development, marketing, manufacturing and quality systems, engineering and information technology. NYSTAR reports that its investments have resulted in 162 patent applications, 47 patents awarded, establishment of 22 new companies, and more than $509 million in non-state research funds to award recipients. The initiative has also created and retained more than 13,000 jobs. Further, NYSTAR efforts have substantially increased New York's share of federally funded research, making New York's universities and research centers' licensing fees the highest in the nation.

Clearly, the goals of these initiatives are to enhance growth opportunities within their state, leverage in-state research dollars in order to attract more federal funds, and ensure quality growth by focusing on research, innovation and cutting-edge technology.

Concluding Thoughts

SFAz as a business proposition may hold particular value for Arizona. The state has three major universities and major research initiatives in its urban centers, e.g., the Translational Genomics Research Institute (TGen). It is a rapidly growing state with the capacity to make strategic investments. Arizona's attractive climate and lifestyle may help retain students who come from abroad or around the nation to participate in the research endeavors sponsored by SFAz. Most importantly, embarking on an initiative like SFAz emits a very important signal for a state like Arizona with a history of individualism and independence. It says that Arizonans can embrace public-private partnerships and understand that investments in a knowledge economy and research-enhancing infrastructure can contribute to the economic well-being of the state. Businesses and individuals who receive this signal will begin to think about Arizona in a new light — in a broader context and with a wider range of assets.

Embracing an initiative like SFAz isn't the first time Arizonans have relied on public-sponsored projects to obtain an economic stimulus. Consider the importance of Roosevelt Dam on the Salt River Valley at the turn of the century, or when Carl Hayden, John Rhodes and Barry Goldwater convinced the federal government to build the Central Arizona Project, or when Maricopa County taxpayers voted in 1985 to build an urban-freeway system. A vibrant research infrastructure can be as fundamental for the state's 21st century economic well-being as were these stalwart public-sector investments of the 20th century.

Are Arizonans really ready to take this challenge? According to a statewide survey conducted by the Morrison Institute of Public Policy in the spring of 2006, 84 percent of respondents said science and technology are important to the state's economic development; 80 percent said science is "as important" or "more important" than reading, writing and math as a part of a good education. The survey revealed that 90 percent of respondents say it is important for Arizona to be a national/international leader in science and technology and nearly half of Arizonans would pay more in taxes if assured these revenues would be used to invest in science and technology.

Is SFAz consistent with the principles of a sound economic development strategy? As we have seen, one of the world's leading economic development organizations, IDA Ireland, certainly endorses the concept. A glance at its Web page reveals the message, *Ireland, Knowledge Is in Our Nature.* Ireland's economic development strategy, founded on the principle of low taxes and low-cost labor, has clearly made a conversion. Moreover, the structure of SFAz is especially efficient in contrast to traditional economic development efforts that focus on offering tax incentives or financial packages designed to attract downstream manufacturing companies from other regions or to compete with other regions to attract relocating firms. Because of capacity constraints, these efforts too often conflict with the achievement of other public-sector goals, such as investing in human capital. A public-private partnership like SFAz is one of the few public investments that achieves multiple goals simultaneously by providing research and development to grow in-state, generating high-value innovations and production, attracting high-value producers, and increasing investments in human capital through enhanced and expanded educational opportunities.

Is the timing right? As a review of Chapter 5 reveals, many states have addressed this concern for years, while some have embraced the science and technology agenda only after their economies encountered challenges. There appears to be increasing bipartisan support for increasing federal investments in research, including plans to increase National Science Foundation funding and launch matching grant programs that allow states to leverage research investments with federal resources.

At the same time, global competition for research and development divisions of industry is intense. Businesses now carefully consider the landscape and view public-research infrastructure and the associated education and skills of the workforce as important determinants in location and relocation decisions.

Can Arizona afford to invest in SFAz? Perhaps the better question is: Can we afford not to? Arizonans are at crossroads. We can continue to take the "low road" of economic development and attract low-wage industry to a low-service, low-wage state, or we can leverage existing world-class resources and invest in the research and technology needed to grow quality, high-wage jobs. Today, we can make a reasoned choice, not a choice made from concern over a stagnating regional economy, but a choice based on a position of regional economic strength with the intent of maintaining overall regional economic strength in the future. But it is also a choice by individuals, for individuals, with the intent of increased economic prosperity for all Arizonans.

CHAPTER 1

The Economic Case For Science Foundation Arizona

A Summary of Findings from Chapter 1

Structure

Science Foundation Arizona (SFAz) is a 501(c)(3) nonprofit organization initiated in 2006 by Greater Phoenix Leadership, Southern Arizona Leadership Council and Flagstaff 40. It is dedicated to building science, engineering and medical research capabilities in the state of Arizona, primarily through strategic investments in research initiatives. The overarching goal of SFAz is to serve as a catalyst in the construction of a knowledge infrastructure in Arizona that will position the state to compete in the global economy.

SFAz's governing board of directors consists of respected and talented research-and-development (R&D) leaders from around Arizona, as well as from outside the state. The board expertise includes academic and business backgrounds and offers a perspective that is essential to developing a more competitive knowledge-driven society.

In fiscal year 2007, $35 million was approved for the Arizona 21st Century Competitive Initiative Fund (HB2477). SFAz successfully obtained the Commerce and Economic Development Commission contract (reviewed by the Joint Legislative Budget Committee) to implement the investment strategy for these resources.

By January 2007, all Request For Proposals for SFAz programs were disseminated to nonprofit and research-performing institutions across the state. All SFAz investments are awarded on a competitive basis. Investments are directed toward research pursuits aimed at attracting significant funding from other sources (such as federal and industry sponsors) and seeding the research opportunities that are crucial to creating the next generation of high-technology companies in Arizona. Another goal of SFAz investments is to help strengthen science and mathematics in Arizona's K-12 education system.

Early programs, as outlined here, reveal SFAz's determination to fund those programs aimed at attracting funding from federal and other external sources. This is an essential element because the overall funding stream is not large enough, by itself, to make a major change in the research structure of the state.

A Rationale for Local Investments in Research

Results show that innovation and research in advanced countries are the driving forces of growth in inflation-adjusted, per-person Gross Domestic Product. Two studies of productivity growth in the U.S. economy during the 1990s concluded that technological change and innovation — especially in the areas of information technology, supply-chain management and robotics — accounted for the largest share of U.S. productivity gains over the period. Relative prosperity among individuals, cities and countries is increasingly based on differences in knowledge and innovative activity.

A key characteristic of knowledge is that it is subject to spillover. Because knowledge spillovers are fundamentally a product of human interaction, they also are highly localized. This gives rise to the phenomenon in economic geography of local research networks and innovative clusters. Examples of clustering in commercial research activity include computer operating systems in Washington, word processing and networking in Utah, biotechnology in San Francisco and Boston, industrial applications of optics in New York, and semiconductor design in Silicon Valley.

In the language of economics, there are positive externalities associated with the production of knowledge. In cases involving externalities, free market outcomes are no longer necessarily optimal. When firms cluster together to enjoy the mutually reinforcing effects of knowledge spillovers, the particular location of the group need not minimize industry costs, but instead may be the result of arbitrary historical conditions. A new semiconductor firm that chooses to locate in Silicon Valley pays a high price in land and labor costs to be near other semiconductor firms. It makes sense for the firm to locate there. But industry costs might be reduced if the industry were relocated.

The existence of spillovers in the production of knowledge provides an intellectually sound basis for local industrial policy aimed at catalyzing the development of inventor networks and commercial research industry. While the effect of market size is important in determining the location of innovative activity, comparative advantage also plays a role. Local industrial policy efforts are more likely to be successful if the region has intrinsic advantages in research activity but is simply held back by small market size. Foremost among the location choice attributes that favor the development of commercial research activity are the existence of high-quality university research faculty and graduate programs, the existence of a large metro area in the region, and natural amenities such as climate that appeal to mobile inventors.

Metamorphic innovations — those associated with the creation of new industries or radical technological transformation of existing industry — typically are driven by breakthrough discoveries in science and engineering. Examples include integrated circuits, recombinant DNA and nanotechnology. Metamorphic discoveries are not well understood initially, and the new knowledge is difficult to codify. Transfer and application to industry require bench-level relationships between industry scientists and the pioneering scientists. If the scientist making a metamorphic discovery has a university appointment that he wishes to maintain, he may serve as a fixed factor that determines the location of firms entering the market to commercially develop the new technology. Biotechnology offers a recent example of an important new industry in which commercial firms are known to have close ties to university-based scientists.

Universities, Research and Economic Development

One of the most important contributions universities make to the national innovation system is in the training of industrial scientists and engineers. Much of the country's inventive activity takes place in corporate labs, but these labs are staffed by researchers who learned science and research methods at universities. Availability of scientific labor is a critical location choice consideration for corporate R&D facilities, and there is an advantage to locating in an area with a research university that trains a large number of scientists and engineers. Firms are particular about the institutions they rely on for new researchers, however. Among large firms especially, only the best graduate programs are an attracting factor.

Innovative activity tends to concentrate in large cities. Geographic concentration of research activity reduces industry costs by allowing for the existence of specialized suppliers of research services and by promoting knowledge spillovers. Large urban areas also offer amenities that professional workers value, and they make it easier for spouses to find employment. In studies of high-tech industry, city size has been found to be more important as a location choice variable than low taxes or wages.

SFAz as a Component of an Economic Development Plan

SFAz is not a local version of the National Science Foundation (NSF). The mission of the NSF and other federal research agencies is to support basic research — research that may at some point generate great commercial value but only, perhaps, after being developed over long periods of time *in a variety of geographic areas and industries. The goal of SFAz is to support research with near-term commercial value that can be developed and realized locally.*

SFAz also is not simply a government venture capital fund, although it may help to attract private venture capitalists. Support provided by SFAz for university research in the state will be in the form of grants. SFAz will not take equity positions in commercial start-ups. The return to the state of Arizona will consist of economic development benefits: jobs and incomes that result from the attraction of corporate labs, the start-up of new high-tech businesses, and any competitive advantages enjoyed by local businesses when their technology is advanced by university research.

Evidence of local economic impacts from university research comes from a variety of sources, including case studies of industries born from the ideas of university scientists and econometric evidence identifying a statistical association between the level of economic activity in an area and the presence of a research university. The evidence shows conclusively that university research programs have local economic impacts, but the size of the impacts varies greatly depending on the university and its location. University research is most likely to generate significant local economic development benefits when the university has highly rated faculty and graduate programs in fields directly related to high-tech industry and when it is located in a large metropolitan area with an existing concentration of industrial labs and high-tech manufacturers.

Economists and the Economic Development Agenda

Economists are generally critical of efforts by governments to target particular industries for public support. One reason is that industrial policy is thought to be flawed in principle. In a free market, private incentives are sufficient to guide resources to their highest-valued use. However, free-market outcomes are not necessarily optimal in knowledge-based industries where spillovers are pervasive. There is a sound intellectual case for industrial policy efforts such as Science Foundation Arizona that seek to catalyze the formation of innovation-based industry in the local economy.

Economists are also skeptical of industrial policy because it is often flawed in practice. In choosing which industries to target for support, governments may be guided by special-interest-group pressures. One potential pitfall and source of political conflict for SFAz is in the regional allocation of funds within Arizona. It will be tempting to try to distribute the economic development benefits of SFAz projects widely across the state. Yet it can be argued that the most economical location for innovative activity is in a large metro area.

Another political temptation for SFAz will be to support projects that align with the interests of the state's existing electronics firms. It is hard to argue that the semiconductor industry in the state needs a boost from SFAz in order to achieve critical scale economies. The best argument for SFAz is as a catalyst for innovative activity that is well-suited to the state but simply lacks market size at the present time.

An Overview of SFAz: Structure and Programs

Science Foundation Arizona (SFAz) is a 501(c)(3) non-profit organization dedicated to building science, engineering and medical research capabilities in the state of Arizona primarily through strategic investments in research initiatives. The overarching goal of SFAz is to serve as a catalyst in the construction of a knowledge infrastructure in the state of Arizona that will help position the state to meet the challenges of the global economy.

SFAz's governing Board of Directors consists of respected and talented R&D leaders from around Arizona, as well as outside the state and country. The board's members have academic and business backgrounds and offer a perspective that is essential to developing a more competitive knowledge-driven society.

SFAz essentially grew out of efforts of the Flinn Foundation and its consultant, the Battelle Memorial Institute. SFAz is consistent with Arizona's Bioscience Roadmap set out by the Flinn Foundation but its mission is to serve needs beyond biotechnology. The creation of SFAz was aided by three groups from across the state: Flagstaff 40, Greater Phoenix Leadership and Southern Arizona Leadership Council. These groups of chief executive officers will provide seed funds for the first five years of operating costs (estimated at $2.5 million per year). Along with these funds, in fiscal year 2007, $35 million was approved for the Arizona 21st Century Competitive Initiative Fund (HB2477). SFAz successfully obtained the Department of Commerce's Commerce and Economic Development Commission contract (reviewed by the Joint Legislative Budget Committee) to implement the investment strategy for these resources. These state funding sources provide funds that are being distributed as grants used to boost scientific, engineering and medical research in Arizona.

Grants will be awarded on a competitive (national expert reviewers) basis and, in addition to building the science and technology infrastructure in the state, will be directed toward research pursuits that are positioned to attract funding from other sources (federal and industry sponsors) and to those research opportunities that may be key to creating the next generation of high-technology companies in Arizona. Program grants also will be awarded to help strengthen science and math in Arizona's K-12 education system.

The first round of SFAz grant programs span the following major areas:

- **Graduate Research Fellowships,** grants designed to transform competent graduate programs into world-competitive programs by retaining the brightest Arizona students in math and science and also attracting new grad students to the state.
- **Small Business Catalytic Funding,** a program that provides seed funding to university-based spin-off companies in order to allow researchers the opportunity to secure much larger amounts of funding for technology commercialization. The end result is the formation of a high-tech company that creates jobs in Arizona.
- **Competitive Advantage Awards,** designed to provide funding to collaborative research teams that have a high potential of attracting large federal grants based on an extensive peer review process.
- **Strategic Research Groups,** partnerships between research institutions and private organizations that will enhance technology transfer.
- **K-12 Teacher Discovery,** a program of research internships for high school science and math teachers that will update their knowledge of modern science and allow them to bring that knowledge back to the classroom.
- **K-12 Student Discovery,** designed to broaden the participation of K-12 students — particularly those from rural and underserved neighborhoods — in scientific discovery activities.
- **Strategic Initiatives,** recognizing that today's research work could generate a solution or cure for tomorrow, these grants allow SFAz to respond quickly to ideas that may not fall into one of the above programs but hold great promise for Arizonans.

The bid process is administered through requests for proposals. SFAz bases funding decisions on the quality of the proposal, the quality and track record of the principal investigators, and the strategic value or competitive advantage that the proposed line of inquiry might have for the state of Arizona. SFAz's grant review process is similar to that of a number of federal programs. An expert external panel comprised of individuals who possess extensive experience with such federal competitive grant processes review funding proposals and recommend awards.

The $35 million appropriation is being distributed according to the Preliminary Funding Schedule depicted in Table 1. The schedule shows that strategic investments in several key research areas will account for 84 percent of funding. Catalyzing the development of new small businesses based on R&D in strategic areas will account for 6 percent of funding, and about 4 percent will go to investments to improve K-12 science and mathematics performance. Six percent remains for expanding research, with teachers paid as researchers.

Table 1
Science Foundation Arizona: Preliminary Funding Schedule

Program	**Funding in Millions**
Competitive Advantage Awards (CAA)	$5.0
Small Business Catalytic (SBC)	2.0
Graduate Research Fellowships (GRF)	4.0
K-12 Student Discovery	1.5
K-12 Teacher Discovery	2.0
Strategic Research Groups (SRG)	18.0
Strategic Initiatives (SI)	2.0
Review/Management	0.5

Source: Science Foundation Arizona

While the initial funding stream is modest, the formation of SFAz sends an important signal to the citizens of Arizona and to interested observers in other states. The message is that the state of Arizona joins with representatives from the Arizona business community to embark on an endeavor that is designed to help build a science, engineering and medical research in the state.

The programs also reflect lessons learned from the early successes of Science Foundation Ireland. The program to support K-12 science teachers reflects the STAR teacher program that has resulted in so many connections between secondary and tertiary science education in Ireland. The proposal review process reflects the integrity and independence employed in Ireland with national expert reviewers passing judgment on Arizona-specific proposals. The early programs and accompanying narrative clearly signal that SFAz is keen to fund those programs that offer potential for attracting funding from federal and other external sources. This is important since the overall funding stream is not large enough, by itself, to make a major change in the research structure of the state.

Similarly, SFAz seeks to fund programs that are likely to attract graduate students in science and technology from out of the state as well as research scientists who wish to work in newly created centers supported by SFAz investments. Finally, SFAz's 501(c)(3) status precludes making direct investments in for-profit enterprises but also mitigates the risk of picking the wrong technology.

Connectivity to private-sector pursuits will be encouraged through interactions between the academic community and the business community.

The Rationale for Local Industrial Policy in a Knowledge Economy

Economists and sociopolitical commentators now routinely refer to the economies of the United States and other advanced countries as "knowledge economies." By this they mean that economic value in these countries increasingly derives from creativity, innovation, and human capital. At an individual level, the growing importance of knowledge is apparent in the rising earnings premium received by workers with college and post-graduate degrees [Hill, Hoffman, and Rex (2005)].

At the macroeconomic level, a high proportion of growth in real per capita GDP in advanced countries now is driven by innovation. Two studies of productivity growth in the U.S. economy during the 1990s [McKinsey & Company (2001) and Federal Reserve Bank of New York (2004)] concluded that technological change and innovation (especially in the areas of information technology, supply-chain management, and robotics) accounted for the largest share of U.S. productivity gains over the period. Differences in educational attainment and innovative activity also account for much of the income differentials between cities and states.

Importance of Local Spillovers in the Production of Knowledge

The nature of knowledge is that once it is created, it can be shared without degrading its intrinsic value to the creator. Thus, a key characteristic of knowledge is that it is subject to spillover. Much of the knowledge embodied in new inventions and technologies is learned by other parties and not fully appropriated by the inventor. Because knowledge spillovers are fundamentally a phenomenon of human interaction, they are also strongly local in character. This is especially true of recently created knowledge. In many cases of scientific discoveries that have revolutionary commercial potential, the new knowledge is tacit and difficult to codify. The knowledge is embodied in the intellectual capital of the discovering scientist and only can be transferred to other parties through active working relationships with the scientist.

Studies of the ways in which knowledge spillovers occur have led to an appreciation of "social networks." Economic sociologists argue that economic interactions cannot be fully understood without attention to the web of social relationships in which these interactions are embedded [Granovetter (1985), Polanyi (1957), Swedberg (2003), Uzzi (1996), White (2002), Zuckerman (2003)]. One can similarly argue that the process of invention cannot be well understood without paying attention to the social interactions among inventors [Arora and Gambardella (1994); Orsenigo, Pammolli and Riccaboni (2001); Powell, Doput and Smith-Doerr (1996); Walker, Kogut and Shan (1997)]. Inventors do not operate in isolation. The creation of new ideas is a process that often involves the integration and recombination of existing knowledge originating from different individuals, locations, institutions, and organizations.

Social networks play an important role in the diffusion of information and knowledge since they provide the formal connections and informal linkages through which information and ideas flow among individuals. These knowledge spillovers occur without the mediation of market mechanisms, transcend the institutional and workplace settings in which individuals operate, and cut across organizational boundaries. The spread of knowledge and ideas tends to be local rather than global, and for early-stage innovating, when tacitness is high, face-to-face contact becomes essential for effective knowledge transfer. Close proximity is thus likely to be not only helpful in capturing knowledge spillovers but necessary. The collaborative and informal, and even serendipitous, interactions among inventors and innovators in effect generate a social network among innovators. Concentrating people engaged in related activities in a particular location thus creates an environment that facilitates the rapid and effective diffusion of ideas.

Social networks have been highlighted as an important facet of regional innovation [Breschi and Lissoni (2001), Owen-Smith and Powell (2004)] and are believed to be vital mechanisms for transferring knowledge and ideas between firms. Much of Silicon Valley's success, for example, has been attributed to its informal networks of friendship and collaboration among scientists, engineers, and entrepreneurs in the area [Saxenian (1994)]. The formation of these networks, in turn, was facilitated by the frequent flow of personnel among the firms in Silicon Valley, and this flow was in turn made possible by the fact that "noncompete clauses" are not legal in California [Marx, Fleming and Strumsky (2006)].

Adam Jaffee, Manuel Trajtenberg, and their co-authors have a clever way of finding a "paper trail" with which to track invisible knowledge flows. Patent records contain highly detailed information on the identity and location of the inventor and references or citations to previous patents. The citations make it possible to study knowledge spillovers by tracing the links between inventors. The authors have assembled a massive database of more than 16 million citations made by patents granted between 1975 and 1999. A collection of papers using this database to analyze patent citations is available in Jaffee and Trajtenberg (2002).

Tests for local connections between patents must control for correlations that may simply be due to an existing concentration of economic activity in the same technological area as the patent. But after controlling for this effect, there is conclusive evidence of geographic localization of knowledge flows. In one particular analysis of patents originating in 1980 and their citations through 1989, Jaffee, Trajtenberg, and Henderson (1993) find that after excluding self-citations, the frequency that a university-owned patent is cited in the same metropolitan area as the university is six times higher than what would be expected given the existing distribution of technical activity.

The strongest evidence of the localization of knowledge spillovers is in the simple observation that innovative activity is concentrated geographically. Examples of geographic clustering in innovative industries include computer operating systems in Washington, word processing and networking in Utah, spreadsheets in Massachusetts, industrial applications of optics in upstate New York, and, of course, semiconductor design in Silicon Valley [Krugman (1993)].

Public Policy Implications

In the language of economics, there are positive externalities associated with the production of knowledge. One implication of this feature of knowledge production is that self-interest will provide insufficient incentive for individuals to optimally invest in the creation of knowledge. This is especially true of basic research where commercial development of research findings may cross many organizational and industrial boundaries and may take a long time to be realized. It can be argued that optimal public policy for basic research involves public support of research effort with the findings made open and available to anyone.

There are also important implications of knowledge spillovers for the location of innovative activity. The fact that knowledge spillovers are predominantly local gives rise to the phenomenon in economic geography of innovative clusters and local innovative networks. When creation and innovation are a social phenomenon that involves informal relationships and extends beyond market transactions, the value of an inventor's research effort depends on the number of other inventors that are in close proximity. An inventor's ideas can be more fully developed, and he will be able to benefit from the ideas of others, if he is a part of large network of inventors.

When scale economies are external to an individual firm, but internal to the industry, market size itself becomes an important determinant of cost and productivity. The particular location of activity may be arbitrary and heavily influenced by distant historical conditions. Once a concentration of innovative activity has occurred, it is in the interest of any new inventor to locate in the same area. Growth becomes self-reinforcing. Location is no longer simply a matter of comparative advantage, and *lassiez faire* is not necessarily the best policy for a city or local jurisdiction. External economies provide an intellectually sound case for industrial policy [Krugman (1993)]. Cities with established R&D networks already enjoy the economies associated with market size and do not need public assistance. But government support of innovative activity can be justified in cities with underdeveloped research networks.

Importance of Universities in Determining the Location of Innovative Activity

While market-size effects are important in determining the location of innovative activity, there are elements of comparative advantage, or intrinsic features of a location, that can also play a role. University research programs, in particular, can have important effects on the location of innovative activity. Some research findings, especially those that are revolutionary and have the potential to create new industries, are difficult to transfer to industry without frequent face-to-face contact between university and industrial scientists. This aspect of knowledge transfer encourages corporate labs and commercial start-ups to locate near university scientists. Secondly, even though U.S. residents are highly mobile, there is still a tendency for graduates with advanced degrees to remain and work in the local area, especially when the degree-granting institution is located in a major metropolitan area. Young scientists and engineers who stay in the area help to transfer university research findings to local firms or they may work in industrial labs that create knowledge that is valuable to local businesses.

Tacit Component of Scientific Breakthroughs

Darby and Zucker (2003) have argued that “metamorphic” innovations — those associated with the creation of new industries or the radical technological transformation of an existing industry — typically are driven by breakthrough discoveries in science and engineering. Examples include integrated circuits, recombinant DNA, and nanotechnology. These kinds of discoveries are not well understood initially and cannot be codified. In the beginning, the new knowledge is largely tacit, and it is difficult for anyone other than the discoverer to see commercial value in the findings. Transfer and application to industry requires bench-level relationships between industry scientists and the pioneering scientists.

If a scientist making a metamorphic discovery has a university appointment that he wishes to maintain, and if he does not want to commute long distances, then he will serve as a fixed factor that determines the location of firms entering the market to develop the new technology. Audretsch and Stephan (1996), Zucker, Darby, and Brewer (1998), and Zucker, Darby, and Armstrong (1998, 2002) have documented the role of pioneering university scientists in the growth and geographic distribution of the American biotech industry. See Hill (2006) for a summary and review of these findings.

The period during which discovering scientists play a major role in transferring new knowledge to industry may only last 10 to 15 years. Eventually scientific findings become codified and can be learned by graduate students at any major research university. But once an industry has been established in a given location, agglomeration economies associated with the rise of specialized suppliers or markets for specialized labor may serve to lock in an industry’s location. In this way, the initial geographic residences of path breaking researchers have a long-term effect on industry location.

Locational Persistence of Graduate Students

One of the most important contributions universities make to the national innovation system is in the training of industrial scientists and engineers. Much of the country's inventive activity takes place in industrial labs, but these labs are staffed by researchers who learned science and research methods at universities. Where these new industrial scientists end up living greatly affects the geographic pattern of the economic benefits of innovation. Industrial labs are considered prized economic development targets. The labs themselves are clean and high paying, and they can generate spin-offs and other new high-tech businesses.

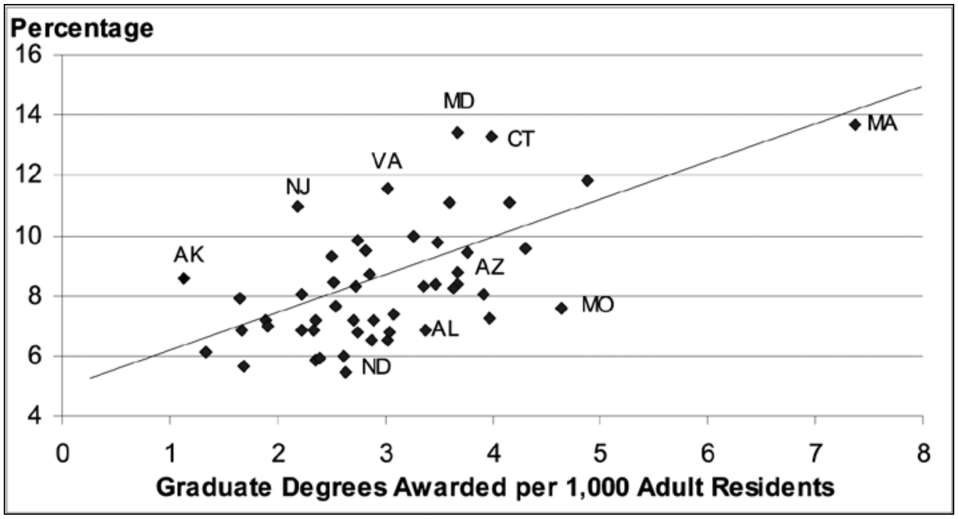
Where young scientists and engineers choose to locate depends on both demand and supply factors. On the demand side, some states have a comparative advantage in the use of highly trained workers with graduate degrees. States bordering the nation's political and financial capitals (Washington, D.C. and New York City), for example, long have been important importers of highly educated workers. Strong demand in these areas derives, in large part, from an arbitrary historical concentration of firms and institutions that make intensive use of highly educated labor.

As argued by Malecki (1987) and Malecki and Bradbury (1992), supply factors and the locational preferences of R&D workers also play an important role in the location of industrial labs. R&D operations are seriously constrained by the labor market for scientists and engineers. Availability of scientific labor is a critical locational consideration for R&D facilities, and there is an advantage to siting in an area with a research university that trains a large number of scientists and engineers. The U.S. population and educated workers especially are highly mobile. Even so, there is a high degree of locational persistence in people's decisions. People build relationships in school, relationships that have value in the workplace after graduation. Those attending graduate school also may have spouses and/or children that tie them to an area.

Data correlations suggest that university graduate programs positively affect the number of highly educated workers in the adult resident population. Figure 1 shows a scatter plot of states with the percentage of the adult population with a graduate degree plotted against the annual number of graduate degrees awarded per thousand adult residents. Data are circa 2000. Graduate degrees include master, doctorate, and professional. The percent of the population with a graduate degree was adjusted for weather, as explained in Hill et al. (2005). Weather is known to be an important amenity that affects migration decisions. States with relatively high production of degrees are disproportionately represented in the East and upper Midwest, parts of the country with a climate generally perceived to be undesirable. Because of this relationship between weather and degrees awarded, a simple correlation between degrees awarded and share of the population with a graduate degree will understate the causal role played by local production of degrees.

After adjusting for weather, there is a statistically significant and strong relationship between graduate degrees awarded in a state and the share of the state's population with a graduate degree. Based on the measured relationship, if the state of Arizona, for example, were to permanently raise the number of graduate degrees awarded from its present rate of 3.7 degrees per thousand to 4.7 degrees per thousand, the long-term effect would be to increase the share of the population with a graduate degree from its current level of 8.4 percent to 9.6 percent.

Figure 1
Graduate Educational Attainment and Degrees Awarded
Adjusted for Weather



** Percentage of population 25 or older with at least a master's degree*

Source: Calculated from U.S. Census Bureau (graduate educational attainment in 2000), National Center for Educational Statistics (graduate degrees awarded), and Rappaport (adjustment for weather).

SFAz as a State Economic Development Program

Science Foundation Arizona can be viewed as an instrument of state and local industrial policy with the goal of promoting the development of knowledge-based industry in Arizona. Because of external economies in the creation of knowledge, the location of innovative activity can be influenced heavily by arbitrary historical conditions. Cities with relatively few inventors and weak existing research networks will find it difficult to attract new innovation-based firms. An agency such as SFAz can serve as a catalyst for building innovative clusters and research networks. Since many of the truly metamorphic inventions stem from university research, it makes sense for SFAz to leverage its efforts off of the talent at the state's universities.

SFAz is not a local version of the National Science Foundation (NSF). The mission of the NSF and other federal research agencies is to support basic research: research that may at some point generate great commercial value but which may have to be developed over long periods of time across wide geographic areas. The goal of SFAz is to support research with near-term commercial value that can be developed and realized locally.

SFAz also is not simply a government venture capital fund, although it may help to attract private venture capitalists. Support provided by SFAz for research and education in the state will be in the form of grants. SFAz will not take equity positions in commercial start-ups that utilize SFAz-supported research. Nor will SFAz funds be loans requiring repayment with interest. The return to the state of Arizona will consist of economic development benefits: jobs and higher incomes that result from the attraction of corporate labs, the start-up of new high-tech businesses, and any competitive advantages enjoyed by local businesses when their technology is advanced by university research programs. The next two sections of this chapter review the evidence on the extent to which university research can generate local economic development benefits and the conditions under which this is most likely.

Evidence of Local Economic Development from University Research

Evidence of local economic impacts from university research comes from a variety of sources, including case studies of local industries born from the ideas of university scientists and econometric evidence identifying a statistical association between the level of economic activity in an area and the presence of a research university. The evidence shows conclusively that university research programs have local economic impacts, although the size of these impacts varies greatly depending on the university.

Silicon Valley and Route 128

The most highly celebrated cases of local economic development stimulated by university research are the electronics clusters in Silicon Valley, CA and the Route 128 beltway around Boston, MA. Agglomeration economies associated with knowledge spillovers and thick markets for specialized suppliers have played an important role in reinforcing industry growth in these areas. But the conventional wisdom is that the initial reason the industry took root in these particular locations is to be close to researchers and research facilities at Stanford University and the Massachusetts Institute of Technology (MIT). Local firms also were aided by a readily available supply of electrical and computer engineers graduating from nearby schools. See Dorfman (1983), Rogers and Larsen (1984), and Saxenian (1996) for a review of the origins of the electronics industry in Silicon Valley and Route 128.

Table 2 shows how dramatic an effect new industries spawned from university research can have on a local economy. To tie in with government statistics available by county, Silicon Valley is represented by Santa Clara County, CA and the electronics cluster in Massachusetts is represented by Middlesex County, MA, which contains by far the highest percentage of electronics employment of any county in the state. The data in the table show how this one industry has profoundly shaped the economic structure of the two counties. In Santa Clara County, even a narrow definition of the industry which includes only electronic and computer manufacturing, computer services, and research and development services shows that computers and electronics accounted for more than 15 percent of county employment in 2004: more than six times the share of the industry in national employment. Similarly, the industry in Middlesex County accounted for 10 percent of county employment, more than four times the national share.

Table 2
Electronics Industry in Silicon Valley and Route 128

2004	Santa Clara County, CA	Middlesex County, MA	United States
Electronics Employment:			
Total	131,077	80,527	2,854,373
Share of Total	15.4%	10.2%	2.5%
Earnings per Worker:			
Industry	$99,879	$92,920	
County	$69,107	$51,274	
State/Country	$41,820	$45,389	$36,967

The electronics industry is defined as electronic computer manufacturing (including semiconductors: NAICS 334), computer programming services (NAICS 5415), and research and development (NAICS 5417).

Source: U.S. Department of Commerce, Census Bureau, County Business Patterns, 2004.

Industries built on scientific advance not only provide growth in the local employment base but, since they employ a large number of highly skilled and educated workers, also serve to raise average earnings in the area. The average wage in the electronics industry in Santa Clara County in 2004 was $100,000, which helped to make the countywide average in earnings per worker 65 percent higher than the state average and 87 percent higher than the national average. Average earnings per worker in the Middlesex County electronics industry was $93,000, helping to raise average earnings in the county 13 percent above the state average and 39 percent above the U.S. average.

Silicon Valley and Route 128 represent best-case scenarios of university research promoting local economic development. There are many examples of highly prestigious research universities that have had very little impact on the local economy. Feldman and Desrochers (2003), for example, document how and why Johns Hopkins University in Baltimore, MD has had little impact on the regional economy despite a long history of substantial academic achievement. In the next section of this chapter, some of the complementary factors that may be necessary for university research to yield significant local economic development benefits are reviewed.

The Biotechnology Industry

Biotechnology offers the most recent example of an important new industry built directly on basic scientific research in which commercial firms are known to have close ties to university-based scientists. Zucker, Darby, and Brewer (1998) were among the first to systematically test for a geographic coincidence between new biotechnology firms and university scientists who made early contributions to gene sequencing. The geographic units in their study were the 183 functional economic areas defined by the Bureau of Economic Analysis. The authors first identified a set of 327 “star” scientists who were highly productive in discovering gene sequences, e.g., each had discovered more than 40 gene sequences by 1990, as reported in *GenBank*. These star scientists represented only 0.75 percent of the authors in *GenBank*, but accounted for 17 percent of the published articles — 22 times the number of the average author. Zucker, et al. found the location of star scientists who were active in gene sequencing research between 1976 and 1980 to be a powerful predictor of the geographic distribution of biotech firms in 1990.

Another early paper on links between biotech companies and pioneering scientists is Audretsch and Stephan (1996). Their analysis differs from that of Zucker et al. in that by examining the prospectuses of biotech companies that made an IPO in the early 1990s, they are able to identify and determine the nature of specific affiliations between university-based scientists and biotech firms. Audretsch and Stephan found that relationships between scientists and firms are not always local, and the degree to which firms rely on local scientific talent varies. Approximately one-half of the university scientists who have affiliations with Boston-area biotech firms have appointments with Boston-area universities. Firms in San Diego and New York, on the other hand, draw only one-quarter of their university scientists from local universities. Audretsch and Stephan conclude that while geographic proximity between university scientists and biotech firms has been important, other factors, such as those related to agglomeration, also have played an important role in the siting of firms.

Audretsch and Stephan hypothesize and find support for the idea that whether a university-based scientist works locally or has a long-distance affiliation with a biotech firm depends on personal characteristics of the scientist and the nature of the services he provides to the firm. If the scientist is a star, in the sense that he has received a Nobel Prize, he is more likely to work with a local firm. Star scientists have more “drawing power” which allows them to attract venture capitalists and other key members of high tech start-up companies. Audretsch and Stephan also found that local affiliations are most common when the service provided by the scientist is one of knowledge transfer. It is less important for a university scientist to live in the same area as the firm if his primary function is to signal the quality of the firm to the scientific and financial communities.

Location of Corporate Innovation and R&D Labs

A number of authors have used econometric techniques to empirically test for a geographic coincidence between university research and corporate R&D activity. Industry labs directly promote local economic development by providing high-paying jobs for scientists and technical workers. They also may generate competitive advantages for local producers who make use of the innovations coming out of these labs.

Jaffe (1989) used state-level data covering 29 states and eight years from 1972 through 1981 to relate the number of patents assigned to corporations in a state to the quantity of industry R&D and university research in the state. Jaffe found a large and statistically significant effect of university research on corporate patent activity. His results indicate that the direct impact on corporate patenting per dollar of research expenditure is two-thirds as large for university research as it is for industry R&D. Jaffe found university research to have an even larger indirect effect on corporate patenting in that university research expenditures induce corporate R&D expenditures. His estimates suggest that the indirect effect of university research on corporate patents is six times as large as the direct effect.

Anselin, Varga, and Acs (1997) use the same model as Jaffe to represent the relationships between corporate innovation, corporate R&D, and university research. Counts of innovation are measured, however, using data from the Small Business Administration on the number of new high-technology products introduced into the U.S. market in 1982. The SBA data were compiled from an extensive review of new product announcements in trade and technical publications. Anselin et al. were able to sharpen the geographic focus of Jaffe's analysis by using professional employment in private high-tech research laboratories as a proxy for corporate R&D activity. The employment data were aggregated to the metropolitan area level. Anselin et al. also were able to control for agglomeration economies by including in their regressions local high-technology employment, a location quotient for high-tech employment, and local employment in business services. The final data set consisted of a cross section of 125 metro areas for which there were positive values for innovations, corporate R&D activity, and university research expenditures. The findings of Anselin et al. generally confirm the earlier results of Jaffe, but for a finer level of geography. University research has a positive and significant effect on local corporate innovation, both directly and through its effect on private R&D activity. The inclusion of agglomeration variables significantly reduces the estimated coefficient for private R&D effort but has only a small effect on the coefficient for university research.

Bania, Calkins, and Dalenberg (1992) examined the role of university research and other factors in determining the geographic distribution of industry R&D activity. R&D activity is measured by the number of people with doctoral degrees working in industry labs. The geographic unit of analysis is the metropolitan area, and the data are for 1986. Bania et al. found that university research expenditures have a statistically significant effect on R&D doctorate employment. The estimated effects are fairly small, however. A 10 percent increase in university research spending generates only a 0.4 percent increase in doctoral employment. One of the other variables included in the regression is the percentage of the population with four or more years of college. Thus the measured contribution of university research to industry R&D activity may not include the potentially significant effect that research universities have on the education level of the local workforce.

Firm Start-ups

In a broad test of the effect of university research on local economic growth, Bania, Eberts, and Fogarty (1993) examined the number of start-ups of new manufacturing firms in 25 large metropolitan areas over the period from 1976 through 1978. Bania et al. try to explain firm births using an econometric model with both traditional business climate variables, such as labor costs and taxes, and variables relating to knowledge infrastructure, including university research expenditures and the percent of employed workers who are scientists or engineers. The authors found mixed evidence for the effect of university research on new company start-ups. University research had a positive and significant effect on new business formation in the electronics industry. But university research was statistically insignificant for instrument manufacturing and for four other manufacturing industries.

The authors conjectured that the reason their strongest findings were for electronics was because their period of study coincides with the emergence of the electronics industry. They offer these results as evidence supporting the theory that the local impacts of university research are greatest in newly emerging industries.

One final note on all of the econometric studies reviewed above: they all seek to measure the local economic impact of university research using a broad measure of research effort — much of which has no deliberately practical or local orientation. SFAz programs likely would have greater local impacts simply because research support would be more selective and focused on proposals with a high likelihood of local commercial success.

Conditions Favoring the Localization of Benefits from University Research

Two universities with research programs that are similar in scale and quality may have very different local economic impacts. MIT and Harvard University have had huge documented effects on the Boston area economy. However, Johns Hopkins University, which is routinely among the largest recipients of federal government research funds, has failed to stimulate significant high-tech production in the Baltimore area. Stanford University and Duke University each had sponsored research expenditures of over $350 million in 1997. But Stanford generated 25 start-up businesses from university-licensed technology while Duke generated no start-ups [Di Gregorio and Shane (2003, p. 209)]. Clearly, high research activity is not a sufficient condition for a university to have large impacts on jobs and incomes in the local economy. This section reviews what is known about other complementary factors that may need to be present if a university's research and its graduate programs are to generate significant local economic impacts.

Quality of University Research and Graduate Programs

There are several reasons to think that universities with the greatest local economic impacts are those with the highest quality research and graduate programs. First, as argued by Zucker, Darby, and Brewer (1998) and Darby and Zucker (2003), the most compelling reason for new firms to locate near universities is to facilitate tacit knowledge transfer from faculty who are on the cutting edge of scientific breakthroughs. In metamorphic scientific discoveries, knowledge is embodied in the intellectual capital of the discovering scientists and only can be transferred to industry through active working relationships with these scientists. It is only the leading-edge researchers in these metamorphic discoveries that have the power to determine firm location.

A second reason for why star academic researchers are the ones most likely to be successful in attracting new industry to an area is what Audretsch and Stephan (1996) refer to as "drawing power." University researchers with a national reputation or researchers from an eminent university serve as a signal of quality which helps to attract resources such as venture capital, management, and technical workers that are necessary to start up new companies.

Finally, Malecki (1987) argues that availability of science and engineering workers is an important determinant of the location of industrial R&D facilities. But he notes that firms are particular about the institutions they rely on for new researchers and that, especially among large firms, only the best graduate programs are an attracting factor. While top university researchers generally go hand in hand with top graduate programs, the locational attractiveness of universities as stressed by Malecki has more to do with graduate programs than with faculty research per se.

There is empirical support for the idea that the size of the impact of university research on the local economy depends on the quality of the university's faculty and graduate programs. The strongest evidence comes from the study of specific industries known to rely on university research for technical advance. In their study of the biotech industry, Zucker, Darby, and Brewer (1998) focused on academic "stars" that were highly productive in gene sequencing research. It was this small group of star performers who best predicted the geographic distribution of commercial biotech firms. Zucker et al. also found that the quality of academic departments especially relevant to the biotech industry (such as biochemistry, cellular biology, and microbiology) had a positive effect on the birth of commercial firms in an area, apart from the number of star researchers in those departments. In their own study of the biotech industry, Audretsch and Stephan (1996) found that university faculty who were involved with commercial biotech firms were more likely to be involved with local firms if they had won a Nobel prize.

In an alternative test of the importance of university quality, Di Gregorio and Shane (2003) analyzed the number of new firms founded from university-assigned patents at 116 universities over the period from 1994 through 1998. The focus of their study was local economic activity since start-up firms who license university technology tend to locate in the same area as the licensing institution. Among the factors examined as possibly being related to local economic activity was the intellectual eminence of the university, as measured by ratings of graduate schools as published in Gourman Reports. The intellectual eminence of a university was found to have a statistically and numerically significant effect on start-up activity. An increase in intellectual eminence of one standard deviation was associated with one additional start-up firm per year.

Agglomeration and Research Networks

Agglomeration economies are known to be an important factor in the production of knowledge. First, spatial concentration of research activity promotes the development of markets for specialized suppliers. A notable strength of the research complex in Silicon Valley, for example, is the availability of specialized firms that manufacture capital equipment, specialty chemicals, and other items necessary for the testing and development of semiconductors [Saxenian (1996)]. As another example, a concentration of biomedical research activity in an area helps to support a local market for law firms that specialize in intellectual property protection for biomedical technologies [Bania, et al. (1992)]. Secondly, agglomeration in research activity facilitates the matching of jobs and workers in specialized labor markets for scientists and engineers. Finally, a spatial concentration of research workers promotes informal channels of knowledge transfer. Knowledge spillovers are considered to be another strength of the decentralized network of firms doing semiconductor research in Silicon Valley [Saxenian (1996)].

It stands to reason that university research will be more productive and more likely to influence local economic activity if it takes place in an area with a large existing concentration of research activity or high-tech production. Audretsch and Stephan (1996, p. 645) provide evidence of this effect in their study of university-firm associations in the biotech industry. They find that for faculty located in the three regions with the highest number of university-firm relationships (San Francisco, Boston, and San

Diego), 65 percent of their associations are with biotech firms in the same area. On the other hand, for faculty who reside in the next five largest regions (New York, Philadelphia, Maryland, Houston, and Dallas), only 28 percent of their associations are with local area firms. These data suggest that university faculty who collaborate with industry in commercial ventures are more likely to do so with local area firms if the industry has a significant local presence. Otherwise, faculty involvement will be long distance. As noted by Audretsch and Stephan (p. 644), in firm location decisions, the benefits of proximity to university researchers to promote knowledge transfer are always being weighed against the advantages of agglomeration and being close to other firms and inputs.

In a case study of the Cleveland area, Fogarty and Sinha (1999) found that technology developed in local universities did not generate local jobs and incomes but instead was quickly diffused to Japan, California, and Texas. The authors attributed this to the fact that the Cleveland economy is heavily oriented toward mature industries and lacks the local research networks necessary to develop university technologies. Fogarty and Sinha measure the extent of local research networks by tracing the direct and indirect citations of university patents and calculating the tendency for subsequent innovations to be localized. Metropolitan areas with the strongest local R&D networks are San Francisco, New York, Boston, and Los Angeles. Areas with much weaker networks are Washington-Baltimore, Philadelphia, Chicago, Detroit, and Cleveland.

Varga (2000) provides an exacting test of the importance of agglomeration as a factor conditioning the size of the effect of university research on local innovative activity. He used an econometric model to explain variations across MSAs in counts of new product innovations made by the Small Business Administration for 1982. Agglomeration effects are identified using the amount of high-tech employment in a metro area. Using interactive variables, Varga found that university research leads to a significant number of local area innovations only when high-tech employment is at least 160,000 workers.

Large Metropolitan Areas

Economic geographers have long recognized that innovative activity tends to concentrate in large cities. One of the reasons for this may be the agglomeration effects described above. Geographic concentration of an industry serves to reduce industry costs by allowing for the existence of specialized suppliers and by promoting knowledge spillovers between workers and firms in the same industry. In an alternative view, Jacobs (1969) argued that the most important knowledge spillovers are those that occur between different industries and that large urban areas are effective in promoting these kinds of spillovers because of the diversity of economic activity made possible in large cities. Finally, Malecki (1987) and Malecki and Bradbury (1992) argued that the siting of corporate R&D laboratories is increasingly guided by the locational preferences of the science and engineering workers who staff them and that city size is an important locational consideration for these workers. Large urban areas offer amenities that professional workers value, and they make it easier for spouses to find suitable employment. Malecki (1987, p. 216) noted that city size has been found to be more important as a siting variable in high-tech studies than low taxes or low wages and argues that much of this has to do with the appeal that large cities have for professional and technical workers.

A positive relationship between innovation and city size is apparent in patent data. Cities with 1 million to 4 million people produce twice as many patents per person as do cities with a population between 50,000 and 250,000. New product innovations also are introduced disproportionately by firms in large metro areas. In the 1982 SBA data, for example, metro areas accounted for 96 percent of product innovations but only 30 percent of the population [Feldman and Audretsch (1999, p. 415)].

Whatever the forces at work, it may be difficult for university research to stimulate additional local innovative activity if the university is not located in a large urban area.

Venture Capital

Venture capitalists often play an important role in the start-up of science-based companies. Venture capitalists not only provide risk capital, but they also help to connect company entrepreneurs with management teams, key technical employees, suppliers, and customers. Unlike other financial markets, venture capital markets tend to be local. Because of the uncertainty associated with new inventions and information asymmetries between entrepreneurs and venture capitalists, it is important for venture capitalists to closely monitor their investments. Geographical proximity helps to reduce the costs of monitoring. Also, the network of contacts that venture capitalists provide to firms is more easily maintained in a local geographic area [Di Gregorio and Shane (2003)].

Availability of venture capital then would seem to be an important conditioning factor when assessing the potential impact of university research on local business activity. While much empirical support exists for the idea that venture capitalists impose geographical constraints on new high-tech businesses, there is also evidence that venture capitalists can be drawn to a new area if that area is home to a star scientist or an eminent research program. Zucker, Darby, and Brewer (1998) found that availability of venture capital had no significant effect on the location of new biotech firms once they had accounted for the geographic distribution of star scientists and highly rated science departments. They argue that since venture capital firms have located around great universities, a failure to account for the drawing power of the university, its faculty and students has led to an overestimation of the importance of venture capitalists. Di Gregorio and Shane (2003) also found that availability of venture capital had no effect on Technology Licensing Office (TLO) start-ups. Among the control variables in their study was the intellectual eminence of the university.

Rating the Phoenix Metropolitan Area

The evidence presented in the previous section suggests that university research is most likely to have significant local economic development impacts when several conditions are present simultaneously, particularly highly rated faculty and graduate programs in fields most directly related to high-tech industry, and a location in a large metropolitan area with an existing concentration of industrial labs and high-tech manufacturers. In general, statistics on these attributes show that Phoenix rates highly among U.S. metro areas in all categories related to engineering: university R&D spending in engineering fields, the quality of local area engineering departments, and the number of nonuniversity engineers who work in the area. However, Phoenix has only a small amount of life science research activity at the present time. Working against the metro area in this regard is the fact that the state's major medical school is located in Tucson.

Industrial labs and high-tech start-ups are more likely to locate near a university if faculty are leading contributors to new research areas with great commercial potential and/or if the university has a top-notch graduate program. One highly regarded, although somewhat dated, study which ranks the quality of university departments is the 1995 National Research Council study of research-doctorate programs in the United States. (A survey administered in 2006 with findings scheduled to be available beginning late in 2007.) Based on the 1995 study, Arizona State University did not have any life science departments that were rated among the country's top 40. However, ASU did have three engineering programs that were rated in the top 40: materials science (rated 27th), electrical engineering (tied for 36th), and mechanical engineering (tied for 36th).

Agglomeration economies are important in the production of knowledge and can be a critical factor in the location decisions of high-tech firms. One way to measure the scale of existing innovative activity in a metro area is by the number of science and engineering workers employed outside of colleges and universities. These figures are shown in Table 3. Phoenix ranks 11th among the largest 25 U.S. metro areas in terms of number of engineers employed. This is not surprising given the well-known importance of electronics firms in the area. Phoenix has very little science-based research activity, however. Phoenix employs only 2,100 life and physical science workers, which places it 24th on the list. These figures are not adjusted for population; the Phoenix metro area ranks 13th.

Table 3
Science and Engineering Employment in the 25 Largest Metropolitan Areas

2005	Total Number	Rank	Scientists Number	Rank	Engineers Number	Rank
New York NY	69,800	1	24,590	1	45,210	2
Los Angeles CA	69,200	2	12,440	5	56,760	1
Washington DC	66,620	3	23,280	2	43,340	3
Boston MA	56,620	4	13,420	4	43,200	4
Chicago IL	48,930	5	9,230	7	39,700	5
Houston TX	46,020	6	8,660	8	37,360	6
Dallas TX	37,920	7	4,290	16	33,630	8
San Francisco CA	37,690	8	13,460	3	24,230	10
Detroit MI	36,820	9	2,120	23	34,700	7
Philadelphia PA	32,230	10	7,050	9	25,180	9
San Diego CA	28,670	11	9,240	6	19,430	12
Minneapolis MN	25,260	12	6,900	10	18,360	13
Phoenix AZ	23,170	13	2,100	24	21,070	11
Seattle WA	22,240	14	5,700	11	16,540	15
Atlanta GA	22,040	15	4,640	15	17,400	14
Denver CO	21,030	16	4,650	14	16,380	16
Pittsburgh PA	17,970	17	4,990	12	12,980	17
Balitmore MD	17,330	18	4,940	13	12,390	19
Miami FL	16,600	19	3,670	17	12,930	18
Portland OR	13,430	20	2,440	21	10,990	20
St. Louis MO	12,360	21	3,490	18	8,870	23
Cleveland OH	12,340	22	1,630	25	10,710	21
Cincinnati OH	11,790	23	2,650	20	9,140	22
Riverside CA	9,250	24	2,750	19	6,500	25
Tampa FL	8,930	25	2,150	22	6,780	24

Workers classified as scientists are included in occupational codes 191 and 192; engineers are included in code 172.
Source: U.S. Department of Labor, Bureau of Labor Statistics.

Although the evidence is mixed, availability of venture capital is widely considered to be a potential constraint on innovation-based business in a local economy. Universities located in cities without a significant number of venture capital firms may find it more difficult than otherwise to generate local economic activity from their research. Data on venture capital funding from 2001 through 2005 show that the Silicon Valley received a staggering one-third of U.S. venture capital. Another region that stands out is the Boston area, accounting for 13 percent of U.S. venture capital. Other regions accounting for more than 5 percent of the national total were the New York metro area, the state of Texas, and the Los Angeles-Orange County area.

The state of Arizona absorbed only 0.6 percent of U.S. venture capital funds. Colorado, a state that is comparable in size to Arizona, received five times the amount of venture capital that Arizona did. Scarcity of venture capital may be an impediment to university-driven economic development in Arizona. But evidence from other regions suggests that this bottleneck can be overcome if universities and their faculty have enough of a national reputation to attract venture capital from outside the local area.

Some Final Cautionary Remarks

Economists generally are critical of efforts by governments to target particular industries for public support (industrial policy). One reason is that industrial policy often is thought to be flawed in principle. In a free market, private incentives are sufficient to guide resources to their highest valued use. Private investors are already motivated to seek out the highest possible rate of return. There is no reason to think that a government can do any better than the market when trying to "pick winners." As argued in this chapter, however, free market outcomes are no longer necessarily optimal if there are external economies. When firms cluster together to enjoy the mutually reinforcing effects of knowledge spillovers, for example, the particular location of the group may not necessarily minimize industry costs, but instead may be the result of arbitrary historical conditions. A new semiconductor firm that chooses to locate in Silicon Valley pays a very high price in land and labor costs to be near other semiconductor firms. It makes sense for the firm to locate there. But industry costs might be reduced if the industry could be relocated. There is a sound intellectual basis for local industrial policy efforts such as *Science Foundation Arizona* that seeks to catalyze the formation of innovation-based industry in Arizona.

A second reason why many economists are skeptical of industrial policy is that it is flawed in practice. In choosing industries to target for support, governments may be guided by the pressures of special interest groups or, in a worst-case scenario, by sheer corruption. There must be safeguards in the process for allocating SFAz grants to ensure that the process is objective and rationally guided. One potential pitfall and source of political conflict is in the regional allocation of funds within Arizona. It will be politically tempting to try to distribute the economic development benefits of SFAz projects widely across the state. Yet it can be argued that the most effective environment for innovative activity is in large metro areas. In many cases, the Phoenix metro area may have a decided advantage as a site for SFAz research projects — as an urban area large enough to support a network of specialized suppliers of research support services and large enough in size and diversity to attract scientists and inventors. Another political temptation will be for SFAz to support projects that align with the interests of the state's existing electronics firms. Arizona, and the Phoenix metro area in particular, are already well-endowed with electronics firms, especially those related to semiconductor production. It is hard to argue that the semiconductor industry needs a boost from SFAz in order to achieve critical scale economies. The best argument for SFAz is as a catalyst for innovative activity that may be well-suited to the state but simply lacks market size at the present time.

A final concern to be noted involves tradeoffs that have to be made in choosing research projects on the basis of how local their operations will be. The return to SFAz funds is expected to be realized in terms of local economic development. Obviously, if the project of a local university faculty member is funded but he spends most of his time out of state collaborating with scientists in other states or countries, most of the knowledge spillovers that accrue through personal interactions will leak out of the state. At the same time, however, it would be a mistake to establish strict standards of local content for the execution of funded research. Some critical research functions may be best outsourced.

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CHAPTER 2

Economic Effects Of University Research

A Summary of the Findings of Chapter 2

Studies and academic articles relating to the economic effects of university research are reviewed in this chapter. The economic impact of research expenditures is distinguished from an assessment of the knowledge created by that research. Most "impact" studies, which estimate jobs, wages and output of research spending, simply follow the money through the economy as the research dollars are spent on wages and purchases in the local economy.

In addition to circulating money throughout the economy — creating jobs, wages and sales — university research creates a substantial amount of knowledge, as measured by inventions, patents and licenses. This knowledge, in turn, creates jobs.

Knowledge creation itself generates jobs in a variety of ways. Licenses, start-ups and spin-off companies can have a substantial and long-lasting impact on the economy. A study of research universities in Utah demonstrates that these firms can have an economic impact each year that is at least as large as the economic impact of the research expenditures themselves. University research expenditures spill over to private-sector research activities, having significant impacts on both the level of industrial R&D and industrial patents, creating innovations and jobs in both the local area and the surrounding region (up to a 150-mile radius).

In addition, human capital created through the education programs affect the formation of new firms, which in turn affect regional growth rates. When founders of small companies are trained in a technology or engineering field, those companies grow comparatively faster than other companies. The presence of key researchers, a.k.a. star scientists, also has been found to increase firm entry.

University research funding has been shown to have positive effects on overall economic growth either directly or through human capital formation or via the effect of research on new firm formation. University research has also been linked to increases in productivity and wage rates. A distinction should be made between assessing the impacts of university research spending and the knowledge created by a university.

University research affects regional, not just local, innovations. Thus, the knowledge-based economy created from university research is not limited to just the county in which the research takes place. However, these regional impacts are geographically limited and proximity to the university research does matter as it relates to how university research expenditures impact innovations.

Universities are recognized not only as centers of learning, research and innovation, but also as important engines in regional economic development. Often major employers in local economies, universities support numerous local vendors through purchases of goods and services for their daily operations, and create additional jobs in various sectors of the local economy through employee and student spending. They also attract numerous visitors and thus contribute to the local tourism industry.

Universities produce highly skilled, highly educated human resources and nurture innovation and technological change, all of which are important as regions and localities compete for investment and high-wage jobs in a global economy. As centers of innovation, universities attract funding for research and development, and thus inject new money into local economies. Transfer of technology from university labs to the private sector and creation of new firms are additional aspects that are gaining attention among regional economic developers.

While the wide range of local economic and revenue impacts that emanate from universities is becoming better appreciated, no single comprehensive method exists for quantifying all components of these impacts. Yet there is a growing need to quantify the roles of universities in the local economy, which are often reduced to simple measures of new jobs, wages and tax revenue. This trend in part demonstrates an increasing public scrutiny of, and demand for, assessment of return on investment in higher education. It also reflects a growing need on the part of universities to better understand their changing roles in the economy at large and to attract additional funding as state support for higher education continues to tighten.

This chapter first examines the effect of outside research dollars on a local economy. Then that information is supplemented from other studies to expand the analysis to include such items as patent generation, royalties, start-up companies, regional growth and well-being.

Including only those components that can be empirically measured a conservative estimate of the induced returns within the state of Arizona for an annual, hypothetical public investment of $10 million could be as high as an additional $76 million per year. That would be possible even when only a portion of the expected social benefits is included in the calculations. The estimates are linear and the $10 million dollar example is for illustration purposes. Hence, a $100 million investment would have impacts that are higher by a factor of 10.

Input-Output "Multiplier" Impacts of Research Expenditures

University impact studies and analyses of university research expenditures typically use input-output models to create economic "multipliers" associated with those expenditures. Multipliers are used to estimate the indirect and induced economic impacts associated with direct research expenditures. The direct effects are sales, income, employment and employee compensation generated directly by the research dollars, such as university employment and wages. Indirect impacts are the sales, income, employment and employee compensation that result from firms in the local economy selling to the university, such as suppliers of laboratory equipment or office supplies, patent attorneys, or other research-related services. Induced effects are the sales, income, employment and compensation that result when the workers at the university and in those industries that sell to the universities spend their money.

Charney and Pavlakovich in 2003 estimated that each $10 million in research spending created the following economic impacts in Arizona:

- 334.5 jobs
- $13,500,000 in total sales (output)
- $8,650,000 in wages
- $452,000 in state revenue.

As these figures indicate, by the time research dollars circulate through the state creating additional rounds of economic activity, 86.5 percent of each research dollar ultimately flows through the pockets of Arizona workers.

Research dollars have a powerful economic impact on the state's economy. But these estimates only "follow the money." Studies that use input-output models or multipliers only measure economic activity that stems from the backward linkages (interindustry firm linkages) that are related to the actual spending of research dollars. They fail to consider the unique qualities of knowledge as a product of universities and essentially treat universities no differently than other kinds of organizations that hire and pay workers and purchases supplies and equipment both locally and outside the region. Thus, these studies do not consider the other benefits of research dollars, such as royalties, start-up companies, new technologies, improvements to human and physical capital (including the training of additional scientists), or the dissemination of knowledge. In the following sections, an attempt is made to broaden this "follow the money" approach.

For several reasons, the "follow the money" impacts outlined above do not include impacts associated with state and local funding for research. First, research is an integral and inseparable part of the educational function of the university. Funds used to pay a professor who both teaches and conducts research cannot be allocated perfectly between the two functions, particularly when the research function plays a critical role in bringing students to the forefront of a discipline. All research dollars, whether state government funds or research grants, are inherently educational dollars as well. It must be noted, however, that without the state-supported research and teaching functions of Arizona's universities, attracting the hundreds of millions of dollars in outside funding would be virtually impossible. State money spent on education and research acts as seed money that can be leveraged to bring in several times that amount in outside funding.

Second, state money comes with an opportunity cost in the sense that the government can either fund the educational/research function of a university, use the money on other state government services, or give it back to taxpayers. Therefore, in assessing statewide impacts of state dollars, the impacts of alternative uses of those dollars may have to be considered. However, few other state functions can leverage state dollars to bring in additional federal dollars (the exception being certain matching programs, such as in health and human services). Dollars spent by Arizona residents do not leverage outside dollars, and purchases of consumer goods rarely leave 86 percent of those dollars in the pockets of Arizona workers. Also, consumer purchases do not have the other types of broad economic impacts that universities and university research can bring to a community, as detailed in the following sections.

Patents, Royalties, Start-ups and Licenses Connected to Universities

The Association of University Technology Managers (AUTM) conducts an annual survey of U.S. and Canadian universities and U.S. hospitals and research institutes. The overall response rate was 65 percent (232 responses), including an extraordinarily high response rate of 96 percent from the top 100 research universities.

Research expenditures for U.S. research institutions that reported for fiscal year 2004 totaled $41.2 billion. During the same fiscal year, U.S. institutions reported receiving 16,871 invention disclosures, filing 10,517 new patent applications, filing a total of 13,803 patent applications (sometimes applications are filed more than once), receiving 3,680 patents, and executing 4,783 licenses and options. Table 4 summarizes these activities per $10 million of research expenditures.

Between 4.0 and 4.3 invention disclosures were received per $10 million in research expenditures in each of the five years through fiscal year 2004. Similarly, each $10 million of research resulted in 2.1 to 2.6 new patent applications and 0.9 to 1.3 U.S. patents issued. Each year, 1.2 to 1.4 licenses and options were executed per $10 million in research. Of those, approximately 62 percent are expected to stay active over time, resulting in 0.7 to 0.9 licenses and options that are likely to stay active over time for each $10 million in research. Of the licenses and options executed in fiscal year 2004, 14 percent were with start-up companies (companies that have been started specifically to take the license/product to market), 54 percent were with small firms (employing less than 500) and 32 percent were with large firms (employing 500 or more).

It must be noted that these figures are averages across many U.S. institutions and any given institution may not produce the same numbers of disclosures, patents and licenses. In addition, it must be noted that there are time lags between when research occurs, when invention disclosures are made, when patents are applied for and received, when licenses and options are executed, and when companies can bring a product to market. In the table, each listed item was divided by the same fiscal year's research dollars (for example, FY 2004 licenses and options executed were divided by total research dollars in FY 2004). It is likely that licenses and options executed in 2004 were based on research that took place in previous fiscal years. Because the average time lag between research dollars spent, disclosures and execution of licenses and options is not known, the same fiscal year research dollar figure was used as the divisor. Thus, the numbers in Table 4 should be thought of as the approximate number of annual patents and so forth from a sustained $10 million of research money. It also should be noted that a slight downward trend in the measures presented in Table 4 is inevitable because inflation erodes the purchasing power of research dollars, but the other concepts in the table (such as disclosures and patents) are *real*, not monetary, concepts.

Thus, these research dollars — in addition to flowing through the economy, generating direct, indirect and induced economic effects — also are creating new knowledge, new intellectual property, new products and new firms.

Table 4

Research Institution Activity per $10 Million of Research Expenditures

	Fiscal Year				
	2000	**2001**	**2002**	**2003**	**2004**
Invention Disclosures Received	4.29	4.21	4.11	4.03	4.09
New U.S. Patent Applications Filed	2.18	2.13	2.09	2.06	2.55
Total Patent Applications Filed	3.43	3.56	3.49	3.45	3.35
U.S. Patents Issued	1.28	1.18	1.00	1.02	0.89
Licenses and Options Executed	1.44	1.24	1.23	1.17	1.16
Percentage to Start-Up Companies					14.2
Percentage to Small Companies					53.6
Percentage to Large Companies					32.2
Licenses and Options Likely to Stay Active	0.91	.78	.78	.74	.73
Start-Up Companies Formed at Institution	0.15	0.14	0.11	0.10	0.10

Source: Calculated from Association of Technology Managers, U.S. Licensing Survey.

University Spin-Offs and Technology Licensees: Utah Case Study

Unfortunately, the information provided in the AUTM survey cannot be used to determine how new disclosures, patents, and licenses and options issued are related to additional jobs, wages and sales. However, the economic impact study of Utah's public research universities that was conducted at the University of Utah (Crispin-Little, 2005) took the analysis a step further than most economic impact studies.

Sixty-two Utah-based firms were identified that either were licensing university technology or could trace their roots to university research. The list included firms that license university-developed technology, as well as start-ups and spin-off companies. Start-up companies are companies that are formed in order to take a new license/product to market; spin-off firms are firms typically established by faculty who use their expertise and knowledge but who are not necessarily purchasing patent rights. It should be noted that any such list would not be totally inclusive. Identifying university-related start-up firms from the past is extremely difficult and identifying spin-off firms is even harder because no formal contractual technology transfer ever was involved. Thus, the Utah researchers likely underestimated the number of these firms.

Companies ranged in size from one-person operations to firms employing more than 1,000 people. In all, these 62 firms directly employed 4,941 persons and paid $223.2 million of wages. Thus, on average, these licensee/start-up/spin-off companies employed 80 people and paid $3.6 million in wages. Using the "follow the money" approach on these 80 jobs and applying multipliers, the Utah study estimated that each licensee/start-up/spin-off firm created on average 215 jobs and $7.5 million in wages.

Utah's two research universities spent approximately $414 million on research in 2003. Scaling this figure down to the $10 million frame of reference used above, each sustained $10 million (in inflation-adjusted terms) of Utah's research created 119 jobs in direct spin-offs/start-ups/licensees and $5.4 million in wages. If the multipliers calculated in the Utah study are used, these figures become 321 jobs and $22.3 million in wages per $10 million in sustained research effort. Thus, Utah's data implies that the impact on employment and wages directly or indirectly connected to the university via spin-offs, start-ups and licenses is as large as the impact of the university research spending itself.

No study of Arizona has been done that identifies firms that are directly related to Arizona's research universities, although it is known that many licensee/spin-off/start-up companies exist because of universities. But even adding licensee companies, start-up companies that use licensed technology, and spin-off companies started by university faculty, the result would represent a serious undercounting of the impacts universities have on their economic environment. In particular, firms often locate in regions because of the existence and/or quality of an area's research universities. In addition, graduates of universities can start companies that neither license university technologies nor involve faculty members, but which provide excellent employment opportunities in the area.

Spillovers from University Research to Private-Sector Research and Development

Spillover refers to university research effects that are much broader than just the licenses, start-ups and spin-offs directly associated with research dollars and faculty at the university. In particular, Jaffe (1989) found that university research dollars increase both the level of corporate research and development (R&D) expenditures and the number of patents received by corporations in the same state. His study did not measure simply the patents/licenses held by a university as they relate to university research; rather he related university research dollars to private research dollars and private patents. He measured a causal relationship between university research expenditures and private-sector R&D and patents that is not captured solely within the university research metrics of patents and licenses. Although assessing causality can be difficult, his conclusions are that university research affects industry R&D, but not vice versa. Thus, writes Jaffe, "A state that improves its university research system will increase local innovation both by attracting industrial R&D and augmenting its productivity."

Jaffe's estimated effects are even stronger when specific industries are isolated. He found the university research effects on corporate patents were highest for medical and drug-related research; electronics, optical and nuclear-related research; and chemicals (excluding drugs). For the three broad categories, elasticities ranged from .09 to .30, depending on the category and the estimated equation. Thus, when a state's university research dollars increase by 10 percent, corporate — not university — patents increase by 0.9 percent to 3 percent, depending on the sector and which of the estimated relationships are used. Jaffe found an elasticity of 0.7 for corporate R&D as it relates to university research. Thus, a 10 percent increase in university research dollars increases corporate R&D by 7 percent within the same state. While that may not seem substantial, corporate R&D expenditures are approximately six times higher than university expenditures, on average. In terms of dollar change, an increase in university research expenditures would increase private-sector R&D expenditures by 4.2 times the dollar increase in university expenditures, on average.

Jaffe's analysis is considered a seminal work and a substantial amount of research has been built on it. In recent years, there has been a renewed attention to the geographic scope of the spillovers between knowledge creation and productivity. As Anselin et al. (1997) discuss, "Universities play a central role in this [technical innovation process], not only as producers of basic research, but also by creating human capital in the form of higher skilled labor. ...The importance of basic (university) research in the stimulation of technological innovation (and higher productivity) is derived from the public good nature of the research, and the resulting positive externalities to the private sector in the form of knowledge spillovers" (p. 423).

Anselin et al. (1997) and Feldman and Florida (1994) used a count of innovations, rather than patents or private R&D expenditures. This relatively old dataset (1982) was compiled from a U.S. Small Business Administration Innovation Database. Feldman and Florida (1994) estimated innovations from university research expenditures, industry research expenditures, the presence of business services, the presence of a related industry, an index of concentration, and measures to control for the size of a state (population was used as a scale variable). They found that university research and private-industry research both positively affect the level of innovations. They also found that university research expenditures and industry research expenditures positively influence each other, but the magnitude of the effect of university research expenditures on private research is substantially larger than the other way around. They did not do a formal causality test on these two variables, however.

Anselin et al. made estimates for both states and metropolitan statistical areas (MSAs); the latter is argued to be preferable for spillover assessment. Anselin et al. examined innovations in "high tech" sectors. In both the state analysis and MSA analysis, they found that university research expenditures significantly contribute to the level of innovations within the same county and spill over into surrounding counties by increasing innovations there as well. Using the MSA data, they also found that university research expenditures significantly affect the level of private research, but only within the same MSA (no spillover effects into other MSAs). Like Jaffe (1989), they found that the effect is one-directional: university research dollars affect private research activity, but not the other way around.

More recently, Anselin et al. (2000) applied the same model to estimate geographic spillover effects from university research expenditures on innovations in specific industries. They found that university geographic spillovers seem to be very specific to certain industries. They found no spillover effects in the drugs and chemicals (Standard Industrial Classification 28) or machinery (SIC35) groups, but found very strong and significant university research geographic spillover effects in the electronics (SIC36) and instruments (SIC38) groups. For these groups, university research extends the effects of university research dollars beyond the boundary of a MSA to a 75-mile range from the central city. Bania et al. (1992) also found that university research activity attracts industry research activity. In addition, the level of education of the workforce (in particular, the portion of the workforce that is college educated) is an important factor in the location of research activity.

New Firm Formation, Human Capital and University Research

The discussion so far has dealt only with (a) spending impacts of university research, (b) patents/ licenses at universities, (c) firms directly connected to universities in some way (licensees, start-ups or spin-offs), and (d) patents/research in the private sector associated with university research. These effects fall not only within the counties in which the university research expenditures are made, but also create spillover effects to surrounding counties. There are also studies that consider the broader implications of university research on economic activity.

Small firms and firm "births" make a significant contribution to economic growth as measured by net new job creation, as shown empirically by a substantial number of researchers (including Almus and Nerlinger, 1999, and Kirchhoff et al., 2002). In addition, Wennekers and Thurik (1999) found that among small firms, newly formed firms create the largest share of net new jobs. And, among newly formed firms, highly innovative new firms create a disproportionately greater share of net new jobs than those of new firms with lesser innovative intensity (Kirchhoff, 1994). Thus, it is important to understand whether links exist between new firm formation and human capital or between new firm formation and research expenditures.

Bania, Eberts and Fogarty (1993) found that university research significantly affects new business startups for 19 high-technology industries within the electrical and electronic equipment SIC group. This finding is consistent with the view that universities have been especially important in the development of the nation's microelectronics industry. This same study, however, did not find that university research significantly affected start-ups in other groups, such as fabricated metal products, nonelectrical machinery, transportation equipment, and instruments and related products. The authors point out that high-technology industries are contained in the electrical and electronic equipment, and instruments and related products groups. Thus, university research affected many of the industries that were considered high tech during their study period (start-ups from 1976 through 1978).

Almus and Nerligner (1999) used firm-level data and found that firms that are "new technology-based" grow the fastest and that their growth is positively affected by the human capital of the firm founder, particularly if he/she has technical or engineering skills. Reynolds et al. (1995) did not find that "knowledge/innovation" affected the rate of new firm formation, but acknowledged that the variables they used to measure that concept may not have been appropriate.

Darby and Zucker (2006) found a strong connection between university research and new firm start-ups across time and across countries. However, their measures of university research and new firm start-ups are unique. They focused on the effect that the location of star scientists — defined as those with large numbers of publications in their field — have on high-technology start-ups. Start-ups, in turn, are represented as first-time publications by individuals in firms. The star scientists who publish extensively are likely to be the same scientists who are the recipients of large grants and contracts. Thus, although there is no direct connection in this article between research expenditures and firm start-ups, the paper reinforces the logical connection between university research and new firm start-ups.

A very recent study by Woodward et al. (2006) analyzed new firm formation across U.S. counties and found that university R&D was significant and positive in its effect on high-technology firm births. They also found that the effect spills over into surrounding counties up to a radius of 25 to 145 miles, depending on whether the analysis was for total high-tech births or for subsectors within that category. The authors state that the effect is "modest," however, when compared to the effects of other independent variables, such as localization (the presence of firms similar to those being studied), urbanization (the density of existing firms of all types) and qualified labor (the portion of persons who graduated from high school). Unfortunately, this study did not ask whether the presence of the universities or their past R&D funding had anything to do with current firm densities (urbanization), the presence of similar firms (localization) or the level of human capital. Other authors (such as Jaffe, 1989, Anselin et al., 1997, and Kirchhoff et al., 2002) studied both the direct effect of university research on new firm formation and the indirect effect of research as it affects some of these other variables. It is possible that the "modest" magnitude of university R&D impact on high-tech firm births is due to the ongoing, long-term impacts of university research funding on those other variables.

Armington and Acs (2001) found that firms are more likely to form in labor market areas (LMAs) that have a high percentage of college graduates than in those LMAs with concentrations of lower-skilled workers. This is suggestive that a positive relationship may exist between the size of a region's knowledge base and new firm formation. They found that human capital, measured as the percentage of adults who are college graduates, positively and significantly impacted firm formation. They concluded that "…regions that have a high percentage of college graduates are much more likely to start businesses than those regions with high concentrations of less skilled workers" (p. 43). Their study did not attempt to link university research dollars directly to new firm growth.

A study by Kirchhoff et al. (2002) explored the relationship between university research and development activity and the local rate of new firm formation across LMAs in the United States. They argued that LMAs are the appropriate geographical detail to use to study economic development issues because (a) they encompass the entire United States (unlike metropolitan areas, which only cover large cities), and (b) LMAs link the workers to the workplace so that measures of college-educated workers (as in Armington and Acs, 2001) are linked to their work place. Kirchhoff et al. argue that the correct use of LMAs as the geographic unit is why Armington and Acs (2001) were able to identify college graduates as a determinant of a region's new firm formation and Reynolds et al. (1995) could not. Kirchhoff et al. (2002) found that university research expenditures strongly impact new firm formation. They found that the strongest effect of university research expenditures on firm formation occurred with a two-year lag, although the effects occurred as early as one year and lasted at least five years. It should be noted that their measure of firm formation included all types of firms. The new firms were described as including primary firms (which might be directly related to research, such as high-technology types of firms and spin-off firms), as well as other firms that either supply those primary firms or provide goods and services to people in the growing community.

University Research, Human Capital, Growth Rates and Other Economic Measures

In addition to finding that university research positively affected firm births, Kirchhoff et al. (2002) discovered that the number of firm births and the level of human capital (as measured by the percentage of the population with college degrees) were significant in explaining variations in LMA growth rates (as measured by employment change). However, university research expenditures were not found to be significant in the growth rate equation as long as the variable "firm births" was included. Thus, in this study, university research affects LMA growth rates via their effect on new firm formation. Universities also influence LMA growth rates through the formation of human capital. The study concluded that research universities and investment in R&D at those universities were major factors contributing to economic growth in the LMAs in which the universities were situated (Kirchhoff et al., 2002, p. 1).

Audretsch and Feldman (1996) found that industries where new knowledge plays an especially important role tend to cluster geographically. However, even after controlling for the concentration of production, they found that innovative activity is more likely to occur within close geographic proximity to the source of that knowledge, whether it is a university research laboratory, the R&D department of a corporation, or the exposure to the knowledge embodied in a skilled worker.

Beeson and Montgomery (1993) found that MSA employment growth rates are positively related to changes in university R&D funding, as well as to the number of nationally rated science and engineering programs at local universities. They also found that the percentage of the workforce employed as scientists and engineers is positively related to the R&D funding and to the portion of bachelor's degrees awarded in science and engineering at local universities. This latter finding implies that university activity differentially affects the demand for and/or the supply of workers with these specific skills. This same study did not find significant effects of university R&D funding on income, the unemployment rate, or industry mix, however. Their finding that university R&D spending positively affects both employment growth rates and the percentage of the work force employed as scientists and engineers seems inconsistent with the finding that R&D spending does not affect industry mix.

Using a quasi-experimental approach, which compared regions with and without research universities, Goldstein and Renault (2004) found that the presence of research universities and their scale of research activity are statistically significant factors in explaining community well-being (as measured by gains in average earnings per job) among MSAs in the 1986 to 1998 period, but not the 1969 to 1986 period. They argue that it was in the 1980s that universities began incorporating economic development into their mission statements, partly in response to reductions in federal research support and partly due to the Bayh-Dole Act (which allowed universities to become owners of equity in patents and innovations). Also, they argued that in the later period, the knowledge economy became more important. Although they found that the presence of research universities and the level of research activity are statistically significant factors in explaining increases in average earnings per job, the impact is relatively small when controlling for other factors, such as agglomeration effects (community size), private-sector patents, and industry structure. Again, it is important to note that such variables may in turn be affected by the presence of the university and the level of university research. These authors did not explore these interrelationships as did Jaffe (1989) and Anselin et al. (1997).

Empirical Evidence from Other Countries

In a study of West Germany, Funke and Niebuhr (2005) found significant effects of university research on productivity growth across regions. Their long-run approach (the study examined regions from 1976 through 1996) found that there are geographic spillovers to the production of knowledge, but that those spillovers are found among geographically close regions. Thus, proximity to the research expenditures matters for purposes of productivity growth.

A study of the Netherlands, by Florax and Folmer (1992), found that industry (in particular, investment in equipment) is affected by university spending (all spending, as opposed to just research spending); however, industry investment in buildings is not similarly affected. The authors believe that, because the Netherlands is a very small country, face-to-face contact is probably possible no matter where industry locates in the country; thus the level of investment in, and the location of, equipment is impacted, but not investment in buildings.

A study of Australia by Fisher and Varga (2003) also confirms the presence of geographical spillovers from university research to private patents. They found that those spillovers decay with distance, a finding that again confirms that proximity to a university matters.

Summary and Conclusions

It is important to draw a distinction between assessing the impacts of university research spending and the knowledge created by a university. Most university and university research impact studies assess only the spending. Even using the spending assessment, which is the most narrow economic impact approach to assessing university research (the "follow the money" approach), a substantial economic impact is measured. In addition to money just circulating through the economy — creating jobs, wages and sales — a substantial amount of knowledge is created, as measured by inventions, patents, and licenses.

This knowledge creates jobs in a variety of ways. First, licensees, start-ups and spin-off companies can have a substantial and long-lasting impact on the economy. A study in Utah identified and collected data on firms that are directly related to university research, either through the licensing process, start-ups, or spin-offs. It demonstrated that these firms can have an economic impact each year that is at least as large as the economic impact of the research expenditures themselves.

Second, university research expenditures spill over to private-sector research activities, having significant impacts on both the level of industrial R&D and industrial patents within the same geographic area in which the university research occurs. These research activities, in turn, create innovations and jobs in the area. It is important to note that this university-private research relationship is unidirectional, flowing from university research to private research, but not vice versa.

Third, university research affects regional, not just local, innovations. Thus, the knowledge-based economy created from university research is not limited to just the county in which the research takes place. Counties in Arizona are quite large compared to counties throughout most of the rest of the country so it is important to note that these "regional" impacts occur largely within areas within a 150-mile radius. Thus, proximity to the university research does matter with regard to how university research expenditures impact innovations.

Fourth, human capital created through the education programs affect the formation of new firms, which in turn affect regional growth rates. Evidence indicates that when founders of small companies are trained in a technology or engineering field, those companies grow comparatively faster than other companies. It is not a coincidence that the same university departments that train people in technology, scientific and engineering fields are the same departments that conduct the most research within a university.

Fifth, star scientists — scientists associated with large numbers of publications — statistically and significantly impact firm entry, even after accounting for other types of local knowledge. It is likely that scientists who have published large numbers of academic articles are also recipients of numerous grants and contracts.

Sixth, university research funding has been shown to positively affect overall economic growth or well-being. Some studies have found a direct link between university research and growth, while others have found the link through human capital formation or via the effect of research on new firm formation. University research also has been linked to increases in productivity and wage rates.

It is important to note that most of these empirical findings on the impacts of university research had little direct connection to patents and licensing activity of the universities themselves. Rather, much of the identified benefits are due to knowledge spillovers, of which the mechanism is not fully understood. As Fisher and Varga (2003) discuss: "Knowledge has some of the characteristics of public goods. It is widely considered to be a partially excludable and non-rivalrous good. Non-rivalry implies that a novel piece of knowledge can be utilized many times and in many different circumstances without reducing its value. Knowledge is only imperfectly excludable and, thus, subject to spillovers" (p. 304).

Concern has been expressed that overemphasis on research that leads directly to patents and commercialization may actually hinder the economic activity in an area because (a) exclusive licensing may limit the knowledge spillover effects, and (b) early stage research — research that may not have a marketable product for years — will be underemphasized or underfunded. Berkovitz and Feldmann (2006) discuss that, while universities have long been recognized in the system of innovation, their role has changed. Viewing universities as engines of local economic development has placed new demands on universities and, as a result, some have restructured their research capabilities to be more responsive to local industry, such as "setting up specialized research units, joint cooperative ventures or interdisciplinary projects that are more receptive to industrial needs" (p.185). But there is concern that universities are being asked to "deviate from a historically successful role and that increased commercial influences may destroy the norms of open science that have promoted the national interest. Universities certainly add more to their local economies than the metrics of technology transfer capture. There are certainly many different modes of how universities interact with and enrich their local economies than simply counting technology transfer indicators" (p. 185).

Others (Feller, 2004, and Florida, 1999) express a concern that the educational function of universities may be underemphasized in the process of commercializing university research. It is important to recognize that university research has always been an inherent part of the teaching role and that university graduates, in whom knowledge is embodied, may play as large a role in advancing the economy as university research focused heavily on commercialization and patent generation. Florida (1999), while supporting commercialization of university research, clearly states the concern: "Universities are far more important as the nation's primary source of knowledge creation and talent. Smart people are the most critical resource of any economy, and especially to the rapidly growing knowledge-based economy on which the U.S. future rests. Misdirected policies that restrict universities' ability to generate knowledge and attract and produce top talent suddenly loom as large threats to the nation's economy" (p. 67). J. Robert Oppenheimer summed it up best when he said "The best way to send information is to wrap it up in a person" (Eternal Apprentice, 1948).

It is also important to note that none of the studies citied above adequately incorporate all of the benefits that accrue to society of research and of the new knowledge it creates. Most of the studies examine the connection between university research (and sometimes human capital) and some economic measure, such as the number of private patents, the level of private research, employment growth in the community, or change in wage levels in the community. Only a few of the reviewed studies actually related measures of innovation to university research dollars and all of those studies used the same database — a 1982 database developed by the Small Business Administration — because it is the only one available.

If one were to adequately assess the impacts of university research, one would want to relate university research first to innovations and then to the benefit to society (social return) of those innovations. Measuring, and even defining, innovation is complicated. A recent National Science Foundation Workshop (*Advancing Measures of Innovation*, June 6-7, 2006), was driven "by recent calls for improvements in statistics on research and development and innovation, in order to better serve policy needs." Innovation encompasses research and development, but it is much more. Innovation measures include not only the introduction to the market of new products, but better ways to make existing products, or better ways to bring products to the market. Innovations can involve developing new ways of doing things or cheaper ways of producing or delivering products or services. Innovations can involve improvements in productivity, quality of products or numerous other desirable objectives, such as products that use less energy (see National Research Council, 2005, p. 91, for this discussion). But even if one were to adequately measure the level and number of innovations that are directly or indirectly related to university research, one still would be left with the task of measuring the benefits to society (social returns) of those innovations.

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CHAPTER 3

Research University Expenditures And Economic Activity

A Summary of the Findings of Chapter 3

A review of academic literature reveals mixed evidence of the impact of research universities on regional economies. More recent studies suggest an impact exists while studies based on historical data find little correlation between research universities and economic prosperity of regions.

In 2004, the average real wage in urban areas with research university activity in excess of $5 million was nearly $3,300 higher than the average of all urban areas. The real per capita income differential was about $2,800. These figures reflect cross-city cost-of-living adjustments using the ACCRA Cost of Living Index. This analysis used a data set that merged research dollars expended at local academic institutions with economic data of 938 metropolitan and micropolitan areas across the United States.

Over the past 35 years, aggregate wages and salaries in urban areas with research universities grew 0.6 percent faster per year than in areas without research universities. While seemingly a small difference, this differential annual growth rate implies about a 20 percent differential over the 35-year period.

In a study of this nature, it may be difficult to disentangle the impact of research universities from the impact of city size, especially when research investments are dwarfed by the size of a city. To mitigate this potential confusion, we focused exclusively on the performance of a sample of 22 urban areas that had very high levels of university research expenditures relative to the size of their economies (greater than 5 percent). Performance of each of these 22 urban areas was compared with the performance of the surrounding region (typically the cities across the rest of the state). The median aggregate wage and salary growth between 1970 and 2005 was 37 percent higher in the research university urban areas than in the surrounding region. Comparing this growth in research-intensive urban areas with cities without research universities over the past 35 years, the median value of the incremental wage and salary gain observed across the 22 areas with high levels of university research expenditures sums to about $736 million annually today. For perspective, this exceeds average annual injections of federal research dollars by a factor of about 5-to-1.

A separate analysis revealed that differential patent intensity, partially induced by the presence of research universities, might be the channel by which the economic impact occurs.

Research Universities and Regional Economic Prosperity

Much of the discussion about the value of research universities focuses on nonpecuniary (nonmonetary) benefits of university research expenditures, such as scientific advancement achieved through the work done in research laboratories. However, considerable economic activity is generated by research expenditures. A recent Milken Institute report, *Mind to Market: A Global Analysis of University Biotechnology Transfer and Commercialization*, documents research activity in the biosciences. It focuses on rates of productivity (such as the number of licenses, patents, or business start-ups per dollar of research expenditures) produced by research universities.

To the extent that university research exports human capital in return for research funding generated outside the regional economy, such as from federal grants or institutional funding, university research activity serves as a base industry for the region in which a university is located. (A base industry is one that imports money into a local economy, traditionally through the sale of a good to a customer outside of the region. Base industries drive regional economic growth.) The dollar injections of research funding stimulate direct employment activity, as discussed in the prior chapter, as well as lead to business start-ups and increased numbers of graduate students. Indeed, as discussed in the second chapter, some authors contend that the activities of research universities serve as attractors or magnets for smart, educated, and innovative entrepreneurs who leverage knowledge-creation activities that take place on university campuses.

An increasing body of empirical evidence indicates that regions with higher levels of education in the workforce are more prosperous (Moretti, 2004a) and firms with highly educated employees are more productive (Moretti, 2004b). However, it has been less clear that the presence of a research university in a local region leads to accelerated economic growth. Studies from more than a decade ago did not uncover such a relationship. Beeson and Montgomery (1993) found "little systematic evidence documenting a relationship between colleges and universities and local economies … and that … university quality has no significant effect on area income, the employment rate, net migration rates, or even the share of employment in high-tech industries." Bania, Eberts and Fogarty (1993) found no strong evidence of the relationship between university commercialization efforts and start-ups in a region.

In contrast, in more recent empirical work, Zucker and Darby (2006) examined the impact of universities on regional development by measuring the effect that the presence of "star" scientists has on the formation or transformation of high-technology businesses. Results suggest that the presence of star scientists and engineers in a particular science and technology field is more closely correlated with business formation than the stock of knowledge in the particular field. That is, business formation and technology innovation in businesses appears more closely tied to the proximity of the researcher to the new business than proximity to the stock of knowledge. Additional work by Zucker and Darby suggests a tendency for star scientists to concentrate in particular regions over time. Thus, efforts to form a small research group of highly productive scientists can pay dividends over time since they continually attract colleagues to join them, accelerating the likelihood of business formations.

Gottlieb and Joseph (2006) examined the migration patterns of technology graduates and holders of doctoral degrees within the United States in recent years. They report that "all of the models estimated show a large and significant tendency among college graduates to stay rather than migrate, other things equal. This suggests that, in the long run, training a relatively large number of university graduates in a metropolitan area could lead to a larger number of knowledge workers settling there."

Zucker and Darby's and Gottlieb and Joseph's results may not be inconsistent with those of the earlier studies. Instead, the earlier studies may be too broad in nature. Identifying the contributions of research universities in regions that already are quite economically vibrant and have large economies in comparison with the size of the research dollar investment is simply a daunting challenge.

University Research Expenditures and Economic Performance by Urban Area

The results of a preliminary analysis of the relationship between research expenditures by universities and economic activity in urban areas are discussed in this chapter. Data on research and development (R&D) expenditures by universities are available from the National Science Foundation (NSF), which reports total R&D expenditures at each of about 600 universities nationwide. Data on economic performance are produced by the U.S. Department of Commerce's Bureau of Economic Analysis (BEA), which reports several measures of economic performance annually for each of 938 urban areas. Personal income, per capita personal income, wage and salary employment, and the average wage were collected for this analysis.

The NSF has conducted a survey of research expenditures at universities since the early 1970s. Over the years about 800 universities have participated in the survey, but considerable variation in participation exists on a year-to-year basis. For this preliminary analysis, a consistent group of participating universities with data for 1997 to 2004 (the latest year) were used. Many of the roughly 600 participating universities have limited R&D spending that would not be expected to have a perceptible impact on economic performance. Thus, this analysis was limited to the 318 research universities that had total R&D expenditures of at least $5 million in 2004. This group accounted for 98.9 percent of all academic research expenditures in 2004. Some of the universities with multiple campuses do not differentiate R&D spending by campus. In these cases, all spending was assigned to the main campus. The result is to overstate the economic impact of university R&D spending in some urban areas housing a main campus and to understate the effect in certain urban areas with branch campuses. However, main campuses traditionally have been the source of most academic research activity. In further investigation of this topic, it will be useful to extend this analysis, where possible, to all universities reporting any research activity, over a longer period of time.

The NSF divides university R&D expenditures into five categories based on the source of the funding: federal government, state and local government, industry, institutional funds, and all other. Special attention is given to the federal funding in this analysis since this funding clearly represents monies imported into local economies.

The R&D expenditures at each of the 318 research universities were assigned to a core-based statistical area using the federal government's current definitions, which identify 361 metropolitan areas and 577 micropolitan areas. (These 938 metropolitan and micropolitan areas are referred to as "urban" areas in this chapter.) Since some of the urban areas have more than one research university, R&D expenditures were identified in only 166 urban areas. Of these 166, federally financed R&D was identified in 150.

The data on urban size and economic performance from the BEA were merged with the university R&D spending figures from the NSF that were allocated to urban areas. In Table 5, the top panel contains descriptive statistics for the 772 urban areas in 2004 that did not have a research university spending at least $5 million in R&D in 2004. The middle panel contains data for the 166 areas that had R&D activity in 2004 of more than $5 million produced by a local research university; the lower panel contains data for the subset of 150 areas that reported data for federally sponsored R&D activity at a local research university.

Table 5
Descriptive Economic Statistics for Urban Areas With and Without Research Universities, 2004

	Population	Wage & Salary Employment	Personal Income*	Average Wage	Per Capita Personal Income	University Research Expenditures	
						Federal*	Total*
772 Urban Areas without Research Expenditures**							
Mean	106,979	47,922	$3,056	$29,484	$26,488	$-	$-
Mediam	57,758	23,950	1,492	28,963	26,118	-	-
Max	1,617,414	905,671	57,040	65,925	64,987	-	-
Minimum	11,828	3,883	202	19,486	11,362	-	-
Std. Dev.	140,787	68,755	4,846	4,194	4,775	-	-
166 Urban Areas with Research Expenditures**							
Mean	1,154,209	572,361	41,451	34,521	30,784	159	253
Median	405,677	198,629	12,670	33,883	30,497	76	129
Max	18,754,585	8,613,197	812,000	68,665	49,276	1,682	2,572
Minimum	13,019	6,445	368	22,560	18,607	0	5
Std. Dev.	2,180,287	1,035,615	87,437	6,692	5,634	259	373
150 Urban Areas with Federally Funded Research Expenditures**							
Mean	1,262,119	626,781	45,551	35,188	31,424	179	279
Median	494,994	265,473	15,222	34,611	31,215	92	156
Max	18,754,585	8,613,197	812,000	68,665	49,276	1,682	2,572
Minimum	13,019	6,445	367,883	22,560	18,607	5	5
Std. Dev.	2,267,465	1,075,508	91,067	6,770	5,611	268	384

** In millions.*

*** Urban areas with/without research expenditures are based on a research university exceeding $5 million in research expenditures in 2004.*

Source: Calculated from National Science Foundation and U.S. Department of Commerce, Bureau of Economic Analysis.

The results indicate that the typical urban area with a research university is significantly larger than those without research universities: median population about seven times larger and median employment and personal income more than eight times larger. The median average wage and median per capita personal income were higher in urban areas with research university activity as well, by approximately 17 percent. The subset of urban areas with federal R&D funding were even larger and had higher average wages and incomes.

Many factors other than research university spending might contribute to the differences in average wage and per capita income. In particular, larger urban areas generally have higher costs of living and therefore higher wages and incomes. Since scale is a factor, it is likely that urban areas with larger populations have made investments in research universities.

The effect on dollar measures of geographic differences in the cost of living can be adjusted by information in the quarterly *ACCRA Cost of Living Index*. ACCRA data for 2004 were available for most of the 361 metropolitan areas and for some of the micropolitan areas. In total, 313 of the urban areas were assigned cost of living index numbers from the ACCRA survey in 2004. Among the 166 urban areas with university R&D spending in excess of $5 million, cost-of-living data were available for almost three-fourths. (ACCRA data for fourth quarter 2004 were used where available. For some urban areas, data were not available for the fourth quarter but were reported for an earlier quarter in 2004.)

Cost-of-living-adjusted data are displayed in Table 6. The top panel is based on only those 313 urban areas with a reported ACCRA index number in 2004. In this sample, the adjusted wage and income figures for urban areas with research universities were nearly $1,700 higher for the average wage and $1,350 higher for per capita personal income (differences of about 5 percent) than in those urban areas without a research university. In the bottom panel, all 938 urban areas were included. The cost of living in urban areas without an ACCRA index was set at the median value (94.77 for metropolitan areas and 93.33 for micropolitan areas). Using this approximation, the adjusted wage and income figure for all urban areas with research universities was nearly $3,300 higher for the average wage and about $2,800 higher for per capita personal income (differences of about 10 percent) than in those urban areas without a research university.

Table 6
Cost-of-Living-Adjusted Average Wage and Per Capita Personal Income
Metropolitan and Micropolitan Areas with and without Research Universities, 2004

	Average Wage	Per Capita Personal Income
313 Metro and Micro Areas with an ACCRA Index in 2004		
With Research University	$34,510	$30,804
Without Research University	$32,816	$29,456
Difference	$1,694	$1,348
Percentage Difference	5.2	4.6
All 938 Areas with Missing ACCRA Index Set at Median Value*		
With Research University	$34,591	$30,913
Without Research University	$31,312	$28,112
DIfference	$3,278	$2,802
Percentage Difference	10.5	10.0

** Areas without ACCRA values were assigned the median value of 94.77 for metropolitan areas and 93.33 for micropolitan areas.*
Note: All differences are statistically significant at the 1 percent level.
Source: Calculated from National Science Foundation, ACCRA, and U.S. Department of Commerce, Bureau of Economic Analysis.

Thus, differences in the average wage and per capita income remain after adjustment for the cost of living. Urban areas with research universities have higher average wages and incomes than those without research universities. However, definitive conclusions cannot be drawn since wage and income differentials across urban areas can be driven by many factors that were not included in this analysis. Moreover, the focus on a single year does not offer any evidence that research intensity is responsible for higher real wages or whether more research universities have been located in more economically prosperous urban areas.

An alternative approach to minimize the impact of amenities, cost of living, and missing ACCRA data on the measured effect of research universities on economic performance is to focus on growth rates. Living-cost differences and other delimiters across urban area presumably developed over decades, if not centuries. Differential inflation rates between urban areas are unlikely to be very large over a short time period such as 1997 through 2004. Average annual growth rates for all urban areas over this period are displayed in Table 7, distinguishing between those areas that have research universities and those that do not. Results for urban areas with less than 500,000 in population are shown separately in order to explore whether the results are unduly influenced by urban size.

Urban areas with research universities displayed higher rates of growth over the 1997 to 2004 period, based both on aggregate measures (population and employment) and prosperity measures (average wage and per capita personal income). Some of the differential may result from the activity of research universities largely being noncyclical. Thus, it is likely that those areas with active research universities were better able to weather the 2001 recession than was the typical urban area. Though the growth rate differences seem minor, the impact of even small differential growth rates can result in significantly different economic prosperity metrics if sustained over long periods of time.

Table 7
Changes in Economic Measures, 1997 to 2004
Metropolitan and Micropolitan Areas With and Without Research Universities

	Population	Wage & Salary Employment	Average Wage	Per Capita Personal Income
All 938 Metropolitan and Micropolitan Areas				
With Research University	0.9%	1.1%	3.7%	4.0%
Without Research University	0.6	0.6	3.4	3.6
Difference	0.3	0.5	0.3	0.4
Metropolitan and Micropolitan Areas with a Population of Less than 500,000				
With Research University	0.7	1.2	3.5	4.0
Without Research University	0.6	0.6	3.4	3.6
Difference	0.1	0.6	0.1	0.4

Note: All differences are statistically significant at the 1 percent level with the exception of the average wage and population growth rates in the smaller urban area sample. The nominal growth rates have not been adjusted for inflation over the period. The analysis is based on the assumption that, regardless of the cost-of-living differences that prevail, the urban areas experienced approximately the same inflation rates over the period.
Source: Calculated from National Science Foundation and U.S. Department of Commerce, Bureau of Economic Analysis.

Little difference is noted between all urban areas and those with less than 500,000 residents.

While focusing on growth rates helps control for interurban variations due to a host of factors, the results in Table 7 shed no light on the relative importance of additional research dollar investments on urban area growth rates. Closer examination of the 1997-to-2004 sample revealed no significant correlation between economic growth trajectories and changes in the amount of research dollar funding at the research universities in the sample. This lack of relationship is not unexpected. Effects of research spending on broad economic measures are likely to occur only with a lag, and probably require a longer time period than the seven years analyzed to have an effect.

Longer-Term Growth Analysis

If research activity has an impact on regional economies it is likely to operate through the impact that a research infrastructure (labs, personnel, graduate student production) has on a local economy over a long period of time. Indeed, the vast majority of the 166 urban areas that had local research activity at universities in excess of $5 million in 2004 have had higher-education institutions active in research for decades. While institution-specific research activity for a large number of research universities is not available prior to 1997, economic data for all urban areas are available from the Bureau of Economic Analysis annually since 1969. The 35-year average annual growth rates of wage and salary employment, total wages, and average wage per job appear in Table 8, differentiated by urban areas with and without research universities (at the end of the period).

Urban areas with research universities grew faster than those without research universities over the 35-year period. The growth advantage largely is associated with faster employment growth; little difference was measured in the growth rate of the average wage. While the growth rate differentials appear small, they result in sizable differences over the 35-year period.

The results suggest that if two urban areas had $1 billion economies in 1970, as measured by aggregate wages and salaries, the urban area with the research-active university would have grown to $11.2 billion in 2005, while the urban area without the research university would have grown to $9.3 billion. This is a difference of 20 percent. After adjusting for inflation (assuming an equal inflation rate in the two areas), the urban area with the research university would have grown to 2.74 times its 1970 size, while the urban area without a research university would have grown to 2.27 times its 1970 size.

The presence of a research university is just one of many factors that might have caused the differential growth rate. If research universities have a significant impact on the growth trajectories of an urban area it likely occurs in urban areas where the research activity represents a significant share of the economic activity.

Urban Areas Where Research Expenditures Are Large Relative to Economic Size

Using the 1997-2004 data, the amount of research expenditures in each urban area per $1,000 in aggregate personal income was calculated annually, with an average for the eight-year period also determined. A total of 22 urban areas had annual average research expenditures of $50 or more per $1,000 of personal income (see Table 9). The median population of these 22 areas (less than 125,000) was quite low compared to the median of all urban areas with research expenditures (more than 400,000). While tending to be small in size, these 22 urban areas with a high research spending intensity are geographically dispersed. Eight of the nine census divisions are represented, with New England being the exception.

Table 8
Annual Average Percentage Growth, 1970 through 2005

	Employment	Total Wages and Salaries	Average Wage
All Metropolitan and Micropolitan Areas			
With Research University	2.1%	7.2%	5.0%
Without Research University	1.7	6.6	4.9
Difference	0.5	0.6	0.1
Metropolitan and Micropolitan Areas with a Population Less Than 500,000			
With Research University	2.2	7.1	5.0
Without Research University	1.6	6.6	4.9
Difference	0.5	0.6	0.0

Note: All differences are significant at the 1% level with the exception of the average wage growth rate in the smaller urban area sample. The nominal growth rates have not been adjusted for inflation over the period. The analysis is based on the assumption that, regardless of the cost-of-living differences that prevail, the urban areas experienced approximately the same inflation rates over the period.

Source: Calculated from National Science Foundation and U.S. Department of Commerce, Bureau of Economic Analysis.

The list of 22 urban areas is comprised of research universities that have been in existence for decades. While information about the scale of the research activities at these universities over the last 35 years is not presented in this analysis, it is safe to assume that research activity in these research-intensive urban areas is not a new phenomenon.

Table 9

Urban Areas with the Highest Research Expenditures Relative to Personal Income

	1997-2004 Annual Average, Per $1,000 in Personal Income		**2004 in Millions**		
Metropolitan (or Micropolitan) Area	Total	Federal Funds	Total	Federal Funds	2004 Population
Ithaca, NY	$189.62	$108.02	$575.6	$339.1	100,080
Starkville, MS (Micropolitan)	162.71	71.61	191.4	82.2	41,136
Pullman, WA (Micropolitan)	158.56	75.49	171.7	80.6	40,182
State College, PA	134.66	73.83	600.1	348.0	139,948
College Station-Bryan, TX	119.63	45.90	521.0	204.0	188,745
Moscow, ID (Micropolitan)	91.89	37.59	93.2	48.6	35,036
Ames, IA	85.47	31.22	212.0	92.2	80,239
Champaign-Urbana, IL	70.89	37.13	506.0	275.9	214,989
Athens-Clarke County, GA	68.75	18.19	313.2	96.3	175,415
Blacksburg-Christiansburg-Radford, VA	67.58	27.60	268.8	95.7	150,597
Corvallis, OR	64.68	37.94	170.3	104.3	78,383
Iowa City, IA	64.59	39.97	312.9	209.9	137,558
Laramie, WY (Micropolitan	63.58	25.04	60.1	23.2	31,397
Bloomington, IN	63.57	30.54	384.2	166.9	177,297
Gainesville, FL	61.89	25.65	447.1	221.9	238,489
Oxford, MS (Micropolitan)	61.83	41.72	79.9	59.8	40,237
Stillwater, OK (Micropolitan)	61.16	20.08	103.9	43.3	69,389
Lawrence, KS	60.21	28.69	181.2	101.9	102,738
Lafayette, IN	60.14	24.47	365.8	144.1	181,427
Logan, UT-ID	57.31	35.39	153.6	107.9	109,291
Durham, NC	53.26	34.64	937.6	652.1	450,260
Ann Arbor, MI	52.60	34.33	769.1	521.3	338,782

Source: Calculated from National Science Foundation and U.S. Department of Commerce, Bureau of Economic Analysis.

The average growth rate in the 22 urban areas, as measured by aggregate wages and salaries, was about 0.8 percent per year faster than urban areas without research universities and 0.2 percent per year greater than urban areas with research university activity that was less than 5 percent of personal income. Each of these differentials is statistically significant.

In an additional analysis, the growth rates in employment and wages in each of the 22 areas were compared to the rates in other nearby urban areas of roughly similar size. In most cases, proximity was defined as being within the same state. All metropolitan and micropolitan areas were included with the exception of the largest metro areas in the state and others considerably larger in scale than the urban area under examination. In some states, more than one research-intensive urban area is compared to the same region. For example, in Indiana, both Bloomington and Lafayette have populations of less than 200,000, so the Indianapolis metro area was excluded from the comparison area. In the more sparsely settled northern Rocky Mountain region, urban areas throughout western Washington, all of Idaho and northern Utah were selected as the comparison area for Pullman, Moscow and Logan.

For each of the 22 urban areas, data were aggregated across the urban areas selected for inclusion as part of the comparison area, forming 22 regional economies that include the research-intensive area being investigated. The growth rates of employment and wages over the period from 1970 through 2005 in each of the 22 urban areas with high-intensity research expenditures were compared to the growth rates in the surrounding regional economy (see Table 10).

In general, research-intensive areas display faster growth in employment than the surrounding region, but little difference exists in gains in the average wage. The growth advantage of the research-intensive area in aggregate wages and salaries appears in the fourth-to-last column of the table. Spurred largely by employment growth, the gain in aggregate wage and salary incomes earned in the research-intensive areas exceeded that in the surrounding region by a substantial margin: a median difference across the 22 areas of 37.1 percent over the 35-year period. The differential ranged widely, however, from 90 percent in two cases to slower growth in four of the research-intensive urban areas.

The third-to-last column of the table quantifies the growth advantage for each research-intensive urban area by comparing the economic activity in 2005 in the research-intensive area to that obtained in a hypothetical area of identical size (wage and employment level) in 1970 that grew at the average rate of the region. The median value of the incremental gain observed across the set of 22 research-intensive areas is $735.9 million.

The 2004 amount of research expenditures by urban area appears in the final two columns of the table to help explain the scale of the research investment today relative to the differential gain in wages and salaries compared to the regional average. Interestingly, incremental wages and salaries in the research-intensive areas exceed research expenditures by rather large factors in many cases. The median ratio of wage and salary increments to total research expenditures is 2.4-to-1 and the median ratio of wage and salary increments to federally sponsored research is 5.1-to-1. While this metric is NOT an appropriate measure of the rate of return to a particular investment of research dollars, the orders of magnitude are noteworthy.

Table 10
Comparison of Growth in Research-Intensive Urban Areas to Surrounding Region

	Average Annual Aggregate Wage and Salary Growth				Average Annual Wage and Salary Employment Growth				Relative to Regional Average		2004 Research Spending (Millions)	
	1970-1980	1980-1990	1990-2000	2000-2005	1970-1980	1980-1990	1990-2000	2000-2005	*	**	Total	Federal
Florida												
Gainesville	7.4%	5.7	3.0	4.9	4.8	3.4	2.6	0.7	12.7%	$598.8	$447.1	$221.9
24 Florida areas	7.0	5.2	3.3	4.1	4.2	4.0	2.3	2.3				
Georgia												
Athens	7.8	5.6	3.3	3.3	3.0	2.7	2.2	0.8	27.2	729.2	313.2	96.3
36 Georgia areas	7.8	5.2	3.6	3.4	1.8	2.1	1.8	0.3				
Iowa												
Iowa City	8.0	5.1	3.6	3.0	3.4	2.3	2.7	2.1	90.2	2,615.0	312.9	209.9
Ames	7.7	4.3	4.0	3.2	3.8	1.5	1.7	0.7	49.6	742.6	212.0	92.2
22 Iowa areas	8.0	3.6	3.6	3.1	2.0	.05	1.7	0.0				
Illinois												
Champaign-Urbana	6.7	5.0	3.6	3.1	1.6	1.6	0.7	0.1	10.7	388.4	506.0	275.9
32 Illinois areas	7.7	4.0	3.4	3.2	1.3	0.8	1.3	-0.6				
Indiana												
Bloomington	6.9	2.8	5.8	2.8	2.4	0.9	3.8	.03	42.5	1,020.1	384.2	166.9
Lafayette	7.2	2.4	6.0	3.2	2.1	0.3	3.8	-0.8	25.6	798.5	365.8	144.1
36 Indiana areas	7.4	3.4	4.4	2.7	1.3	0.8	2.4	-0.8				
Kansas												
Lawrence	6.9	4.2	3.2	2.6	4.1	2.7	3.8	0.7	69.0	1,032.7	181.2	101.9
18 Kansas areas	7.7	4.1	3.3	3.0	2.2	0.9	1.6	-0.4				
Mississippi												
Starkville	8.4	4.8	3.5	2.5	3.3	1.5	2.4	1.0	39.7	213.0	191.4	82.2
Oxford	7.5	5.1	3.7	4.8	4.1	1.7	3.2	1.7	83.9	479.2	79.9	59.8
22 Mississippi areas	8.5	4.8	3.4	3.4	1.9	0.7	1.6	-0.7				
Michigan												
Ann Arbor	7.0	4.8	4.2	2.8	2.8	1.7	2.3	0.4	28.8	2,285.9	769.1	521.3
31 Michigan areas	7.4	4.3	3.5	2.4	2.1	1.7	1.6	-1.0				
New York												
Ithaca	5.4	6.1	3.5	3.1	2.5	3.7	0.4	1.2	70.4	1,385.1	575.6	339.1
22 New York areas	6.3	5.4	3.0	2.6	0.9	1.4	0.3	-0.3				
North Carolina												
Durham	7.7	6.7	5.6	1.8	3.2	3.6	2.8	0.5	68.0	8,615.3	937.6	652.1
39 N. Carolina areas	7.7	5.5	4.0	3.2	2.1	2.5	1.8	0.3				
Oklahoma												
Stillwater	7.8	5.2	2.5	4.0	4.0	1.4	3.0	-1.1	34.5	313.8	103.9	43.3
19 Oklahoma areas	8.4	4.1	2.7	3.6	2.7	0.5	1.8	0.5				
Oregon												

Table 10 *(continued)*

Corvallis	7.6	4.3	5.1	1.5	4.2	2.4	1.9	1.6	27.2	401.7	170.3	104.3
18 Oregon areas	7.4	3.7	3.6	2.7	3.9	1.6	2.2	1.5				
Pennsylvania												
State College	6.2	5.7	2.4	2.7	3.4	2.3	2.6	1.7	65.6	1,624.4	600.1	348.0
29 Penn. areas	7.4	4.6	3.3	3.0	1.2	0.9	1.0	0.2				
Texas												
College Station	7.9	5.3	3.2	3.5	5.6	2.9	3.1	1.6	90.1	2,429.4	521.0	204.0
61 Texas areas	8.3	4.2	3.2	3.5	3.4	0.7	2.0	0.7				
Virginia												
Blacksburg	7.1	5.7	3.1	3.7	2.5	1.7	1.1	-0.1	-2.6	-59.0	268.8	95.7
Virginia areas	7.7	5.4	3.4	3.9	2.0	1.9	1.0	0.3				
Washington-Idaho-Utah												
Pullman	7.9	4.3	3.9	2.5	1.1	1.1	1.6	0.6	-32.0	-174.4	171.7	80.6
Moscow	7.9	3.5	4.0	2.3	4.3	1.5	1.7	1.0	-8.5	-34.6	93.2	48.6
Logan	7.7	4.9	3.6	3.1	5.2	3.0	3.6	2.3	68.8	913.8	153.6	107.9
22 WA-ID-UT areas	7.9	4.0	3.7	2.9	3.7	1.6	2.4	1.5				
Wyoming												
Laramie	8.1	3.4	2.9	4.1	3.7	0.8	2.0	1.1	-19.6	-94.1	60.1	23.2
8 Wyoming areas	9.8	2.7	2.9	4.5	6.2	-0.8	1.7	2.1				
Median Difference	-0.3	0.6	0.1	-0.1	1.1	0.8	0.6	0.7				
Median of Column									37.1	735.9	290.8	106.1

** Difference in aggregate wage and salary growth over the 35-year period.*
*** Increase in wages and salaries in millions relative to the gain at the regional rate of growth.*
Source: Calculated from U.S. Department of Commerce, Bureau of Economic Analysis.

The results of this analysis suggest that research-intensive areas have experienced growth over the 1970 to 2005 period that has resulted in annual wage and salary income that is significantly greater than their urban counterparts in their respective states. Further, the annual dollar magnitude of this difference is sizeable in comparison to the annual research dollars that are expended by the university. The expenditures are largely financed by corporations and the federal government and the wages and salaries are earned by the employees throughout the urban economy. Growth differentials often can be linked, at least in part, to differences in injections of monies into the urban economy from external sources. The empirical results are consistent with the notion that the presence of research universities in these urban areas was responsible for some of these injections.

Several cautions are in order in interpreting these results. First, in four of the 22 research-intensive urban areas, growth has been less rapid than in the surrounding region. Three of these four are located in the sparsely settled but relatively fast-growing northern Rocky Mountain area. In Pullman, Washington, growth has been substantially less than in the region despite its high rank on research spending relative to personal income. Growth slower than in the surrounding region also was observed in Moscow, Idaho and Laramie, Wyoming. In contrast, Logan Utah, part of the same region as Moscow and Pullman, has experienced much more rapid growth than the regional average. In Blacksburg, Virginia, growth was only slightly less than in the surrounding Virginia region, which includes the economically vibrant areas close to Washington D.C.

Second, the surrounding region designations are not based on any particular economic geography so the results are largely illustrative. This can influence the Gainesville, Florida results since it is unclear how many southern Florida urban areas should be in the comparison region. It also influences the Durham results since Raleigh, within the comparison region, benefits from the research triangle activities of Duke, the University of North Carolina, and North Carolina State. Growth in the Raleigh area has outstripped the growth of the North Carolina region by a wide margin and all of these universities are likely contributors. In general, however, the size of the comparison region is quite large so it is not likely that the results would be significantly altered by the inclusion or exclusion of a particular urban area.

Third, the focus on 22 urban areas that have significant research expenditures relative to urban size does not imply that research universities in larger urban areas have no impact. It simply may be harder to measure the impact of research expenditures in larger urban areas from aggregate data.

Fourth, the results do not suggest that the benefits of university research only accrue to the local urban area; as discussed in earlier chapters, the effect spills over into adjacent areas up to 50 to 100 miles away. Finally, the activity of the research universities in these regions dates back decades prior to 1970, but the analysis is constrained by data availability.

The estimates obtained from this analysis could be refined by a more thorough selection of the comparison region, comparing the research-intensive area to regions in close proximity and similarity in scale. Additional precision would be obtained by examining a longer time period, particularly by collecting the amount of research dollars expended prior to 1997. Further, tabulating all research dollars — including those of less than $5 million dollars in 2004 — would provide a more complete picture.

The Role of Patents as a Channel of Research Impact

Knowledge creation is one of the objectives of research universities. The production of patents — owned by the university itself, produced and owned by faculty, or produced in the local area due in part to affiliation with a university — is a measure of knowledge creation. Even purely private-sector patents may be produced by workers at corporations that chose to locate in proximity to a research university to tap an educated pool of workers. According to a variety of studies (see the "Economic Effects of University Research" chapter), patent creation is positively affected by the activities at research universities, though the rate of patent production varies across research universities.

If patents are a reflection of innovation that is conducive to economic growth, then changes in patent intensity in a region may be associated with measures of economic growth. In order to test this hypothesis, a unique dataset that contains patent information annually in each of the 938 metropolitan and micropolitan areas over a period spanning 1970 to 2003 was examined. (The source is a proprietary dataset developed by Lee Fleming and Deborah Strumsky for the Research Division of the Harvard Business School. The authors thank Deborah Strumsky for providing access to the data.) The results of a series of simple statistical tests suggest that there is modest correlation between changes in patent intensity — as measured by the number of patents per thousand people in an urban area — and economic growth.

In an effort to understand the linkages between patent intensity and economic prosperity, a multiple regression was estimated. In this analysis a number of variables in addition to the number of patents were used in combination to measure the effect on economic growth. To isolate the impact of patents a number of control variables were included: a series of lagged economic variables, the impact of time, inflation, and the fixed effects (variables that account for any idiosyncratic characteristics that are city specific) of each urban area. The results indicate that, through time, increases in patent intensity in the most recent five-year interval lead to positive economic outcomes today.

In this regression approach, patent activity is measured by changes in the five-year moving average of the rate of patents per 1,000 residents. (A moving average was used to smooth out large single-year gyrations in the number of patents.) The five-year average per capita number of patents was calculated for each year and then compared to current economic activity. One regression was run for all 938 urban areas; another was limited to the 361 metropolitan areas.

The impact of changes in historical patent intensity on subsequent economic growth is slightly larger in metropolitan areas than in all urban areas. The regression coefficients suggest that one-unit changes in the patent intensity variable have large impacts on annual growth. However, one-unit changes rarely occur. Instead, a conventional metric is used to assess the importance of patent intensity: the impact of a one standard deviation change in the patent variable. The results suggest that one standard deviation increases in patent intensity can add between 0.2 and 0.3 percent to annual real growth in an urban area. Changes in patent intensity of this magnitude occurred relatively frequently in the sample. For example, changes in patent intensity of this magnitude or larger occurred seven times over the last 35 years in the Phoenix metro area. Only population growth rates are essentially unaffected by changes in patent intensity (see Table 11).

While considerably more work should be undertaken to understand the role played by patents in determining urban area growth, the results suggest a linkage between the number of patents and the economic trajectory of urban areas. This correlation still is observed after controlling for a series of variables and examining the impact of historical moving averages of patents on subsequent economic activity. In further experiments, based on impulse response patterns (commonly used in time series analysis), significant economic variable responses followed simulated "shocks" to patent intensity. The magnitudes of these responses essentially matched the findings of the regression results in Table 12. The lesson from this analysis is that if the impact of research universities results, at least in part, from new patentable ideas that are generated, then research dollars likely will have more impact on those regions where there is a high rate of patent production per research dollar invested

Table 11
The Impact of Patents on Economic Growth

	Wage & Salary Employ-ment	Population	Real Personal Income	Real Per Capita Personal Income	Real Average Wage
938 Urban Areas					
Change in five-year moving average of patents per 1,000 residents	3.6%	0.6	4.9	4.5	2.7
Impact of one standard deviation (.065) acceleration in patent intensity	0.2	0.0	0.3	0.3	0.2
361 Metropolitan Areas					
Change in five-year moving average of patents per 1,000 residents	4.1	0.6	5.1	4.5	2.7
Impact of one standard deviation (.065) acceleration in patent intensity	0.3	0.0	0.3	0.3	0.2

Note: In addition to the patent variable, each regression contains an urban area fixed-effect binary variable, a time trend, and four lags of the dependent variable (economic growth). All patent coefficients are significant at the 1 percent level.

Source: Calculated from U.S. Department of Commerce, Patent and Trademark Office and Bureau of Economic Analysis.

Table 12 contains comparisons of patent intensity over the 1970 to 2003 period for all urban areas and for the 22 urban areas (in which university research expenditures accounted for at least 5 percent of personal income) that were examined above. The results cited earlier indicate that in 18 of these 22 areas, local urban area growth outstripped that of the surrounding economic region. These 18 urban areas with higher growth than in the surrounding region also had high levels of per capita patents and a high growth rate of patent intensity. The change in the rate of patents per 1,000 residents was 4.5 times greater in these 18 urban areas than in the average urban area and the level of patents was higher than in the average urban area by about 38 patents per 1,000. The four slow-growth but research-intensive urban areas had higher patent intensity than in the average urban area, but their patent intensity was significantly less than in the 18 top performers, averaging about half in both level and growth in the per capita number of patents.

Conclusions

The empirical analysis described in this chapter is designed to investigate the linkage between activities at research universities and the economic prosperity of the urban areas in which they are located. The analysis suggests that a correlation exists between activity at research universities and measures of economic prosperity. An analysis of patent intensity suggests that those universities that are most successful in translating research efforts into patent production are located in urban areas that have experienced faster economic growth in recent decades.

Table 12
Patent Intensity in Urban Areas with a Research University

	Patents Per 1,000 Residents	Change in Patents Per 1,000 Residents
18 Fast-growing Urban Areas*	0.62	0.045
4 Slow-growing Urban Areas*	0.32	0.025
Difference	-0.30	-0.020
Other Urban Areas	0.24	0.010

** The 22 urban areas are listed in Table 11. The four slow-growing areas are Pullman, Moscow, Blacksburg and Laramie.*
All entries are significant at the .01 level.
Source: Calculated from U.S. Patent and Trademark Office.

The preliminary analysis reported in this chapter requires further investigation. Information on all research activity at all universities should be included in the analysis. The level of research activity needs to be monitored over decades and compared with the pace of patent generation over long periods of time. More detailed data can help determine whether research universities contribute a kind of economic energy that is different from the economic stimulus added by nonresearch universities or other major public-sector activities such as power plants, hospitals, or even correctional facilities. Finally, particular emphasis should be placed on the differential impact that federal versus industry sponsored research has on economic growth of urban areas.

The findings so far are consistent with the notion that research universities attract research dollars from the federal government and from corporations. These injections have positive impacts on economic growth, as measured by the average wage and wage and salary employment, with most of the impact reflected in employment growth. Considerably more work will need to be undertaken to understand exactly how this linkage operates, and much more data will be required to determine the marginal impact of incremental research dollars on a region.

The results indicate that urban areas have benefited from university research expenditures in recent decades, but the numbers may understate the role these institutions will play in the future. For example, the state of Michigan has prospered for many decades from a large automobile manufacturing employment base. Still, the research activities in the Ann Arbor area have resulted in growth in Ann Arbor that outstripped the rest of the state. As Michigan transitions away from its reliance on automobile manufacturing, it will rely on places like Ann Arbor, East Lansing, and a number of other urban areas with lesser research expenditures to help provide knowledge-economy opportunities for workers. So, in the industrial Midwest, Ann Arbor, Bloomington, Lafayette, Champaign, Iowa City and Ames may be even more important in adding diversity to their regional and state economies as other segments of their economies face pressure from globalization during the coming decades.

Though less dramatic, this general tendency prevails across the nation. As traditional industries face increasing pressures from globalization, new innovation-driven job opportunities must fill the void. Research universities need to assist this transition by producing the ideas and knowledge-economy workers that are the catalysts for the innovation. Those research universities with highly developed research infrastructures and the most highly regarded scientists and inventors will be positioned best to fill this role.

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CHAPTER 4

Ireland and Science Foundation Ireland: Lessons for Science Foundation Arizona

Summary of Findings from Chapter 4

Science Foundation Ireland

After more than a decade of rapid, export-driven growth caused by aggressive economic development policies designed to attract foreign capital, Ireland chose to broaden its economic development strategy in 2000. This plan to bolster the nation's ability to compete in knowledge-economy pursuits aligned with the traditional development strategy pursued by Industrial Development Agency Ireland to entice multinationals to locate in Ireland.

Ireland's policymakers determined the best way to retain and develop national competitiveness and ensure major multinationals maintained a strong manufacturing presence in the country was to create an environment that promoted development of R&D divisions within those same companies.

As a result, Science Foundation Ireland (SFI) was created, investing €646 million between 2000 and 2006 primarily to fund research projects and to construct academic research centers designed to attract academic researchers and research teams that would generate new knowledge, technologies and competitive enterprises in biotechnology and information and communications technology. (Using the current exchange rate of 1 Euro = 1.2963 U.S. dollars, the investment equates to $837 million.)

According to an international review panel recently convened to review the activities of SFI, the effort has been successful in:

- *Attracting leading foreign research scientists to Ireland.*
- *Attracting Irish researchers who established distinguished careers working abroad back to the country*

Additionally:

- *81 research groups in biotechnology received awards from SFI.*
- *82 in information and communication technologies (ICT) hold awards from SFI.*
- *More than 1,150 researchers have been supported by SFI. These include 163 principal investigators, 34 of which came to Ireland from laboratories abroad, and 444 postgraduate students.*
- *SFI received significant support from Irish businesses and encouragement to continue to improve the quality and quantity of research in Ireland.*

Recent reports suggest that private-sector research activity has accelerated with R&D investments by multinationals up 10 percent and no fewer than 550 companies investing €100,000 (approximately $130,000 in U.S. dollars in 2007) or more in R&D. Ireland currently plans to ratchet up investments dramatically.

How This Translates to Arizona

Ireland and Arizona have economies that are similar in size. However, economic growth in Arizona over the last 60 years has been marked by a high rate of net in-migration, while Ireland has historically *experienced population outflows. The trajectory of growth on a per-capita basis has been more rapid in Ireland.*

Overall, Arizona's educational attainment compares favorably with that of Ireland. However, Arizona's overall figures are boosted by high attainment among the older population, many who are no longer economically active; the attainment of younger workers is below the national average. In contrast, younger Irish workers have a higher level of education than their counterparts in the European Union while elderly workers in Ireland have lower educational attainment.

SFI results, however, do offer some guidelines for Science Foundation Arizona (SFAz). SFAz needs to achieve the same integrity of external review process and adherence to the highest standards that the external review committee found in its audit of SFI.

In order to expand the research base across the spectrum, SFAz needs to emphasize research that will attract scientists with diverse interests. A key objective of SFAz in its early years needs to be building a research infrastructure that can be used to leverage external funding opportunities from federal sources and from the industry.

While scientific, engineering and medical research are the primary focus, raising literacy levels in science and mathematics also will be a valuable objective for SFAz. Results will soon be available from the SFI-sponsored Secondary Teacher Assistant Researchers program, which connects teachers with researchers in universities and technology institutes to develop science skills that they can pass along to their students.

SFI focuses on biotechnology and ICT to align with industry clusters already in place in Ireland. The SFI experience and independent research suggests that such programs are more successful, at least initially, if the scope is kept narrow. Arizona needs to carefully examine its existing technology clusters and overall strengths and weaknesses to determine how to structure the expenditures of SFAz.

The Origins of Science Foundation Ireland

Much of the widely documented "Celtic Tiger" success in the latter two decades of the 20th century resulted from efforts to entice multinational corporations to locate in Ireland by offering tax incentives, government-facilitated coordination with labor leaders, and a business-friendly regulatory environment. This strategy ensured that Ireland was positioned optimally for multinationals seeking an entrée into Europe.

Following these aggressive inward foreign direct investment building strategies, Ireland became heavily dependent on export-led growth. In the late 1990s the country had one of the highest per capita gross domestic product (GDP) figures among Organization for Economic Co-ordination and Development (OECD) countries, but had lost much of its comparative advantage in attracting additional inward investment. Eastern European countries had become aggressive competitors for businesses enticed by prospects of low business costs and low taxes and Asia loomed as a global competitor for high technology manufacturing.

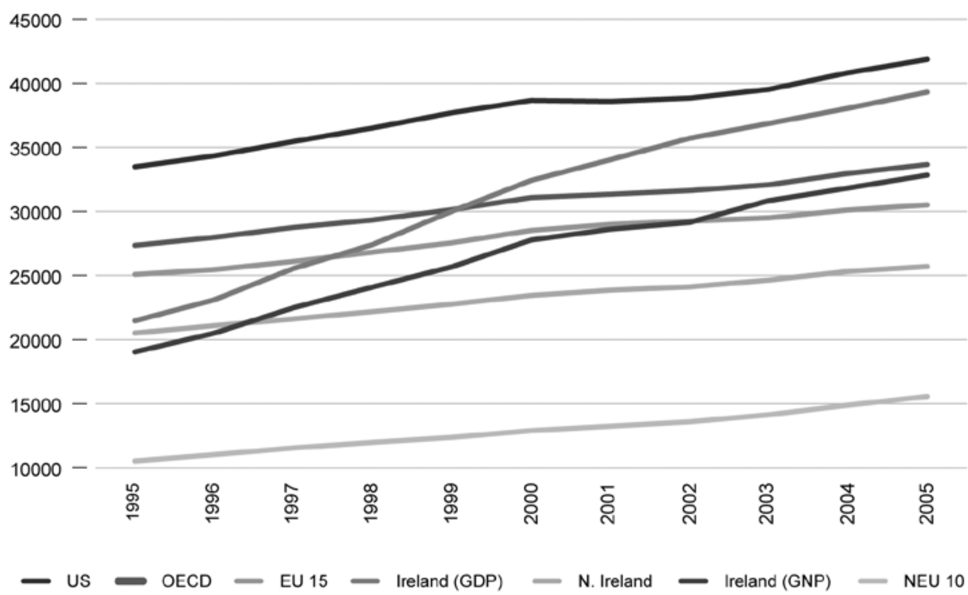
In order to retain and increase national competitiveness, Ireland began to pursue development strategies designed to bolster the nation's ability to compete in knowledge-economy pursuits. This agenda was designed as the logical extension of the traditional development strategy pursued by IDA Ireland (Industrial Development Agency) to court multinationals. Ireland's policymakers determined that that the best way to ensure that major multinationals maintained a strong manufacturing presence in the country was to create a climate conducive to nurturing the research and development divisions of these same companies. In order to do so, the government sought to "establish a fund which would enable Ireland to become a centre for world class research excellence in niche areas of ICT [information and communication technologies], biotechnology and their underlying sciences" (*Science Foundation Ireland, the First Years*, 2001 – 2005).

Figure 2, which is reprinted from Ireland's *Annual Competitiveness Report 2006*, reveals that the growth trajectory of Ireland has been spectacular over the last 10 years: GDP per capita climbed from levels below the average of OECD countries in 1995 to levels approaching the United States in 2005. Coupled with the attractive tax and regulatory environment, Ireland's emphasis on new research investments may have helped buffer the sharp decline in the modern manufacturing sector — job growth in the 1990s averaged 6 percent per year, but from 2000 to 2005 the number of manufacturing jobs decreased 5 percent per year (*Annual Competitiveness Report 2006*, page 34). At the same time, the number of researchers per 1,000 employees in Ireland grew from 5.0 in 2001 to 5.8 in 2004. However, the target level of 9.3 in 2010 (which compares to 2004 figures of 8.0 in the OECD countries and 9.6 in the United States) remains a lofty goal (*Annual Competitiveness Report 2006*, page 97).

Figure 2

Per Capita Gross Domestic Product: Selected Countries and Regions

Levels of GDP per Capita, Ireland and Selected Economies, 1995-2005 (US$ PPP)



Source: Forfás Calculations; Groningen Growth & Development Centre, Total Economy Database, March 2006; OECD, Annual National Accounts Database; United Kingdom, Office for National Statistics, 2006 [online]

Note: This table presents per capita GDP in U.S. dollars PPP (purchasing power parity). PPP adjusts for relative cost of living and inflation as well as exchange rates.

Source: Reprinted from Forfás, Annual Competitiveness Report 2006, Figure 2.01.

The direct benefits of Science Foundation Ireland (SFI) investments are hard to measure in the short run and certainly are not as easily forthcoming from traditional cost-benefit analysis since the likely benefits accrue over decades or generations. SFI is designed as a forward-looking foundation-building program that was undertaken "to ensure Ireland will have the skilled people who can handle the next period of change" (*Science Foundation Ireland, the First Years* 2001-2005, page 11).

At the center of the SFI agenda is an effort to encourage skilled Irish researchers working abroad to return "home" and to entice foreign researchers to perform world-class research in Ireland. So SFI is a part of Ireland's current economic development strategy where economic growth is increasingly reliant on innovation, which in turn depends on the quality of the research infrastructure. Irish policymakers believe that the pressures of competing in the 21st century global economy are different from those of even a decade or two in the past — and they are meeting the challenge straight on. Attempting to compete by exclusively using the incentive-laden traditional economic development paradigm is not their strategy.

Ireland's current approach aligns with Malecki's (2004) distinction between high-road versus low-road development strategies. Malecki characterizes the use of incentives as "low road" development strategies. In contrast, "high road" strategies lead to 21st-century knowledge economies and involve research and development, strong but flexible institutions, a culture of trust and networking, and broad capabilities to capture and absorb external knowledge. The Science Foundation Ireland initiative is aimed directly at increasing Ireland's capabilities in the areas of science and technology.

Science Foundation Ireland

SFI is basically a government institution that disburses funds for basic science research. It is a part of Forfás, the national policy and advisory board for enterprise, trade, science, technology and innovation, which operates under the auspices of the Department of Enterprise, Trade and Employment. SFI has a strategic focus mainly in two fields: biotechnology and information and communication technologies (ICT). Hence SFI, the Higher Education Authority, Health Research Board, two Research Councils and a number of government departments constitute the public research funding system for the country (*Science Foundation Ireland, the First Years 2001-2005*, page 20). Examples of the programs currently available to researchers in Ireland through SFI are listed in Figure 3.

Science Foundation Ireland invested €646 million between 2000 and 2006 primarily in funding basic research projects and constructing academic research centers designed to attract academic researchers and research teams. (Using the current exchange rate of 1 Euro = 1.2963 US$, the investment equates to $837 million.) Priority in funding was directed to those projects most likely to generate new knowledge, innovate with leading-edge technologies, and support the creation of competitive enterprises in the fields underpinning the two broad areas of biotechnology and ICT.

An Example of an SFI-Funded Research Center

The Digital Enterprise Research Institute (DERI) in Galway is a good example of the types of research centers that exist today as a direct result of an SFI investment. The case study, taken from the 2006 Forfás report *Open Source Trends and Business Models*, describes DERI and outlines how the diverse missions of a research university and a multinational corporation like Hewlett-Packard can be aligned to forge an alliance that allowed DERI to grow in size and international stature. The case study outline in the report is reproduced in Figure 4.

Figure 3
Science Foundation Ireland Award Programs for 2007

SFI Programme
Principal Investigator
Centres for Science, Engineering & Technology (CSET)
Strategic Research Clusters (SRCs)
Research Professor Recruitment
Industry Supplement
UREKA Supplements
STARs
Workshops & Conferences Grants
President of Ireland Young Researcher Awards (PIYRA)
Research Frontiers Programme
SFI/Dell Scholarship
Principal Investigator Career Advancement Award (PICA)
Institute Planning Grant
ETS Walton Visitor Awards
Institute Development Award
Mathematics Initiative
Equipment Call
UREKA Sites 2007
UREKA Site International Exchange Programme
Overhead Investment Plans
China Ireland Research Collaboration Fund
Centres for Science Engineering and Technology in Systems Biology

Source: Reprinted from the website of Science Foundation Ireland: www.sfi.ie

Figure 4
Deri Case Study

The Digital Enterprise Research Institute (DERI) is based at the National University of Ireland, Galway (NUIG). DERI is a research institute which aims to make the Semantic web vision a reality.

DERI was initially funded by a 12M Euro grant from Science Foundation Ireland (SFI), as a new Centre for Science, Engineering & Technology (CSET) in Ireland, with Hewlett-Packard (HP) as the major industrial partner. The DERI CSET is initially a five year project, which started in 2003. Since foundation DERI has expanded rapidly, securing significant funding from other sources including Enterprise Ireland, The European Union (Framework 5 & 6 funding) and industry. HP has been a significant stakeholder in this expansion, including joint participation in EU funded projects. Today, DERI has over 70 researchers based at NUIG and has also established relations with other research institutes in Europe, USA and the Far East which are affiliated to DERI under the DERI umbrella and with other industrial partners. HP provides management support and industry grounding for the research programmes of DERI including joint participation in other funded research projects and shaping projects for commercialization. Today, DERI is a flagship for collaboration between traditional IT vendors and HEIs.

As a HEI NUIG is primarily an education and research intensive university and is not positioned to directly commercialize IP, unlike an industrial partner. During the early formation years of DERI different perspectives emerged as to the needs of commercial and academic institutions in the protection and commercial exploitation of IP, and to large degree open source software only compounded the cultural differences that exist. HEIs need to publish papers and ISVs need to attract revenues. While the two are not mutually exclusive they can pull a project in different directions and at varying speeds.

Open source projects within DERI have encountered many of the challenges in commercializing software in the OS context. Paramount in importance is the clear and early setting of commercial objectives (if any) for each project. In this regard it has been very beneficial for HP to communicate the particular requirements of commercial ventures based on open source and for NUIG to put management structures in place to ensure such objectives are maintained.

In developing new IP, NUIG has an eye as to how best to commercialize such IP, be it through licensing or other means and recognize the balance required to protect IP and to enable industrial partners to commercialize such IP in a timely manner. In this regard NUIG has put guideline policies in place which are designed to facilitate IP commercialization through licensing or collaboration with industrial partners, while at the same time putting management structures in place to facilitate IP commercialization and protect the interests of industrial partners and software developers.

HP and NUIG have established 3 types of projects in order to clarify scoping and ownership issues:

- Projects owned and delivered solely by HP
- Projects owned and delivered solely by NUIG
- Collaborative projects, in which ownership and scoping are shared.

The project type structure mitigates the risk of confusion and purposes of projects. It also means that there is no room in DERI for a single contract type, since each project must have the appropriate terms of reference based on ownership and scope of the project and recognizing that different industrial partners have different needs.

The decision on which project follows which type is driven by the degree of shared interest; projects that interest both HP and NUIG tend to result in collaborative projects with shared value to both parties. The other determining factor for collaborative projects is the joint bidding for EU funds, which are well-scoped and defined prior to the project commencing.

Source: Reprinted from Forfás, Open Source Trends and Business Models, July 2006, p. 47-48.

An International Review of SFI

As a part of a recent assessment process, Ireland retained an international review panel to evaluate Science Foundation Ireland. The members of the review panel included academic and business leaders from outside Ireland. The criteria for evaluation of SFI are listed below (*Science Foundation Ireland, the First Years 2001-2005*, page 43):

Appropriateness or efficacy:

- Whether the objectives for SFI are still consistent with the current state of the Irish research system/science base and with national research and innovation policies.
- Whether the level of investment in SFI is appropriate to meet its objectives and what continuing investment will be necessary to sustain it.
- Whether there are sufficient and appropriate complementary measures to SFI, which would allow the desired economic effects to materialize.

Effectiveness:

- Is SFI effective in meeting its objectives?
- Are its programs and activities likely to lead to the desired outcomes?
- What are the outputs and impacts of its activities?
- What impact is SFI having on the research system as a whole?

Efficiency:

- Examine the operational efficiency of SFI in relation to a range of relevant issues (such as application and review procedures, monitoring).

The report on progress to date includes the following summary of results:

- Leading foreign research scientists have been attracted to Ireland.
- Irish researchers who have established distinguished careers working abroad have returned.
- Eighty-one research groups in biotechnology and 82 in ICT hold awards from SFI. To date, more than 1,150 researchers have been supported by SFI. These include 163 group leaders (principal investigators), 34 of who came to Ireland from laboratories abroad, and 444 postgraduate students. Most of the postgraduates hold Ph.D. degrees.
- SFI has maintained objectivity by using an international peer review panel for project proposals that applies internationally high-quality standards to the review process.
- SFI received considerable support from Irish businesses that were polled by the review team. The businesses encourage SFI to continue to improve the quality and quantity of research undertaken at research institutions in Ireland.

Comments and Basic Recommendations of the Review Panel

The following comments were cited in the report:

- SFI has been a positive driving force for change in the Irish research system.
- The energy and purpose of the efforts to date have been acknowledged, including tangible evidence of developing research capability in biotechnology and ICT.
- The emphasis on excellence is serving as a catalyst for improving research quality across the country.
- Site visits reveal potential for linkages between research centers and industry through tangible evidence of commercialization efforts.
- A need exists for more coordination between SFI and other research support efforts in Ireland.
- Irish business schools need to focus on research and teaching in the area of innovation processes and in the commercialization of research. This focus could help SFI realize goals in commercialization of research activities.
- Appropriate safeguards for the use of public money have been put in place.

The review panel made the following recommendations:

- SFI needs to clarify how individual projects will be assessed as they come towards the end of their life. Opportunities for obtaining a second award need to be clearly defined.
- Irish universities should be encouraged to offer research positions and grants to the best foreign and domestic researchers to keep them in Ireland.
- Programs designed to target young researchers should continue and, if possible, should be strengthened.
- After projects have passed initial screens, a relatively small review committee can serve to assess the merits of proposals. Reducing the number of reviewers at advanced stages of the review process could improve efficiency of the process. The independence and integrity of the review process is key to its success. The process of selecting project review members based on their scientific background and experience needs to be retained.
- SFI should retain its focus on two areas: biotechnology and ICT. They should not extend the support to other areas without securing additional funding.
- An efficient national research system must be linked to the international system and must be capable of recognizing and exploiting new developments wherever they arise. Hence, SFI should continue to link its research to international research.
- SFI needs to continue in its quest to link investments in research projects with tangible downstream commercial benefits.

Outcome metrics suggested by the audit report

- The review panel considered the numbers of publications and citations, excluding self citations, both by foreign and domestic researchers prior to their coming to SFI.
- The peer review system needs to maintain international standards. Hence SFI staff needs to maintain an inventory of information available from the research funding agencies in the United States, United Kingdom, Finland, and Australia.
- Face-to-face and phone interviews were carried out with large foreign-owned multinational firms, small-scale high-tech firms and large national firms about SFI and their awareness of this institution. An ongoing record of feedback from the business community should be maintained.

Progress in Ireland

So what is the payoff from Ireland's attempts to raise its level of research infrastructure? The *Forfás End of the Year Statement 200*6 suggests significant progress. Martin Cronin, Chief Executive of Forfás, notes, "Ireland is continuing its evolution towards a knowledge-based economy and is catching up in terms of research and innovation activity. R&D expenditure in the enterprise sector recorded a strong ten percent increase in 2005 and is forecast to continue growing at the same rate into 2006. This can also be seen in the high quality of inward investment that Ireland witnessed in 2006, including R&D investments by firms such as Amgen, Cisco, GlaxoSmithKline, PepsiCo and Servier. Among indigenous companies in 2006, more than 550 companies invested €100,000 or more in R&D, with major R&D investments announced by companies ranging from Dawn Farm Foods, Qumas and Foamalite."

While it is impossible to know how much of this private investment would have occurred without the SFI and related initiatives, Ireland's economic development community has clearly embraced the research programs as a key element of current strategy. The community cautions that more work needs to be done to address research infrastructure deficiencies under the €3.8 billion Government Strategy for Science, Technology and Innovation (SSTI) investment plans for 2006 to 2013.

A Comparison of Ireland with Arizona

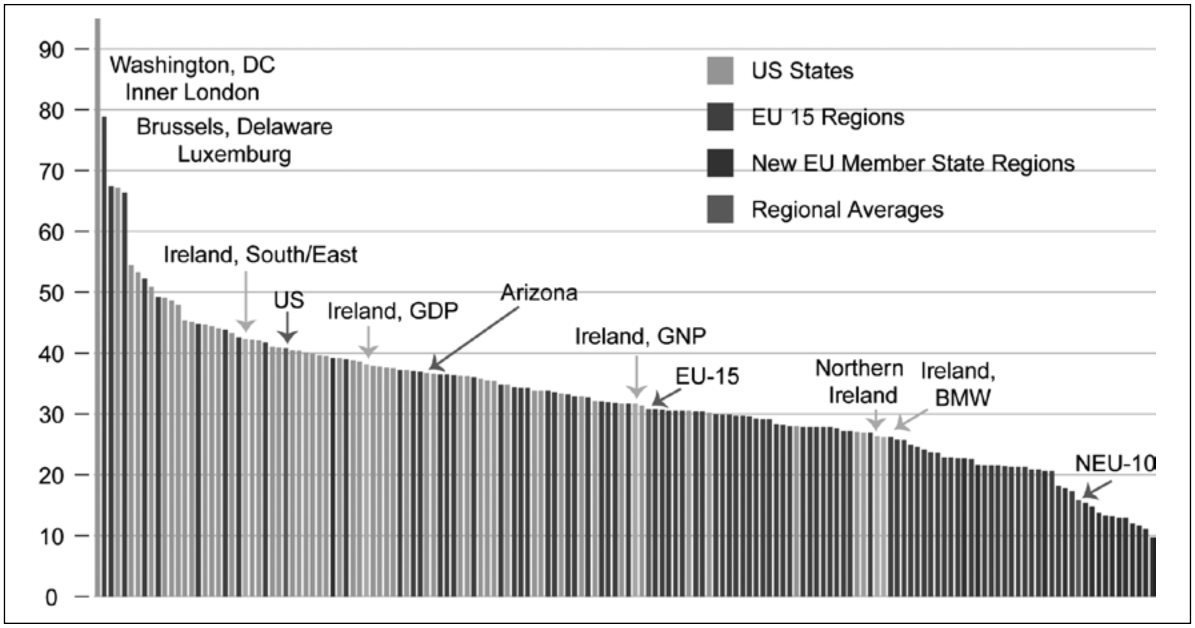
Arizona's economy shares few similarities with the Irish economy, which is about the size of the economy of the Phoenix metropolitan area. Economic growth in Arizona over the last 60 years has been marked by a very high rate of net in-migration. In contrast, Ireland historically experienced population outflows. While some multinational job opportunities exist in Arizona, the labor force is characterized by relatively large numbers of service jobs that exist to meet the needs of the rapidly growing population. The state has witnessed the loss of some high-tech manufacturing jobs since 2000, but strong growth in other sectors has helped temper the negative effects of globalization pressures that are more apparent in other regions of the United States.

A comparison of per capita GDP reported by Forfás is reproduced in Figure 5, with Arizona's per capita gross state product (GSP) added. In terms of this common measure of economic prosperity, Arizona's figure is slightly less than that of Ireland and further below the level of the United States.

Figure 5

Per Capita Gross Product: Selected Geographic Areas

Levels of GDP per Capita, US States and EU Regions, 2003/04 (US$ 000s)



Source: Forfás Calculations; Groningen Growth & Development Centre, Total Economy Database, March 2006; Eurostat, General and Regional Indicators, 2006 [online]; United States, Bureau of Economic Analysis, 2006 [online]

Source: Reprinted from Forfás, Annual Competitiveness Report 2006, Figure 2.02. Arizona added from author's calculations.

In recent years, growth in Arizona GSP per capita has essentially matched that of the U.S. per capita GDP, as illustrated in Figure 6. Thus, the state's historical shortfall from the national average remains. Figure 6 includes Ireland's GDP per capita from the data in Figure 2. Interestingly, the trajectory of economic growth in Ireland has been steeper in recent years than that observed in either the United States or Arizona. The chart reveals that Ireland is reducing the economic disparity with the U.S., at least based on per capita GDP. Though Ireland appears to have similar economic capacity to Arizona (as explored below), it recently has experienced greater economic gains.

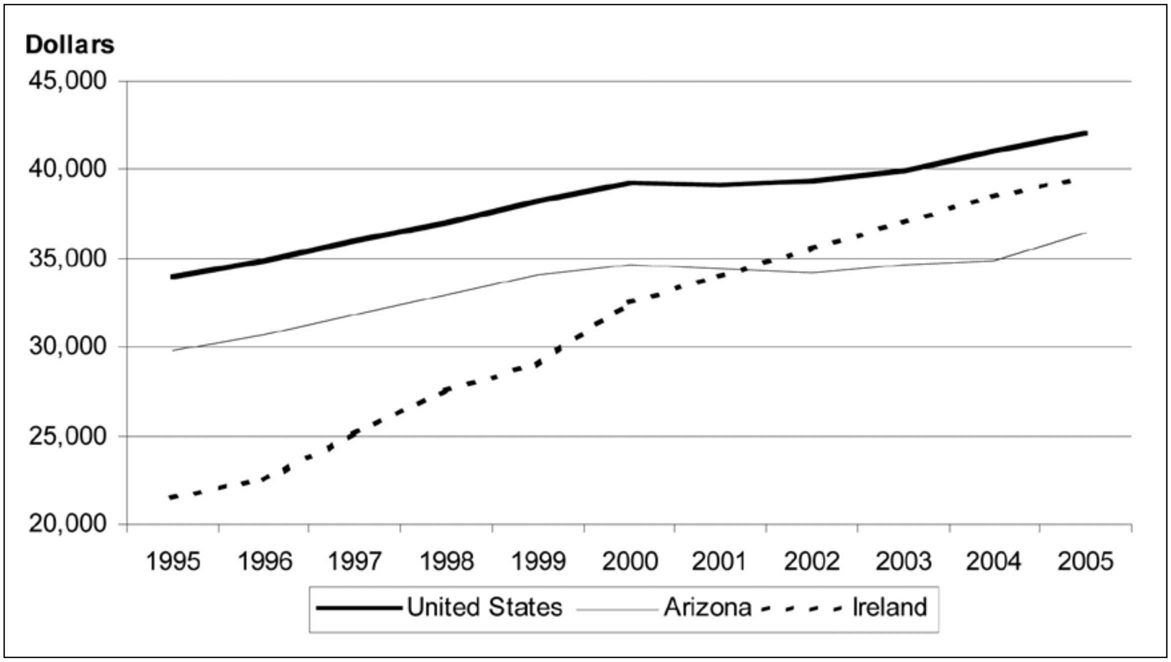
Aggregate GDP comparisons offer no conclusive support for the effectiveness of a particular program. Any number of factors may be responsible for the differences in economic level and growth rate between Arizona and Ireland. Still, comparing output on a per capita basis remains the most commonly used measure of economic prosperity.

Educational attainment of the workforce is one measure of the capacity to absorb benefits from R&D investments. Ireland's workforce educational attainment is similar to the average OECD or European Union (EU) country, although it has a relatively high percentage of workers without the equivalent of a high school diploma (see Figure 6). Using decennial census data for 2000 for Arizona, 18 percent of the working-age population had less than a high school education, 50 percent had a maximum achievement of a high school diploma or some college with no degree, and 32 percent earned a two-year associate degree or more. Arizona's attainment was slightly inferior to the United States average. Comparisons between these percentages and those in Figure 7 are not exactly comparable, but Ireland appears to have lower levels of educational attainment in the working-age population than Arizona.

Figure 6

Per Capita Gross Product: Ireland, United States And Arizona, 1995 To 2005

(Constant 2005 Dollars Adjusted For Purchasing Power Parity)



Note: This table presents per capita GDP in U.S. dollars PPP (purchasing power parity) in 2005. PPP adjusts for relative cost of living and inflation as well as exchange rates.

Source: Figure 1 for Ireland and the U.S. Department of Commerce, Bureau of Economic Analysis for the United States and Arizona.

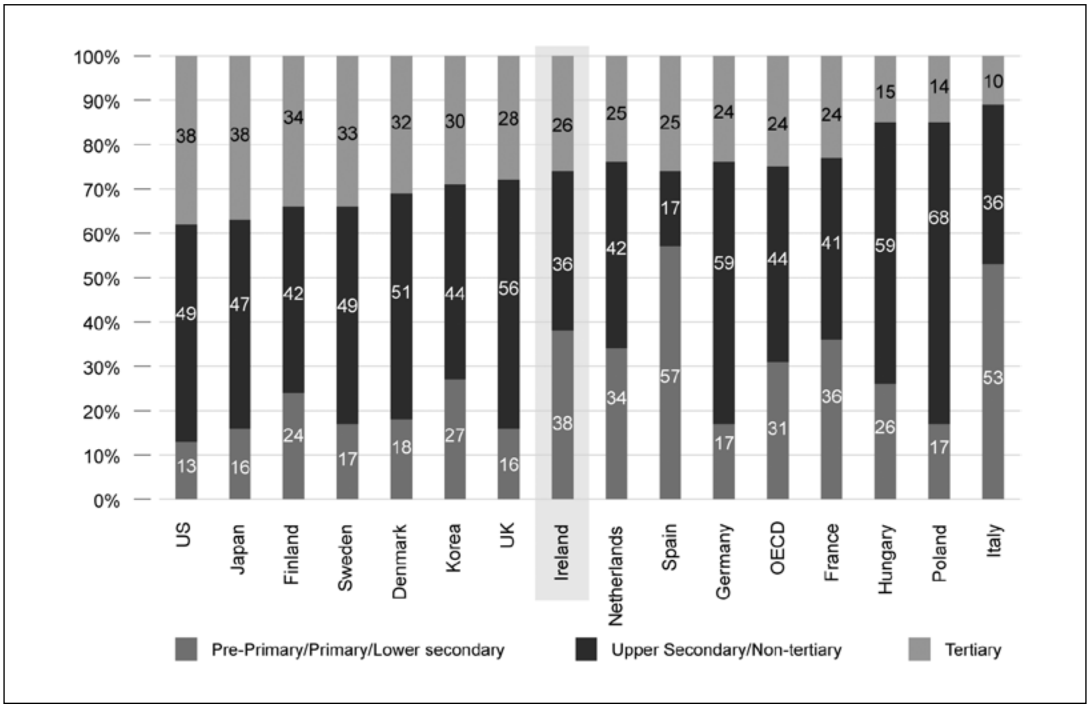
More information about the knowledge and skills of the working-age populations in Ireland and Arizona can be obtained by examining the level of educational attainment by age cohort. Figure 8 reveals that Ireland has a relatively high degree of educational attainment, in comparison with the OECD and especially the EU averages, among younger segments of the working-age population. Attainment among those 25 to 34 years old is close to that in the United States, while Irish attainments in older age groups are far less than the U.S. average.

Figure 7

Educational Attainment of Working-Age Population:

Selected Countries and Regions

Educational Attainment of Population Aged 25-64 by Highest Level of Education, 2003



Source: OECD, Education at a Glance, 2005

Source: Reprinted from Forfás, Annual Competitiveness Report 2006, Figure 4.42.

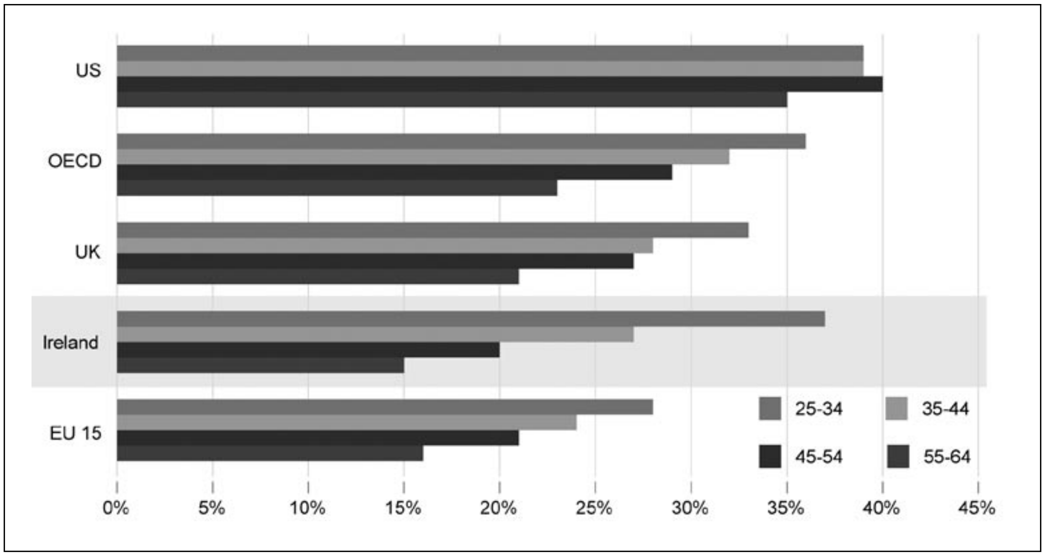
Though Arizona's educational attainment is near the U.S. average among the 25-and-over population, the category most commonly reported in the United States, the state lags the nation in educational attainment in the younger age groups. Only in those older age cohorts with low workforce participation rates does Arizona exceed the U.S. average (see Table 13). So, in terms of educational attainment by younger and older segments of the population, the situation in Arizona and Ireland is quite different. Young workers in Ireland are relatively more educated than those in the surrounding region, but Arizona's younger workers are less educated than their counterparts across the United States.

Arizona's younger adults consist of those who grew up and were educated in Arizona and those who moved to the state after their primary and secondary education was complete. Both groups contribute to the state's subpar educational attainment among younger adults. That in-migrants have substandard educational attainment suggests that the state is producing a disproportionate number of jobs that do not require an advanced education.

Figure 8

Educational Attainment by Age Group: Selected Countries and Regions

Population by Age Cohort That Has at Least Third Level Education, 2003



Source: OECD, Education at a Glance, 2005

Note: A third level education is a postsecondary or tertiary education.

Source: Reprinted from Forfás, Annual Competitiveness Report 2006, Figure 4.53.

Table 13
Educational Attainment: Arizona and United States, 2000

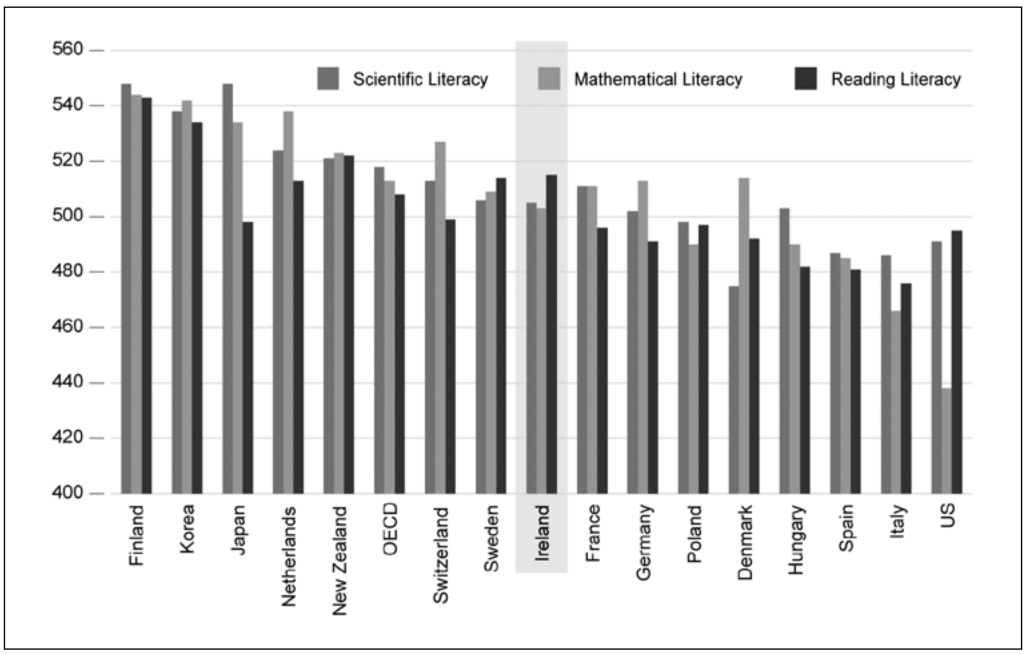
	Percentage with at Least a Bachelor's Degree			Number with a Doctorate Degree per 1,000 Residents		
Age	U.S.	Arizona	Difference	U.S.	Arizona	Difference
25-34	27.5	22.9	-4.7	5.0	3.8	-1.2
35-44	25.9	23.8	-2.1	8.6	7.0	-1.7
45-54	28.8	28.0	-0.8	12.7	12.1	-0.6
55-64	22.7	24.4	1.7	15.1	14.3	-0.8
65-74	17.3	20.8	3.5	10.6	12.4	1.8

Source: U.S. Census Bureau, 2000 census.

The Relevance of Science Foundation Ireland to Science Foundation Arizona

Since educational attainment is the key component to achieving high rates of productivity, aligning initiatives in Science Foundation Arizona (SFAz) with programs designed to increase levels of educational attainment can help address the state's shortcomings in this area. Indeed, science and technology education is the primary focus of SFAz. Reports such as *Rising Above the Gathering Storm, Energizing and Employing America for a Brighter Economic Future* have widely documented the deficiencies in STEM (science, technology, engineering and math) educational attainment in the United States. Figure 9 displays some comparable math and science literacy data from around the world. Clearly, the United States lags much of the world in STEM education skills, with mathematical literacy especially low. The lack of emphasis on science and mathematics subjects at an early age impedes college degree attainment in STEM disciplines. SFAz programs designed to integrate high school instructors with research activities underway at the state's college campuses can help address this issue.

Figure 9
Literacy: Selected Countries and Regions
Scientific, Mathematical and Reading Literacy of 15-Year-Olds, 2003



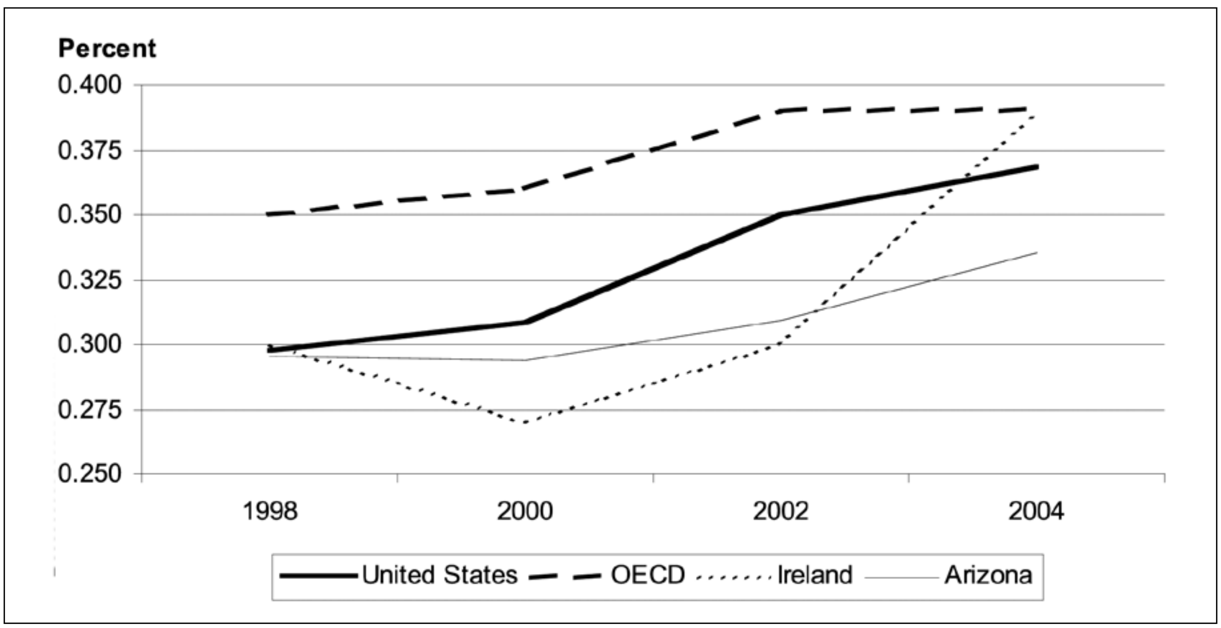
Source: OECD, PISA Database, 2003
Source: Reprinted from Forfás, Annual Competitiveness Report 2006, Figure 4.50.

Science Foundation Ireland's STAR program for secondary school teachers can serve as a useful guide. Science teachers are paid a summer stipend to support time spent on college campuses working in lab assistant support roles under the direction of particular scientists. In the summer of 2006 researchers from seven universities across Ireland supported projects for SFI's STAR teacher program.

Most of SFI's programs are devoted to supporting research, through grants for such purposes as specific research projects, support of visiting scholars, supporting the formation of centers at foundation stages, and supporting research symposia. The overall intent is to raise the level of basic research investment.

A comparison of the recent trajectory of research expenditures at higher education institutions can help illustrate how SFI can be a model for Arizona. Figure 10 depicts total research expenditures at institutions of higher education as a share of gross product for the average OECD country, the United States, Ireland and Arizona. The chart illustrates that research expenditures at universities account for a very small share — a little more than one-third of one percent of gross product in 2004. While Arizona experienced an increase in research expenditures relative to gross product from 1998 through 2004, the state failed to keep pace with increases at other universities in the United States, remained below the average OECD country, and *went from being ahead of Ireland in 2000 to below Ireland in 2004.* Research has been a key focus at the state's universities in the last two years, but there is no reason to believe that total research expenditure growth has eclipsed the sharp rise in the state's gross product from 2004 to 2006. Thus disparities likely remain. It is also probable that, due to efforts like SFI, Ireland's trajectory continues to be steep.

Figure 10
Research Expenditures at Institutions of Higher Education
As a Percentage of Gross Product



Source: Calculated from Forfás, [Annual Competitiveness Report 2006,] National Science Foundation, and U.S. Department of Commerce, Bureau of Economic Analysis.

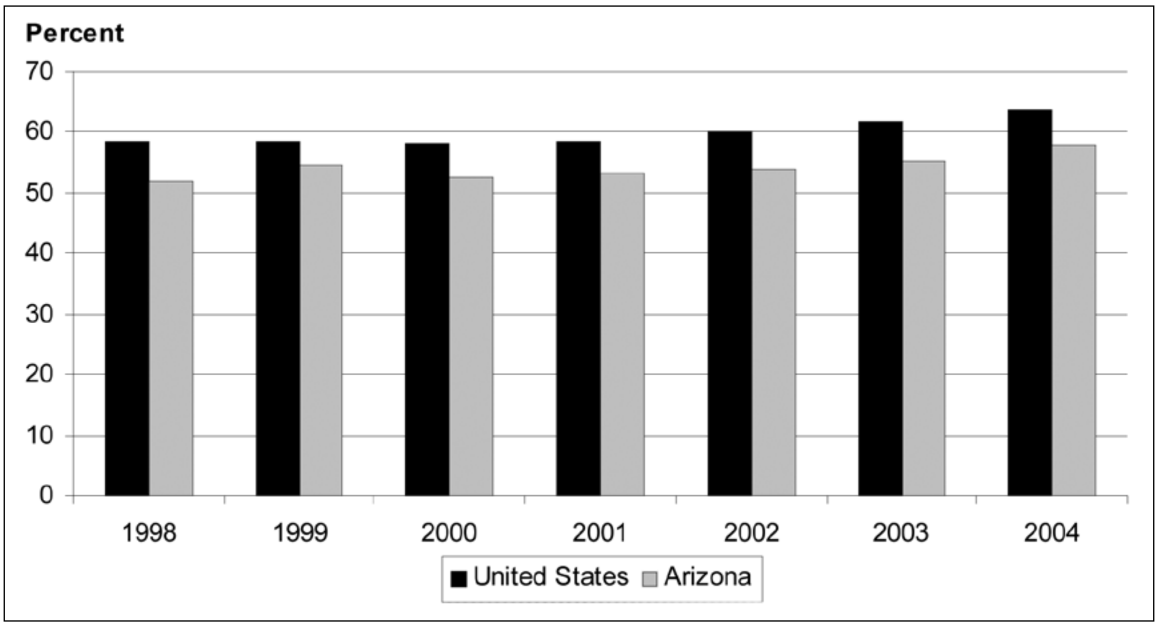
Figures 11 and 12 suggest that low research investment rates at universities in Arizona are more likely attributable to the lack of investment by federal sponsors in the state's research programs. Federal funding in Arizona is less than the national average, both as a share of total research spending and as a share of the state's gross product. Between 1998 and 2004, federal spending as a share of gross product increased less in Arizona than the national average.

This analysis of research intensity, with comparisons to Ireland, provides some direction for SFAz programs. If the state wishes to raise its research intensity to match the average OECD country, it will take nearly $1 billion in total research spending — based on current levels of Arizona Gross State

Product. Total spending in 2004 was approximately $650 million.

The lesson from SFI is that the seed money provided by SFAz should be closely linked to efforts to leverage the modest SFAz investments, attracting additional industry and federal sponsors. The state is well positioned to leverage industry relationships and the opportunity for tapping additional federal resources clearly exists. Grant programs initiated in the early years of SFAz must be used to leverage these other sources of funding for the initiative to have the desired impact on the state's overall university research efforts.

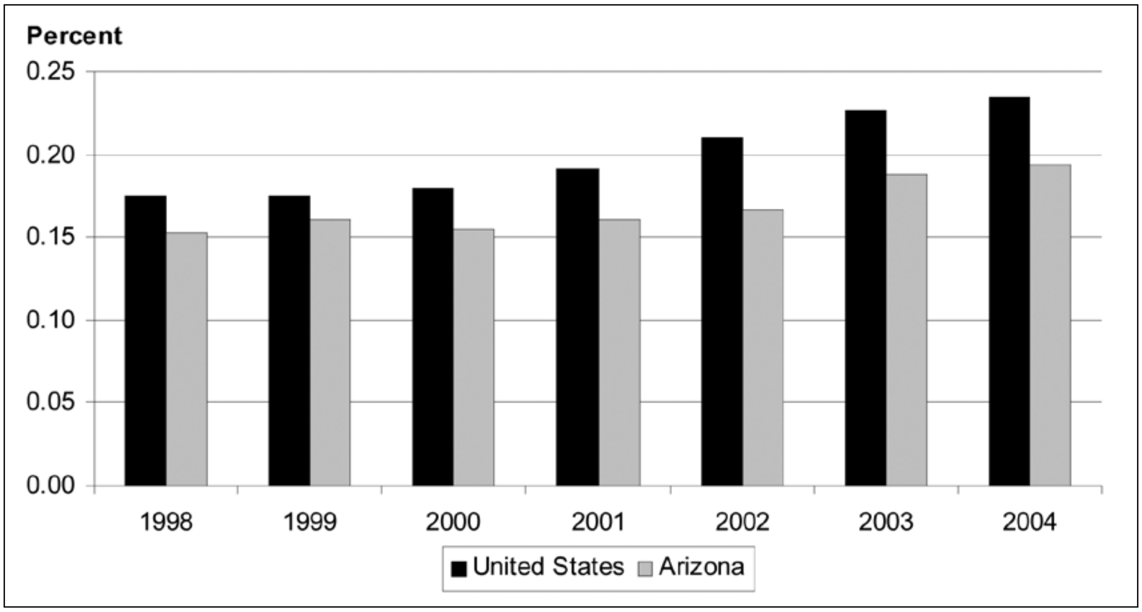
Figure 11
Federally Funded Research Expenditures
As a Percentage of Total Research Expenditures at Universities



Source: Calculated from National Science Foundation.

Figure 12

Federally Funded Research as a Share of Gross Product



Source: Calculated from National Science Foundation and U.S. Department of Commerce, Bureau of Economic Analysis.

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CHAPTER 5

Inventory of Initiatives in Other States Designed to Promote Research and Innovation

A Summary of Findings From Chapter 5

The state research initiatives reviewed in this chapter are diverse, and vary greatly in size of investment, timeframe, scope and focus. However, all are aimed at driving quality economic growth and innovation through increased funding for university-based research in high-technology areas and facilitating commercialization of research ideas and discoveries. These initiatives variously provide funding for research, construction of research facilities, the establishment of centers or institutes, and the formalization of private-public partnerships in research and innovation.

An inventory of a variety of initiatives under way in 37 states designed to promote research and innovation represent tens of billions of dollars in investments being funneled into local economies nationwide. Included are grants intended for research, the funding of research facilities, the establishment of centers or institutes, and the formalization of private-public partnerships in research and innovation. The funding sources vary from philanthropists to corporations to direct investments by the states themselves, sometimes by voter initiatives.

The initiatives range from small investments to multibillion-dollar programs. Some provide single-year funding for a particular building or project, while others are long-term investments that are scheduled to last 10 to 20 years.

Initiatives also vary in their intent, such as improving existing research infrastructure, using additional state funds to supplement university or other research facility building programs, and providing the funding for new institutes, including new facilities and labs.

Other initiatives establish entities, such as centers and institutes, in which funding for a particular type of research is provided. In some cases, the funding is for brick and mortar, while other initiatives include operational funds and funds to attract new faculty and researchers.

Initiative-funded projects also include research parks that provide the space needed by high-tech companies. In some cases, research centers are established via public-private partnerships.

Some initiatives appear to be geared toward traditional research efforts, such as building new research, classroom and clinical space. Other initiatives are aimed toward commercialization of research-driven patents and inventions. Similarly, other initiatives strongly encourage or require interactions between universities and state-based companies, providing firms with resources such as business incubation and security-matching grants.

A Case Study of New York State

Between 1999 and 2002, New York enacted a series of comprehensive economic development initiatives aimed at expanding the state's high-technology and biotechnology sectors through leveraging the resources of New York's research universities.

The first of these initiatives, the Jobs 2000 Act passed in 1999, included a $156.5 million investment in high-tech academic research and created the New York Office of Science, Technology and Academic Research (NYSTAR). NYSTAR funds and coordinates construction of high-tech research facilities, oversees programs to leverage federal and private funding for applied research and top faculty recruitment, and facilitates industry-university collaborations and technology transfer.

*Three years after the passage of the Jobs 2000 Act, three more major university research-based development programs were launched: the Centers of Excellence Program, established with an appropriation of $250 million; Generating Employment through New York Science Program (Gen*NY*sis), initially funded at $225 million; and Rebuilding the Empire State through Opportunities in Regional Economies (RESTORE) program at $150 million.*

*These programs support major high-technology and biotechnology capital projects and assist New York's universities and research institutions in securing federal and private funding. The capital plan continues to fund the Centers of Excellence, Gen*NY*sis and RESTORE Programs at more than $1.3 billion.*

Although these state investments in university-based economic development are significant, they are relatively new as much of the funding did not begin until 2003. Thus, it is too early for any comprehensive independent evaluations of economic impact to have been performed.

However, evidence of success cited by NYSTAR reveals the significant economic impact. NYSTAR reports that federal research funding outlays to New York research institutions now increase at 1.5 times the national average. By February of 2006, NYSTAR investments:

- *Generated a credited impact of more than $4.4 billion.*
- *Resulted in 162 patent applications and 47 patents received.*
- *Established 22 new companies.*
- *Awarded more than $509 million in non-state research funds.*
- *Created and retained 13,484 jobs.*

In addition, New York universities ranked No. 1 in the nation in revenue from licensing and patents, netting $305 million.

Background

All of the initiatives outlined in this chapter relate to research in some way: through grants intended for research, the funding of research facilities, the establishment of centers or institutes, or the formalization of private-public partnerships in research and innovation.

The initiatives range from rather small investments (such as $2.8 million in state funds to target investments in specialized research in South Dakota's public universities) to huge, multibillion dollar initiatives (for example, the $3 billion initiative for California's Institute for Regenerative Medicine). Some of the initiatives provide single-year funding for a particular building or project; others are long-term investment programs that are scheduled to last 10 to 20 years.

Initiatives also vary in their intent. Some aim to improve existing research infrastructure, using additional state funds to supplement university or other research facility building programs (including New Mexico's 2002 Bond Measure B, used to renovate and equip labs, teaching, and research facilities). Other initiatives provide the funding for new institutes, including new facilities and laboratories (such as the University of Michigan's Life Sciences Institute, which is part of the Michigan Life Science Corridor planned for development over a 20-year period).

Other initiatives establish entities, such as centers and institutes, in which funding for a particular type of research is provided. Examples are wide-ranging and include Alabama's Center for Transportation Technology, California's NanoSystems Institute, Georgia's Life Sciences Innovation

Center, and Illinois' Rare Isotope Accelerator Science Center. Sometimes the funding is for brick and mortar; other initiatives include operational funds and funds to attract new faculty and researchers. Part of the Texas Emerging Technology Fund initiative was set aside to hire top research teams away from other universities and research facilities.

Sometimes the initiative-funded projects include research parks, which include space for high-tech companies and provide "incubator" space (such as Tennessee's University of Tennessee-Baptist Research Park). In some cases, research centers are established via public-private partnerships. For example, BMW provided a $10 million endowment, which was combined with $25 million in state funds, to create a graduate engineering education center in Greenville, South Carolina.

Some initiatives appear to be geared toward traditional research efforts, such as New Jersey's $518 million building program to house new research, classroom and clinical space at the University of Medicine and Dentistry of New Jersey or Missouri's new research centers, designed to increase the state's investment in life sciences research.

Other initiatives are clearly geared toward commercialization of research-driven patents and inventions. Most of the funding from the Texas Emerging Technology Fund (aside from the portion set aside to hire researchers) is awarded to Texas companies who partner with a university researcher, rather than making awards directly to universities.

Similarly, other initiatives strongly encourage or require interactions between universities and state-based companies, such as Georgia's Life Sciences Innovation Center, which was created to provide life-sciences companies with resources, such as business incubation and security matching grants. This center will "promote and facilitate" interactions between the state medical college and Georgia-based companies to drive research and development, commercialization, and job creation.

The following list of initiatives was derived from multiple sources, as described below. None of the cited sources provided the detail necessary to completely understand the workings of these initiatives, however. Thus, several state initiatives were selected and researched independently to provide more insight into the purpose and legal framework surrounding those initiatives. The criteria for selection of particular state initiatives for further analysis included (a) the dollar amount attached to the initiative and (b) whether or not the initiative strongly focused on research. The more detailed description of selected initiatives follows the listing.

An Inventory of Research Initiatives by State

The following list of initiatives across states is derived from four sources:

1. Arizona State University, Office of Public Affairs. I*nvesting in Arizona's Future* (January 2003). Retrieved from (http://www.asu.edu/president/azfuture/). When a paragraph is a direct or almost-direct quote from this source, it is followed by (A). Most, if not all, of these references relate to funding for research facilities.

2. Salt Lake Chamber (Janice Houston, Houston Consultants, and Steve Mecham, Callister Nebeker & McCullough, Compilers). *Economic Development and the High Technology Industry in Utah: Trends, Implications and Recommendations* (January 12, 2005). Retrieved from (http://www.saltlakechamber.org/media/pdf%20files/2005-01-18.researchunivwhitepaper.pdf). If a research facility or research initiative listed is obtained from this source, it is followed by (U).

3. Texas Tech Initiative (Wade Garrett Chappell, Compiler). *National Competition for Emerging Technology Edge* (undated — appears to be from early 2006). Retrieved from (http://www.txti.org/docs/Competitive%20Analysis.pdf). The document contains a list of 23 state initiatives. When a (T)

follows a paragraph or section under a state, that paragraph is a direct or almost-direct quote from this source.

4. National Governor's Association (NGA), Center for Best Practices. *Enhancing Competitiveness: A Review of Recent State Economic Development Initiatives* (May 2006 and January 2005). Retrieved from (http://www.nga.org/portal/site/nga/menuitem.9123e83a1f6786440ddcbeeb501010a0/?vgnextoid=cbf076fc6041b010VgnVCM1000001a01010aRCRD). Research-related initiatives drawn from this source are labeled with (G).

Alabama:

2001: Governor Don Siegelman agrees to provide $35 million from a state economic development fund to boost a $90 million biomedical research facility at the University of Alabama at Birmingham. He also announces formation of the Alabama Research Alliance, a state, business and research university partnership designed to boost the state's research investment. (A)

2002: Auburn University will receive a $20 million match from the state for $20 million in federal money for construction of the 194,000 square-foot Center for Transportation Technology on campus. The center will house researchers developing analytical approaches to highway design and construction, traffic modeling and vehicle safety. (A)

Arizona:

Business Incubation at University Science Parks (http://researchpark.asu.edu/index.html). $500 million to attract Translational Genomics Research Institute and International Genomic Consortium. (T)

Arkansas:

Arkansas Nanotech Alliance. During a visit to the Arkansas Research & Technology Park, U.S. Senator Mark Pryor (D- Ark.) announces ANA's formation. Pryor will chair the statewide consortium, bringing together universities, federal agencies, and private-sector partners to develop, launch and nurture nanotechnology initiatives. (T)

California:

1985: The University of California at San Diego founds CONNECT at the request of San Diego's business community (http://www.connect.org/). Today, UCSD CONNECT is widely regarded as one of the nation's most successful regional programs linking entrepreneurs with critical resources for success. CONNECT provides expertise to San Diego's technology-based business community through partnerships with the region's prominent industry-specific organizations and individuals; and world-class UCSD resources. (T)

2000: $100 million for each of the following: California NanoSystems Institute (CNSI), Center for Information Technology Research in the Interest of Society (CITRIS), California Institute for Quantitative Biomedical Research (QB3), and Telecommunications and Information Technology (Cal-(IT)2). (T)

December 2000: California Governor Gray Davis announces establishment of the California Institutes for Science and Innovation, which will be underwritten by $300 million in state funds over four years and more than twice that amount from corporate sponsors. There will be three major research institutions dedicated to nanotechnology, biotechnology and telecommunications and computing. (A)

The institutions, comprising joint ventures among campuses in the University of California system, are intended to increase the competitiveness of the state's economy by focusing on technology challenges from transportation to agriculture. They will include these components:

- The California Nanosystems Institute, at the University of California at Los Angeles in collaboration with the University of California at Santa Barbara, which will focus on the development of extremely miniaturized technologies.
- The California Institute for Bioengineering, Biotechnology and Quantitative Biomedicine, at the University of California at San Francisco in collaboration with the University of California at Berkeley and the University of California at Santa Cruz.
- The California Institute for Telecommunications and Information Technology, at the University of California at San Diego in collaboration with the University of California at Irvine, whose work will include development of a more powerful, wireless Internet. (A)

2001-02: The University of California at Davis constructs a $39.6 million Plant and Environmental Sciences Building with half of the funding provided by state bonds and the other half coming from campus funds. UC Davis also is set to open a $95 million Genome and Biomedical Center in 2004, funded in part by the Whitaker Foundation with the remaining funding from the Garamendi legislation (the Garamendi law allows the university to take out a construction loan and then pay it off using the overhead charges to research grants that would otherwise be funneled to the state). (A)

2002: Proposition 47 (approved by voters November 2002) will provide $13.05 billion in bonds, issued and repaid by the state of California for the construction and modernization of elementary, secondary and higher education facilities; $1.65 billion is reserved for college campuses. The governor and the legislature will select the projects to be paid for by the bond dollars and some of this funding likely will go toward the completion of a new science building at California State Long Beach that will contain state-of-the-art teaching and research laboratories for chemists, biochemists and biologists. (A)

2003: California recently began a $300 million initiative to create new centers for biomedicine, nanotechnology and telecommunications. Each center will receive $100 million in state funds over the next four years, and each is expected to raise twice that amount on its own, making the total potential investment worth $900 million. (U)

2004: $3 billion in bonds for the California Institute for Regenerative Medicine (stem cell research). (T)

Californians vote to publicly fund a $3 billion stem cell research initiative. Taxpayers' money will be used to underwrite research to use embryonic stem cells to develop cures for Alzheimer's disease and other illnesses. Under the plan, the research will be financed by a state bond issue over 10 years. (U)

Proposition 71 creates an Independent Citizens Oversight Committee (27 members) that will oversee funding of research on stem cell techniques to explore potential cures for 700 diseases and debilitating conditions. (G)

2004: The University of California-Davis recently dedicated the $95 million Genome and Biomedical Center (see above). (U)

Colorado:

2004: The Colorado General Assembly passes legislation to establish a Colorado Venture Capital Authority (http://www.state.co.us/oed/bus_fin/VCA.shtml). (T)

Connecticut:

2005: Governor Jodi Rell establishes a 10-year, $100 million fund to encourage stem cell research financed by a state budget surplus and tobacco settlement fund dollars. A Stem Cell Research Advisory Committee will be responsible for conducting peer review research and administering grants from the fund in consultation with the Department of Public Health. (G)

Governor Jodi Rell's 2006 proposed budget (http://www.opm.state.ct.us/budget/2006-2007Books/2006-2007GovBudget.htm) asks for:

- $10 million over the next two years for stem cell research.
- $7.5 million for university research programs.
- A new "21st Century Skills Fund."
- A new "Next Generation Manufacturing" initiative. (T)

Florida:

June 2002: Vincent A. Stabile, local philanthropist and retired businessman, donated $15 million to the H. Lee Moffitt Cancer Center and Research Institute. The money is the largest private donation ever made to the Moffitt Center, which opened in 1986. The Stabile Building will be one of many additions made to the Moffitt Center over the next few years. (A)

The Moffitt Center tower project is funded by multiple sources, with the majority financed by the James L. Stevens Act as part of the tobacco settlement that was passed in May 2002. The Stevens Act provides that a portion of the cigarette tax be paid monthly to the Board of Directors of the Moffitt Center to finance cancer research at USF. Monies transferred to the Board of Directors of the Moffitt Center will be used to secure financing to pay costs related to constructing, furnishing, and equipping the cancer research facility. Financing for the Moffitt Center will come in the form of tax-exempt bonds by a local authority, municipality, or county. (A)

October 2002: A new $180 million addition to the H. Lee Moffitt Cancer Center and Research Institute — the Vincent A. Stabile Research Building, which is to be completed in April 2003 — will add 350,000 square feet of research space that can be used as a recruitment tool and help the University of South Florida gain national recognition as a Research I university. The new research center will have three floors of research laboratories and will provide Moffitt with research and clinical areas as well as a conference center and auditorium. The project's approved budget is $122 million and is expected to reach $180 million when the multiphased project is completed in the next few years. (A)

2003: With a $10 million grant from the state, the University of Florida's Center of Excellence for Regenerative Health Biotechnology is created to stimulate promising research, facilitate commercialization of treatments that provide cures for human diseases, and create new companies and high-wage jobs for Florida. (U)

2003: $300 million to attract the Scripps Research Institute to conduct biomedical research in Palm Beach (www.scripps.edu/florida/e_index.html). (T)

2004: Governor Jeb Bush recommends $20 million in the fiscal year 2004-05 budget for a Centers of Excellence program in Florida, designed to foster innovative, cutting-edge technology research at Florida's colleges and universities. (U)

In addition to research funded at universities, the Governor has invested in Florida's biotechnology and biomedical cluster through research grants for scientists and commercialization. Funding has been secured for longer-term biomedical research projects and training new scientists. The program is administered through the Florida Department of Health. (G)

Georgia:

1990: Since 1990, the state has invested $200 million in the Georgia Research Alliance, matched by $50 million from the private sector. This has resulted in an additional $500 million from the federal government in increased grants and contracts awarded competitively based on the increased merit and achievement of the research enterprise built at the six research universities. (A)

The enterprise has doubled since 1990, from $400 million annually to over $800 million. Venture capital has tripled, patents awarded have tripled, and industry relationships with university researchers have more than quadrupled. (A)

2004: Despite slashing spending across state government by $800 million, Governor Sonny Perdue still finds $5 million for the Medical College of Georgia Research Initiative and the money to give teachers and state workers a modest pay raise, keep hospitals and state parks open, and borrow $1 billion for a building program aimed at speeding the state's economic recovery. (U)

Governor Sonny Perdue hopes to create new jobs, increase investment and ensure long-term economic opportunity through a public-private-university partnership. Georgia's Centers of Innovations strategy focuses on the development of centers of excellence in the areas of aerospace, biosciences, digital media, logistics, medical technology, precision agriculture, and transaction processing. In addition to the centers' research function, entrepreneur-outreach specialists will provide technical expertise and access to state resources. The program was launched in coordination with universities, private corporate sponsors, and the Departments of Economic Development and of Industry, Trade and Tourism. (G)

The centers of innovation strategy launches the Agriculture Center of Innovation, where researchers from universities will collaborate to develop new solutions for agribusiness. Private corporate sponsors who join the center will be able to leverage that research and work with local farmers to give these solutions practical evaluations. The Georgia Department of Economic Development is working to recruit member companies to the center and create the collaborative environment that will drive technology research and development. (G)

2005: Georgia's fourth center of innovation, the Life Sciences Innovation Center, is created to provide life-sciences companies with resources, such as business incubation and security matching grants through the Georgia Research Alliance. The center will promote and facilitate interactions between the state medical college and Georgia-based companies to drive research and development, commercialization, and job creation. (G)

2005: Governor Sonny Perdue's fiscal year 2006 budget (http://www.gov.state.ga.us/press/2004/press629.shtml) introduces:

- $25+ million in new tax credits (over three years) to promote economic growth.
- $22.3 million for the budget of the University of Georgia System for the Advanced Technology

Development Center/Economic Development Institute (ATDC/EDI) (http://www.atdc.org/).

- $4.6 million in funds to provide equipment and lab renovations for Georgia Research Alliance projects.
- $27.4 million for the Georgia Research Alliance (http://www.gra.org/). (T)

Hawaii:

Governor Linda Lingle's budget (http://www.state.hi.us/budget) includes the following proposals:

- $36 million in a venture capital fund for the State Private Investment Fund.
- A 20 percent Business-Research Institute Tax Credit to companies who partner with the University of Hawaii on research projects in order to foster world-class research institutions in Hawaii.
- $1.5 million in state funds and $3 million in matching federal funds from the National Science Foundation through the Experimental Program to Stimulate Competitive Research grant. (T)

Idaho:

2002: Governor Dirk Kempthorne approves the use by Idaho State University of about $1 million in funds to build an expansion of the Idaho Accelerator Center in Pocatello. Despite poor state tax revenues, Kempthorne says school President Richard Bowen's responsible fiscal management and planning helped him feel comfortable authorizing the construction. (A)

Illinois:

2000: Governor George Ryan launches VentureTech, a $2 billion, five-year program to invest state resources in technology. The program is funding projects like the construction of research facilities at Northwestern University's Chicago campus and the University of Illinois at Chicago. VentureTech also is funding the following "bricks and mortar" investments:

- Rare Isotope Accelerator Science Center at Argonne National Laboratory.
- Center for Nanofabrication and Molecular Self-Assembly at the Institute for Nanotechnology at Northwestern University.
- Argone Nanoscale Center.
- Thomas M. Siebel Center for Computer Sciences at the University of Illinois.
- University of Illinois National Center for Supercomputing Applications Building.
- Fermi Accelerator Research: a partnership with Fermilab and a consortium of Illinois universities, led by the Illinois Institute of Technology, to examine the next generation of accelerator technology.
- Advanced Photon Source: a national synchrotron radiation research facility in which six Illinois universities participate collaboratively with scientists from private industry and the federal government.
- UI Microelectronics Laboratory at UI in Urbana.
- UI Tech Incubator as part of the Champaign-Urbana research park.

- UI Medical School state-of-the-art research facility at the Illinois Chicago campus.
- Chicago Tech Park Expansion.
- UI Medical Resonance Imaging, a medical imaging research/clinical facility.
- UI Chemical Sciences Building, a research facility in Chicago.
- Northwestern University Biomedical Research Building.
- Southern Illinois University Cancer Institute: to create a new research and public-service cancer institute at the SIU School of Medicine in Springfield.
- University of Chicago Juvenile Diabetes Center located at the University of Chicago.
- Illinois Institute of Technology Biomedical Research Center: a new facility designed to house programs in biomedical engineering, pharmaceutical manufacturing, genetics research, cancer research and preclinical trials. (A)

October 2002: Governor George Ryan's VentureTech program will provide $123 million to the University of Illinois so it can develop three high-tech research facilities on its Urbana-Champaign campus. The money is separate from the state's higher-education budget and will be included in the state budget for the current fiscal year, approved in June. The disbursement includes:

- $67.5 million for the Post Genomic Institute: The 110,000 square-foot building will include laboratories and facilities for scientists from several disciplines to study plant genomics and conduct cutting-edge biotechnology research.
- $27 million for a new National Center for Supercomputing Applications building.
- $18 million to expand the Micro and Nanotechnology laboratory. (A)

Indiana:

2004: $1.3 billion over 10 years for the Energize Indiana Fund (http://www.in.gov/gov/energize). (T)

2005: Governor Mitch Daniel's 2005-07 biennial budget recommends:

- $41.59 million each fiscal year for the Indiana 21st Century Research and Technology Fund (http://www.21fund.org/).
- $4.5 million each fiscal year for the Technology Development Grant Fund Program and $621,250 each fiscal year for the Capital Access Program (http://www.indianacommerce.com/Grants/grants.asp?SectionID=0&ProgramID=5).

Iowa:

Governor Tom Vilsack directed the Iowa Department of Economic Development to commission third-party research to identify opportunities in the state for biosciences. In particular, the resulting recommendations focused on commercializing biotech R&D and encouraging growth and sustainability of bioscience firms. (G)

Kansas:

1988: Kansas Technology Enterprise Corporation (KTEC) (http://www.ktec.com/) is a state-owned corporation that promotes advanced-technology economic development in Kansas. The organization's funding is determined each year by the state legislature and comes from the Economic Development Initiative Fund, created using revenues from the Kansas Lottery and Racing Commission. To manage the state's investment, KTEC leverages its state funds with private-sector and federal funding. (T)

September 2002: Kansas State University officials break ground on the new $7 million Bioprocessing and Industrial Value-Added Program facility, an agriculture research building. This facility also will provide pilot space for private-industry interests to test such processes as plastic molding and thermal processing of grains. Funding has been provided by a $3 million appropriation from the legislature and a $4 million state loan. (A)

2003: Economic Growth Act provides $500 million over two years mainly focusing on biosciences (http://kdoch.state.ks.us/public/agency/spotlight/econ_growth_act.jsp):

- Will fund community organizations that provide seed financing to entrepreneurs.
- Creates clearinghouse to assist entrepreneurs.
- Expands support for use of the enterprise facilitation program.
- Angel Investment Tax Credit Program provides a 50 percent tax credit (up to $50,000) for investments in qualified Kansas businesses.
- Aids Kansas towns with tax incentives for downtown business development.
- Funding for Kansas Bioscience Initiative. (T)

2006: Governor Kathleen Sebelius proposes for the Kansas Technology Enterprise Corporation (http://da.state.ks.us/budget/gbr.htm) $12.3 million in state funds, an increase of $19,000 over fiscal year 2005 and $2.9 million in federal funding. (T)

Kentucky:

2003: "Bucks for Brains" (www.one-ky.com/bucksforbrains.html): $120 million for program to reform higher education. (T)

2005: Governor Ernie Fletcher establishes a $1.5 million energy research and development fund to help state universities enhance their energy R&D capacity. Matching grants are available to help energy-related R&D projects at public universities compete for larger sums of federal and private research dollars, and seed grants will support future energy R&D at universities. (G)

Maine:

2004: Governor John Baldacci launches an initiative to issue $60 million in bonds to finance research and development, primarily by investing in research infrastructure. The bonds were allocated for nonprofit biomedical research facilities, the creation of a marine sciences educational hall by marine and fisheries research laboratories, and infrastructure improvements at technology development centers and several research centers in the University of Maine system. (G)

2006: Governor John Baldacci's request for fiscal year 2006-07 (http://www.maine.gov/budget/fy0607.htm) includes:

- $197 million bonds package to support critical research and development projects.
- $78.9 million for his Jobs Proposal (http://www.maine.gov/governor/baldacci/issues/bond_proposal).

    - » $9 million for the Marine Research R&D Competitive Fund.
    - » $6 million for the Franklin USDA Aquaculture R&D Facility.
    - » $5 million for Forestry and Agricultural R&D Competitive Fund.
    - » $3 million for FAME business loans.
    - » $2 million for Small Enterprise Growth Fund Recapitalization.
- $34 million to support and grow biomedical R&D.
    - » $22 million for biomedical research.
    - » $5 million for R&D at the University of Southern Maine.
    - » $4 million for University of Maine's R&D Lab Surface Science Technology.
    - » $3 million for the University of Maine Biomedical Research Triangle. (T)

Massachusetts:

2003: The Massachusetts Science and Technology Initiative is a $100 million economic stimulus package that places a special emphasis on higher education and science and technology (http://www.mhtc.org/policy/science_technology.html). (T)

2004: A collaboration between the University of Massachusetts-Amherst campus, three other universities, and various companies, including Raytheon of Waltham, will create a new engineering research center. With a $17 million grant from the National Science Foundation and with contributions from the state ($10 million) and from the business community, the project is now funded at $40 million. (U)

Michigan:

1999-2002: In May 1999, the University of Michigan committed $200 million for the establishment of a life sciences institute. By 2002, the University of Michigan is spending about $700 million on new life sciences facilities including a Life Sciences Institute Building, a 236,000 gross square-foot research laboratory. Construction costs are estimated at $96 million with construction scheduled to be completed in the summer of 2003. The University of Michigan is investing approximately $220 million for a new Biomedical Science Research Building. The state has set aside $1 billion to develop its Michigan Life Science Corridor over the next 20 years. (A)

Michigan Economic Development Corporation/Michigan's Technology Tri-Corridor fosters growth in life sciences, advanced automotive technologies, and homeland security industries through funding and resource collaboration, focusing on emerging technology sectors (http://medc.michigan.org/index_flash.asp?homepage=index.asp). (T)

Next Energy Corporation (http://www.nextenergy.org/) is founded for development of alternative energy for automotive and stationary use. (T)

Minnesota:

October 1999: The University of Minnesota breaks ground for its new $79 million Molecular and Cellular Biology building, expected to be completed in 2002. Governor Ventura's capital budget recommends major asset preservation improvements including $35 million to complete the Molecular and Cellular Biology Building and $10 million to match an equal amount of private funds for construction of a Microbial and Plant Genomics Building. (A)

2004: Governor Tim Pawlenty will ask the Minnesota Legislature to fund his biosciences initiative this year, with the governor's biotech advisory council recently recommending $250 million to grow the state's biotech industry. The biosciences initiative includes $117 million to help develop facilities in the Twin Cities and Rochester to support biotech growth (including $32 million for a biofuels research facility at the University of Minnesota), $70 million for biotech research funding for a new biosciences research partnership with the Mayo Clinic and the University of Minnesota, and $50 million in endowed professorships for the University of Minnesota. (U)

2004: Governor Tim Pawlenty creates bioscience and health science zones to cluster existing and start-up companies close to university and clinical researchers. The goal is to help them gain access to University of Minnesota and Mayo Clinic researchers and to provide tax incentives to help them lower their overall costs and facilitate their growth. Bioscience companies in the zone receive tax exemptions from the corporate franchise tax, sales tax on business purchases and property taxes, and credits for employment taxes for high-paying jobs and research and development taxes. (G)

Missouri:

September 2002: Governor Bob Holden pledges to provide $31 million in state funds for a life sciences building that business leaders hope will boost Kansas City into the top ranks of bioresearch centers in the nation. The building would house the university's schools of Pharmacy and Nursing and cutting-edge laboratory and research facilities. Holden says he will release $1.7 million immediately, which will allow the university to begin seeking an architect. (A)

2003: State House Speaker Catherine Hanaway and Senate President Pro Tem Peter Kinder gathered support for a bond issue that will raise $190.4 million to renovate buildings and build new research centers at each of the four University of Missouri campuses to increase the state's investment in life sciences research. (U)

2004: $350 million bond proposal for higher education facilities is before the State Senate. (U)

Nebraska:

2001: To help support University of Nebraska Medical Center's growing research enterprise; the renovation of 33,000 gross square feet is approved. (A)

2002: Creighton University Medical Center is squeezing a six-story science center between buildings and renovating existing space into a neurosciences lab that can be used only by scientists funded by the National Institutes of Health. (A)

New Jersey:

Summer 2002: The University of Medicine and Dentistry of New Jersey breaks ground on a $100 million cancer center. The university's Cancer Institute of New Jersey will receive $20 million in financing from the state's tobacco settlement fund. The buildings will be funded through $95 million in state bonding authorized by the Whitman administration and an additional $280 million in bonds underwritten by the university. The rest will be financed with gifts and other internal funds. (A)

September 2002: The University of Medicine and Dentistry of New Jersey is beginning a $518 million building program to house new research, classroom and clinical space:

- International Center for Public Health is a $78 million building in Newark financed with the help of the New Jersey Economic Development Authority (the authority sold $46 million in low-interest, long-term bonds). The remainder is being funded through grants and loans obtained by UMDNJ).
- University Heights Science Park.
- $37 million behavioral health science building in Newark.
- $45 million research tower for molecular biology in Piscataway. (A)

2004: Since 1998, over $300 million in state funds have been granted for technology infrastructure and interinstitutional connectivity including scientific and other equipment, technology-based economic development initiatives, recruiting of renowned faculty, and programs in targeted high-tech disciplines. (U)

2004: Governor James McGreevey unveils plans for the creation of Innovation Zones. This concept is the state's latest initiative that builds upon the Economic Development Administration's past successes in strengthening university, business and government collaborations. This proposal, designed to spur collaboration between universities and the business community, will target financial and other state resources to provide funding and technical support that encourages universities and private businesses to collaborate on projects, encourages businesses to locate in the defined zones and attracts more federal and other research dollars to businesses and universities located in the zones. (U) (G)

2005: New Jersey Governor Richard Codey submits the following budget requests (http://www.state.nj.us/treasury/omb/):

- $5.5 million for the initial planning and development of the Stem Cell Institute of New Jersey.
  - » $150 million investment in bond funds that remained from a prior securitization for construction and start-up costs of the Stem Cell Institute.
- $32.3 million for cancer research, prevention and treatment.
  - » $23.3 million to support the Cancer Institute of New Jersey (http://www.cinj.org/).
  - » $9 million is recommended for various cancer programs.
- $8 million for the New Jersey Commission on Science and Technology (NJCST). (T)

New Mexico:

2002: Voters pass Bond Measure B, which allows the state to issue general-obligation bonds in an amount not to exceed $93.4 million to pay for facilities at public schools and colleges.

2004: From the 2002 Bond Measure B, the University of New Mexico will receive $21 million and plans to use it as follows:

- $8 million for an anatomy teaching laboratory at the Health Sciences Center.
- $2 million for patient care equipment at the Health Sciences Center.
- $4 million to help plan, design, construct and equip the $30 million Centennial Engineering Center at the School of Engineering on the main campus.
- $3 million to renovate existing buildings on the main campus.

- $200,000 to install equipment for a computer technology "clean room" on the main campus.

In all, UNM will receive $550,000 for its Valencia branch campus and $3.2 million for its branch campuses in Los Alamos, Gallup and Taos from Bond Measure B. (U)

New York:

2000: New York State Science & Technology Law Center (NYSTAR) (http://www.nystar.state.ny.us/):

- $250 million for Centers of Excellence.
- $225 million for Gen*NY*sis (Life Sciences).
- $150 million for RESTORE (Rebuilding the Empire State Through Opportunities in Regional Economies). (T)

2002: The New York State Legislature approves Gen*NY*sis, a $225 million fund created to promote the biotechnology industry. Gen*NY*sis' budget includes $225 million during the following three years and is part of a $1.2 billion capital program to expand businesses and create new high-tech and biotech businesses in the state. (A)

2002: Governor Pataki announces three major Gen*NY*sis investments:

- The University of Albany will build a $45 million Center for Excellence in Cancer Genomics at its east campus. Besides university scientists, researchers from the Stratton Veterans Affairs Medical Center Hospital in Albany and Taconic Biotechnology also will be included in the project. Other companies which already have facilities at the East Campus will take space in the new building. Other smaller companies are being sought as tenants. The state's $225 million Gen*NY*sis science fund will provide $22.5 million. The university, along with private partners, will add the rest. The state's outlay will include $19 million for the building, $2.5 million for equipment and $1 million to match federal grants. The exact amounts of private-sector funding have not been determined.
- The state will provide $48 million to support a $71.5 million partnership between industry and university groups on Long Island to bolster biotechnology and educational and research programs.
- Rensselaer Polytechnic Institute will receive $22.5 million from the state to create a Center for Bioengineering and Medicine. (A)

2002: Governor Pataki announces the following investments in research space:

- $30 million pledged to the University of Rochester Medical Center.
- The state will supply $20 million of the $35 million needed to build the first phase of a proposed 240,000 square-foot Central New York Biotechnology Research Center, jointly run by SUNY Upstate Medical University and the SUNY College of Environmental Science and Forestry.
- $4.5 million in state funding will help to build the Griffiss Institute for Information Assurance, a cyber security and information assurance laboratory. (A)

2004: As part of a comprehensive initiative to spur technology-based applied research and economic development, Governor George Pataki awarded colleges with grants from the New York Office of Science, Technology and Academic Research's College Applied Research & Technology Center program. The grants will be used to encourage applied research collaboration and innovation with industry, promote workforce development, and better leverage state funds with investments by the federal government, industry, foundations, and nonprofit economic development organizations. (G)

2005: Governor George Pataki's budget recommendations (http://publications.budget.state.ny.us/executive.html) include:

- $250 million for a new High Technology and Development Program, which will support the recently announced $1.9 billion investment by IBM to build and operate the next generation semiconductor plant.
- Tax credits and grants to support Operation SPUR (Strategic Partnership for Upstate Resurgence), a job creation and economic growth initiative announced during his State-of-the-State Address in January (http://www.ssti.org/Digest/2005/011005.htm - Govs).
- $50 Million for the Office of Science, Technology and Academic Research (NYSTAR). (T)

North Carolina:

2000: Vision 2030 (http://www.ncscienceandtechnology.com/) provides $3.1 billion in bonds for university infrastructure. One half of state's tobacco settlement is earmarked for Science & Technology (several hundred million dollars). The Golden LEAF Foundation (http://www.goldenleaf.org/), a nonprofit corporation, was created in 1999 to receive one-half of the funds coming to North Carolina from the master settlement agreement with cigarette manufacturers. In turn, the Foundation is helping North Carolinians make the transition from a tobacco-dependent economy through grants and investments that will positively affect the long-term economic advancement of the state. It gives priority in its grant making to tobacco-dependent and economically distressed counties. (T)

2001: The Legislature votes for $5.1 billion in bonds, with $4.5 billion going to the University of North Carolina for new buildings and renovations. The measure passes in every county of the state with an overall 73 percent of the vote. (A)

2002: Several major projects have been successfully funded, including the B. B. Dougherty Renovation at Appalachian State, Film Archives Building at the North Carolina School of the Arts, Central Utilities Plant at North Carolina State University, and Health Sciences Library Renovations at University of North Carolina at Chapel Hill. (A)

2002: North Carolina State University's Centennial campus in Raleigh will soon break ground for a new building devoted entirely to nanotechnology research and development. The building will be 80,000 square feet and will cost $24 million. (A)

North Dakota:

Governor John Hoeven created the Centers of Excellence Fund, bringing expertise, quality instruction and research to help stimulate quality jobs and new educational opportunities through the state's colleges and universities. The centers for excellence initiative uses $50 million in state funds to leverage additional private and federal investments for research and commercialization of new products and services. (G)

Ohio:

2002: Governor Bob Taft unveils Ohio's Third Frontier Project, the state's largest commitment to expanding high-tech research, innovations and company formation:

- $1.1 billion, 10-year program.
- Build world-class research capacity.
- Support early-stage capital formation and the development of new products.
- Finance advanced manufacturing technologies to help existing industries become more productive.
- Private-sector support can boost the total investment to more than $4.5 billion.
- Long-term strategic S&T Study. (T)

Under the initiative, various programs are instigated to foster collaboration among Ohio's higher-education institutions, nonprofit research organizations, and local companies to ensure the state's successful economic future. These programs include:

- Wright Centers of Innovation ($40 million in grants to support collaborations).
- Wright Projects ($10 million in grants).
- Biomedical Research and Technology Transfer Partnership Program.
- Third Frontier Fuel Cell Program (grants to support growth of the fuel cell industry in Ohio).
- Product Development Pilot Program.
- The Innovation Ohio Loan Fund.
- The Third Frontier Network (high-speed fiber-optic network for linking Ohio's colleges and universities, elementary, middle and high schools, and state and local governments, medical research centers, and federal research centers). (U)

2004: The Biomedical Research and Technology Transfer Partnership Awards provide grants to support biomedical and biotechnology research lending to commercialization and long-term health improvements in the state. Awardees include collaborations among Ohio higher education institutions, nonprofit research organizations, and Ohio companies in the areas of human genetics and genomics, structural biology, biomedical engineering, computational biology, plant biology and environmental biology. These awards are part of the Governor's Third Frontier Project. (G)

2005: Governor Bob Taft's fiscal year 2006 budget requests (www.obm.ohio.gov/budget/executive/0607/) include:

- $15.4 million for the Thomas Edison Program (http://www.odod.state.oh.us/tech/edison/default.htm).
- $50 million for the Research and Development Loan Fund.
- Funding for the creation of an Economic Growth Challenge (http://www.chee.ohio.gov/index.asp?p=0&text=0):
    - » $18 million in each fiscal year for the Research Incentive.
    - » $2.3 million in fiscal year 2006 and $4.7 million in fiscal year 2007 for the Innovation Incentive.
    - » $500,000 to begin the new Technology Commercialization Incentive in fiscal year 2007.

- $134 million in new research, product and process innovation, and job creation through the Third Frontier. (T)

Oklahoma:

2002: Governor Frank Keating signs legislation that appropriates $38 million to establish a national weather center at the University of Oklahoma in Norman and state-of-the-art bioterrorism research facilities at Oklahoma State University in Stillwater. The federal government has set aside funds to match the state's investment, including $19 million for the OU weather center. OSU is expected to receive a sizable portion of the $20 billion the Bush administration and Congress are expected to allocate for bioterrorism research. (A)

2003: Tulsa County's Vision 2025 passes. Vision 2025 has projects under consideration to receive part of the proposed $99 million funding package for higher education, including a research and medical clinic at the University of Oklahoma at Tulsa. (G)

2005: Governor Brad Henry's fiscal year 2006 budget includes:

- $475 million bond issue for the Oklahoma Higher Education Promise of Excellence Act of 2005.
- $100 million toward a $1 billion Economic Development Generating Excellence (EDGE) endowment fund to promote research and economic development (http://www.okhighered.org/edge/).
- $21.7 million (an 86 percent increase) for the Oklahoma Center for the Advancement of Science and Technology. (T)

Oklahoma Center for Advancement of Science and Technology (OCAST) (http://www.ocast.state.ok.us/):

- $3 million for Health Research Program.
- $500,000 for Small Business Research Alliance R&D Faculty & Student Research Partnerships.
- Multiple centers in health and applied research with an emphasis on commercialization.
- Applied Research Program.
- Additional commercialization activities. (T)

Oregon:

2003: The Oregon Legislature allocates $20 million for construction and $1 million for operation of the Oregon Nanoscience and Microtechnology Institute (ONAMI) (www.onami.us/). The University of Oregon will receive $9.5 million of the construction funding and $475,000 of the operating money when bonds for the project are sold in early 2005. (U)

ONAMI, established through a partnership between Hewlett-Packard and Oregon's institutions of higher education, has leveraged more than $22 million from federal research dollars and $3 million from the private sector since opening in May, according to the governor's office. (T)

2005: Governor Ted Kulongoski's recommended budget (http://www.governor.oregon.gov/) includes:

- $18.4 million in 2005-07 general fund support for Oregon Economic and Community Development Department (OECDD) (http://www.econ.state.or.us/).
- $9 million from the Lottery Fund for a preseed or "proof of concept" fund for the newly created. (T)

Pennsylvania:

1982: Governor Thornburgh creates the Ben Franklin Partnership (BFP) (http://www.benfranklin.org/). Four centers governed by nonprofit boards are created to deliver services on a decentralized, regional basis. These centers report to an umbrella public/private board lodged in the state Department of Community and Economic Development, since expanded and reformed several times. The signature Ben Franklin "challenge grant" is aimed at encouraging small firms and faculty at public or private universities to work together on projects of mutual interest. (T)

2000: "SciTech Scholarships" is a key initiative of Governor Ridge's administration to reverse the high-technology "brain drain" that threatens Pennsylvania's technology-intensive business development. Launched on October 12, 1999, the program prepares Pennsylvania's workforce for the technology-based economy of the 21st century and stems the migration of Pennsylvania's graduates to other states (http://www.unisys.com/news/releases/1999/mar/03106665.html). (T)

2000: "Link-to-Learn" is a multiyear, $166 million initiative to expand the use of technology in the classroom, and it includes new or upgraded computers for schools and high-technology training for teachers. It is a catalyst for the effective use of information technology to enhance education, promote community partnerships, and support economic growth in a knowledge-based society (www.L2L.org). (T)

2004: Governor Ed Rendell creates a tradable research and development tax credit for first-time technology-oriented businesses. Young companies will have the opportunity to sell unused tax credits for capital to buyers who will use the purchased tax credits to offset up to 75 percent of their own tax liability. Companies can apply for a credit equal to 10 percent of the growth of qualified R&D expenditures from one tax year to the next. The state doubled the credits from $15 million to $30 million in 2005. (G)

2004: The Keystone Innovation Zone (KIZ), a cornerstone of Governor Ed Rendell's economic-stimulus initiative, designates zones in college and university communities that will foster innovation and create entrepreneurial opportunities to keep young, talented graduates in Pennsylvania. As part of the KIZ program, each year $25 million in tax credits will be available for companies. As an incentive to universities that are involved in a KIZ partnership, $10 million will be available over the next three years to create or enhance technology-transfer programs at the universities for the benefit of entrepreneurs. (G)

2005: Governor Edward Rendell's fiscal year 2005-06 budget (http://www.governor.state.pa.us/governor/cwp/view.asp?a=1101) calls for:

- $109 million for Job Ready Pennsylvania.
  - » $101 million to improve the state's workforce development system and its high schools.
  - » $71 million of existing state resources.
  - » $26 million in private-sector matching funds.
- $360.2 million for the Department of Community and Economic Development (http://www.inventpa.com/).
- $15.2 million to promote manufacturing.
- $50.2 million to the Ben Franklin Technology Development Authority (www.inventpa.com/default.aspx?id=30). (T)

South Carolina:

2002: BMW announces a $10 million endowment for Clemson University to create a graduate engineering education center in Greenville. BMW's pledge will endow the academic programs and Governor Jim Hodges has said that the state will give $25 million to build and equip a state-of-the-art research facility. (A)

2004: South Carolina unveiled a $500 million technology-based economic development package that targets life sciences and commits state funds to venture capital and facility and infrastructure improvements at the state's three research universities. (U)

2005: Governor Mark Sanford's budget targets (http://www.scgovernor.com/) include:

- $55.88 million ($22,800 decrease) in general fund expenditures to the South Carolina Commission on Higher Education (http://www.che400.state.sc.us/).
- $2.5 million in funds for the South Carolina Research Authority (http://www.scra.org/). (T)

South Dakota:

2004: The Homestake Mine was designated by the National Science Foundation as an ideal location for a deep underground laboratory. The conversion project has been a priority for Governor Mike Rounds. South Dakota hopes the laboratory will bring the world's best physicists to the Black Hills to conduct advanced experiments.

2004: Governor Mike Rounds announced that four university-based research centers will receive nearly $2.8 million in state funds in a first-ever initiative aimed at growing the state's economy by targeting investments in specialized research at South Dakota public universities. The centers are housed in the departments of veterinary science, cardiovascular research, materials and metallurgical engineering, and chemistry. (G)

2004: The South Dakota Board of Regents created an undergraduate minor in entrepreneurial studies to be offered beginning in spring 2005. Interest in the new 19-hour program is high, especially among nonbusiness majors.

Tennessee:

2002: Memphis hopes to build a $40 million lab building that will be phase one of the University of Tennessee-Baptist Research Park. When complete, this park will include an incubator. The Tennessee Department of Economic and Community Development announced a grant of $750,000 to the City of Memphis to begin the infrastructure. The goal is to raise $32 million from public and private sources. (A)

In Nashville, a $74 million biomedical research center is to be built. (G)

Texas:

Governor Rick Perry created the $200 million Texas Emerging Technology Fund to improve university research, help start-up technology firms get off the ground, and quickly move inventions out of the lab and into the market. (G)

Utah:

2005: Senate Bill 192 (http://www.utahsenate.org/perl/spage/index.pl) passed by the Legislature provides $7.35 million to support tech-based economic development by the state's two largest public universities. (T)

Virginia:

2002: Voters approve a law, endorsed by the General Assembly and by Governor Mark Warner, which allows the commonwealth to sell bonds for capital projects at public colleges, museums and other education facilities. The total amount of bonds that can be issued will be no more than $900.5 million. The University of Virginia will get $68.3 million in projects, including more than $24 million toward a medical research building. Another $7 million would help the University of Virginia build a research facility for the engineering school's material science engineering department and the Center for Nanoscopic Materials Design. At the George Mason University campus in Fairfax, their share of the bond would go toward both a performing arts facility and a research facility; community colleges would receive $231 million for repairs, renovations and construction.

Washington:

2004: Governor Locke promotes the Bio 21 initiative, a plan to invest as much as $750 million in public money over the next 15 years to nurture Washington's infant biotechnology industry. Under the plan, the state's top research institutions could vie for competitive, peer-reviewed state grants, with preference given to researchers who team up to speed progress. Venture capitalists and corporations like Microsoft and Amgen would be involved early. (U)

2005: Governor Christine Gregoire creates a $1 billion Life Sciences Discovery Fund through legislation that uses tobacco settlement funds. The state's seed capital investment ($35 million per year) is contingent on attracting at least $10 million in private capital by 2008. The fund will provide grants for promising university research, sometimes in partnership with the private sector, to promote research, particularly in the areas of debilitating diseases and agricultural crops. (G)

A Closer Look at Some of the Initiatives

California:

Name of Fund: California Institute for Regenerative Medicine (CIRM).

Funding Source: Bonds.

Amount/Timeframe: $3 billion over 10 years.

Description/Purpose: Provide grants/funding for stem cell research, research facilities and other medical research.

Legal Structure: Proposition 71 was passed by voters in 2004 to create the California Institute for Regenerative Medicine and authorize the sale of $3 billion in general obligation bonds to provide funding for stem cell research at California universities. It is governed by a 29-member Independent Citizen's Oversight Committee whose members are primarily from the medical or academic areas.

Additional: Since there are pending lawsuits regarding the proposition, the governor ordered a $150 million general fund loan as well as sale of bond anticipation notes to private individuals and foundations in 2006. This will finance the initiative until the litigation is settled and the general obligation bonds can be sold.

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Oklahoma:

Name of Fund: Economic Development Generating Excellence (EDGE) Endowment Fund.

Funding Source: General fund and private donations.

Amount/Timeframe: Expected $1 billion endowment. According to the Oklahoma FY-2007 Executive Budget, $92 million was deposited in fiscal year 2006 (this was later updated to $150 million for 2006) as initial funding.

Description/Purpose: To help fund research, commercialization of technology and development of important sectors, such as biotechnology, aerospace, weather service, energy and agriculture.

Legal Structure: A trust fund was created in 2006 by Senate Bill 99. This fund will be financed from general revenue collections left after the Constitutional Reserve (Rainy Day) Fund reaches its cap for the year. The statutes indicate that the "trust fund principal shall consist of all funds appropriated, transferred, donated or otherwise directed to the fund by law." The Board of Investors of the fund consists of five members: the State Treasurer (or designee) and appointees of the Governor, State Auditor and Inspector, Speaker of the House of Representatives, and President Pro Tempore of the Senate.

"The Governor proposes this fund be administered under OCAST [Oklahoma Center for the Advancement of Science and Technology] administrative umbrella with a separate board and Executive Director, advised by scientific and technology experts. The Board will be charged with investing in projects that have the greatest potential for creating new economic opportunity for Oklahoma. The Board will also be asked to look for opportunities to creatively co-invest and coordinate activities with existing sources of state funds such as OCAST, OCIB, and private research dollars such as those of the Oklahoma Medical Research Foundations, the Warren Foundation and the Noble foundation to further maximize the impact of the fund." (*Oklahoma FY-2007 Executive Budget*)

Additional: "Since 1987 OCAST, the Oklahoma Center for the Advancement of Science and Technology has invested $126.7 million in Oklahoma research, development, technology commercialization and manufacturing modernization and, with this funding, has attracted nearly $2 billion in private investments and federal funding." (OCAST website)

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Texas:

Name of Fund: Emerging Technology Fund (TETF).

Funding Source: 50 percent from General Revenue and 50 percent from Rainy Day Fund surplus.

Amount/Timeframe: $200 million to be spent during Fiscal Years 2005-06 and 2006-07 (Fiscal years end August 31).

Description/Purpose: The TETF has the following goals:

- Increasing research collaboration between public- and private-sector entities to develop new Regional Centers of Innovation and Commercialization where the seeds of an idea can take root in a university lab and eventually grow into a new product marketed by a new firm.
- Matching research grants provided by both federal and private sponsors to help innovators acquire the capital they need to bring their idea to life.
- Attracting more top-notch research teams from other universities around the nation that will help put Texas universities on the cutting edge of technology research and development.

Eligible industries are those that will lead to immediate or long-term creation of high quality new jobs in Texas and/or could lead to medical or scientific breakthroughs. Industries include but are not limited to semiconductor, information, computer and software technology, energy, manufactured energy systems, microelectromechanical systems, nanotechnology, biotechnology, medicine, life sciences, petroleum refining and chemical processes, aerospace, defense, and others determined by the governor, lieutenant governor, and speaker of the House.

The funding is allocated as follows: $100 million is reserved to Regional Centers of Innovation and Commercialization project activity (Subchapter D), $50 million is reserved for emerging technology research matching grant activity (Subchapter E), and $50 million is reserved for acquisition of research superiority grant activity (Subchapter F).

Legal Structure: The governor may reallocate money from one component of the fund to another component subject to the prior approval of the lieutenant governor and speaker of the House.

The Governor shall appoint a 17-member Texas Emerging Technology Committee comprised of industry leaders from Texas and nationally recognized researchers from Texas public and private institutions of higher education nominated by (1) the Texas Higher Education Coordinating Board, (2) presidents of public and private institutions, (3) the commissioners of the Texas Workforce Commission, (4) the chief executive officer of the Economic Development and Tourism Division of the Governor's Office, and (5) representatives from the Texas Technology Initiative. The Governor will appoint the presiding officer of the committee.

Terms of commercialization grants under Subchapter D include:

- A commitment to use the grant to expedite commercialization that will lead to an increase in high-quality jobs in Texas and only to use the funds to introduce the agreed-upon product or service to the market.
- A substantial percentage of any new or expanded commercialization of manufacturing resulting from the grant must be established in the state of Texas. The grantee must target certain milestones defined in the agreement and show proof of compliance annually.
- The grantee will provide the state with an equity position in the form of a warrant. The percentage of the equity position will be the real market value of the grant award as determined by the most recent valuation of the grantee, the next round of financing, or at a valuation agreed upon by both parties. The warrant will be a right to common stock, and no voting rights. The warrant strike price will be a nominal amount. There will be a pari passu investor rights with preferred shareholders or other applicable investors. The state's position will be subject to dilution. The grantee must cooperate fully in providing a fully executed warrant agreement to the satisfaction of the state.

Under Subchapter D, priority will be given to proposals that:

- Involve emerging scientific or technical fields that have a reasonable probability of enhancing Texas' national and global economic competitiveness.
- Could lead to medical or scientific breakthroughs.
- Are matched with other funds available by the private or nonprofit entity and institution or institutions of higher education.
- Are collaborative between any combination of private or nonprofit entities, Texas public or private agencies or institutions, and public or private nonstate institutions.
- Have a demonstrable economic development benefit to the state of Texas.

Under Subchapter E, TETF appropriations shall be reserved to match funding from federal or other nonstate research sponsors. Proposals eligible for funding shall be recommended to the governor, lieutenant governor, and speaker by the Texas Emerging Technology Committee described above. Priority for matching funds will be given to proposals that accelerate commercialization into production by targeting programs which:

- Address federal or other major research sponsors' priorities in emerging scientific or technology fields.
- Are interdisciplinary, such as electrical engineering and medicine, or computer science and biology.
- Are collaborative with any combination of Texas public or private institutions of higher education.

- Have a likelihood of leading to medical or scientific breakthroughs.
- Have a demonstrable economic development benefit to the state of Texas.

Under Subchapter E, participating entities must guarantee via contract with the state specific actions to be performed that are expected to provide benefits to the state. Failure to perform those actions by a time specified in the contract with the state shall result in the state's financial investment being returned by the participant.

Under Subchapter F, TETF appropriations shall be reserved to acquire new or enhance existing research superiority at Texas public institutions of higher education. Proposals eligible for funding shall be recommended to the governor, lieutenant governor, and speaker by the Texas Emerging Technology Committee described above.

"Research superiority" is defined as two-or-more world-class or nationally recognized researchers and associated assistants. Eligible research superiority must be related to eligible industries, as defined above.

Funds awarded for research superiority may be used for research and research capability acquisition, including salaries and benefits, travel, consumable supplies, other operating expenses, capital equipment, and construction or renovation of facilities.

Under Subchapter F, priority will be given to proposals that:

- Involve scientific or technical fields that have a reasonable probability of enhancing Texas' national and global economic competitiveness.
- Could lead to medical or scientific breakthroughs.
- Are interdisciplinary.
- Have or can attract federal and other funding for research superiority.
- Are likely to create a nationally or internationally recognized locus of research superiority.
- Are matched with other funds available to the institution or institutions.

Participating entities under this program must document specific benefits that the state may expect to gain as a result of attracting the research superiority.

Under both Subchapters E and F, royalties, income and other benefits realized as a result of projects undertaken with the TETF proceeds shall be divided among the collaborating entities according to terms specified in the contract. The TETF also will define in the contract a percentage of royalties, income or financial benefits from each project to be placed in the fund.

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Utah:

Name of Fund: Utah Science Technology and Research Initiative (USTAR).

Funding Source: Issuance of general obligation bonds and general fund.

Amount/Timeframe: $50 million one time (fiscal year 2007); $19.25 million per year ongoing; $111.1 million in bonds for construction of research buildings.

Description/Purpose: The intended scope of this initiative includes the creation of a technology outreach program delivered at strategic locations around Utah to assist in developing commercial applications for research and connecting Utah's research universities with Utah's business and entrepreneurial community; the funding of research teams to conduct science and technology research; the construction of a Bio Innovations Research Institute, an Infectious Disease Research Center, and an Informatics/Computing Research Center at Utah State University; and construction of a Neuroscience and Biomedical Technology Research Building and an Information Technology and Bioinformatics Research Center at the University of Utah. Also, it provides support for centers of excellence programs though the Governor's Office of Economic Development.

Legal Structure: The Utah Science Technology and Research Governing Authority, created by Senate Bill 75 (effective July 1, 2006), which was passed during the 2006 General Session, will manage the USTAR initiative. Senate Bill 75 also defines the scope of the Utah Science Technology and Research Project. The Authority is governed by a board consisting of the state treasurer and eight appointed members: three members appointed by the governor; two appointed by the Senate; two appointed by the House; and one appointed by the commissioner of higher education. The powers and goals of this authority include:

- Expand key research at the two research universities.
- Enhance technology transfer and commercialization of research and technologies developed at the research universities to create high-quality jobs and new industries in the private sector in Utah.
- Allocate appropriated monies for research teams and for the commercialization of new technology between Utah State University and the University of Utah.

- Establish economic development objectives for the project.
- Verify that the project is being enhanced by research grants.
- Develop methods and incentives to encourage investment in and contributions to the project from the private sector.
- Enter into agreements necessary to obtain private equity investment in the project.
- Review state and local economic development plans to ensure that the project and appropriations do not duplicate existing or planned programs.

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Washington:

Name of Fund: Life Sciences Discovery Fund.

Funding Source: Expected tobacco settlement money.

Amount/Timeframe: $350 million ($35 million per year for 10 years, beginning in 2008).

Description/Purpose: "The stated purpose is to 'promote life sciences research to foster a preventive and predictive version of the next generation of health-related innovations, to enhance the competitive position of Washington State in this vital sector of the economy, and to improve the quality and delivery of health care for the people of Washington.' It is expected to be achieved by making grants to research institutions in the State." (Governor's Office website, Washington state)

Legal Structure: The Life Sciences Discovery Fund Authority, created by Senate Bill 5581, which was passed during the 2005 Regular Session, will manage the fund. The Authority is governed by an 11-member board, with seven members appointed by the Governor and four members appointed by the Legislature. According to the Final Bill Report E2SSB 5581, the Authority can make grants to entities pursuant to contract for the promotion of life sciences research to be conducted within the state. The Authority must solicit requests for funding and evaluate the requests by considering the following factors:

- The quality of the proposed research.
- The potential to improve health outcomes and lower health care costs,
- The potential for leveraging additional funding.
- The potential to provide health care benefits or benefit human learning and development.
- The potential to stimulate health care delivery, biomedical manufacturing, and life sciences-related employment in the state.

- The geographic diversity of the grantees within Washington.
- Evidence of potential royalty income and contractual means to recapture such income.
- Evidence of public and private collaboration.

Additional: This bill was based on a plan, known as "Bio 21," designed to direct state and private resources to Washington's universities and nonprofit research institutions and their industry partners. The plan, developed by a committee comprised of scientists and staff from large research organizations, executives of biotech and technology companies and venture capitalists, among others, was designed to build on Washington's existing assets in life sciences and information technology. "For-profit companies could help pay for research by matching grant money but could not directly apply for money from the fund" (Howland 2005). The first appointed executive director is a science professor emeritus at the University of Washington.

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A Case Study of New York State

A Summary of Findings from the New York Case Study

Some states, such as Utah and New York, have established umbrella agencies to coordinate their efforts in leveraging university-based research to increase the number of high paying jobs and companies in the state, as well as maximize federal and private research dollars flowing into the state.

For example, the New York Office of Science, Technology and Academic Research (NYSTAR) oversees a $250 million Centers of Excellence Program supporting five research centers located at universities throughout New York. These centers have strong industry partnerships, focus on applied research in such fields as bioinformatics and life sciences, nanotechnologies, photonics and information technology, and are expected to leverage $1 billion in private and federal funds. From a $95 million capital projects fund, NYSTAR administers 14 academic research centers that target emerging technologies and serve as research arms for the Centers of Excellence Program. NYSTAR also oversees 16 research centers through the $225 million Generating Employment through New York State Science Program focused on life sciences research at public, private and not-for-profit research institutions. These funds are expected to leverage additional resources to support the construction of high-tech and biotech facilities.

New York casts its net wide, and in addition to administering and coordinating the above research and capital projects, NYSTAR also administers a faculty development program, a technology transfer incentive program, and a matching grants leverage program, and it coordinates 10 Regional Technology Development Centers that provide financing, venture capital formation and federal research grant information to technology-based businesses in New York.

History and Description of Recent Science, Technology and Academic Research Initiatives

In 1983, the first Center for Advanced Technology (CAT) was established to foster university-industry collaborative research, encourage technology transfer in relevant technologies, and facilitate the transfer of technology from New York's top research universities into commercially viable products produced in the private sector. There are now 16 CAT programs in high-technology and biotechnology research at universities across New York state.

The Jobs 2000 Act (J2K), signed into law by Governor George E. Pataki in November 1999, was a comprehensive $522 million economic development program intended to increase the state's support for high-technology academic research and capital investment in high-tech business growth. J2K established the New York Office of Science, Technology and Academic Research (NYSTAR). J2K included a $156.5 million investment in high-tech academic research, $280 million in venture-capital funds to invest in emerging businesses in New York State, $34 million to retrain employees to operate new high-tech equipment, and $51.5 million for infrastructure improvements to supply water to accommodate business growth (New York, Governor's Office, 1999).

NYSTAR now is responsible for development and oversight of eight Strategically Targeted Academic Research (STAR) Centers and five Advanced Research Centers (ARCs) through its capital projects fund. These centers are intended to expand high-tech research and provide state-of-the-art facilities and equipment to foster the development of new technology-based jobs and businesses programs (New York, NYSTAR website).

NYSTAR also is responsible for a statewide network of cooperative research and development centers among private universities, private industry, and state government. It also oversees a network of centers that provide business planning, access to venture capital, product development, marketing, manufacturing and quality systems, engineering, and information technology. (New York, Governor's Office of Employee Relations). A detailed description of NYSTAR programs, their locations, and funding levels from the 2002-03 and 2003-04 budgets is presented in the appendix to this chapter.

Legislation appropriating $250 million over five years to create the Centers of Excellence Program (CoE) was passed in 2001. The CoE Program is administered by the Empire State Development Corporation and supports major upgrades of research facilities and other high-technology and biotechnology capital projects, allowing colleges and universities and research institutions to secure research funding. It is hoped that enough private financing will be acquired to provide a three-to-one private-public match (New York, Office of State Comptroller, 2002). The program focuses on industry-research connections and is intended to augment and work in tandem with the NYSTAR STAR Centers.

Also in 2001, the Generating Employment through New York Science Program (Gen*NY*sis) was created. Funded by $225 million in borrowing to be disbursed over three years, the Gen*NY*sis funds are intended to leverage $3 billion in private financing. The funds are intended to support the construction of high-tech and biotech research facilities throughout the state. Gen*NY*sis is funded through the Dormitory Authority of the state of New York. An additional initiative, this one put forward by the Assembly — Rebuilding the Empire State through Opportunities in Regional Economies (RESTORE) — was passed in 2001 and funded for $150 million through the Dormitory Authority (New York, Office of State Comptroller, 2002). The RESTORE Program is a broad initiative funding high technology and biotechnology incubators and worker training, as well as, other economic development and redevelopment projects (New York, NYSTAR website).

NYSTAR now works closely with the Empire State Development Corporation and the Dormitory Authority to provide consulting, review research, coordinate efforts, and focus development for the Centers of Excellence and Gen*NY*sis Programs (New York, Division of Budget, and Hamilton).

Detailed descriptions of these programs, their funding sources, legal frameworks and purpose are in the appendix at the end of this chapter.

Evidence of Economic Impacts

The economic development initiatives described above have been promoted as a response to a perceived failure on the part of New York to take full advantage of the potential of its research institutions to drive economic development. In the introduction to the Jobs 2000 Act, the Senate Majority commented (emphasis in original document):

> "In 1996, $24.8 billion in economic activity in the U.S. was attributed to academic licensing. However, while the link between academia and economic development at the university level has been established, New York is not a strong participant. For example, the States of California and New York are two of this country's educational and economic leaders. In 1996, the State University of New York (SUNY) attracted $425 million in sponsored research, ranking it 8th in the nation. In that same year, the University of California (UC) system attracted $1.5 billion in sponsored research, four times that of SUNY. The State of California is now the home to 2,086 biotechnology firms while New York has 140 (1996 data). Already the leader in biotechnology, California has recently announced plans to spend hundreds of millions on a new biotechnology campus, and a biotechnology research center.
>
> "In addition, since 1981, research funding available from the Federal government through the National Institutes of Health (NIH) has tripled, from $2.5 billion to almost $8.5 billion in 1995. Unfortunately, New York has not taken advantage of this increase in funding. Instead,

since 1981 New York's share of NIH funds has declined 27 percent, while states such as Massachusetts and California have increased the research dollars they attract. During this same period, 11 of New York's 12 academic medical schools suffered declines in their national ranking among the nation's NIH-funded medical schools."

Legislation creating NYSTAR was passed in 1999 but disbursement of the NYSTAR capital projects fund did not commence until the beginning of 2003 (Hamilton); the Gen*NY*sis and Centers of Excellence programs first received funding in the 2002-03 Enacted Budget. As these initiatives are relatively new, at this time independent studies evaluating the economic impacts of the NYSTAR, Gen*NY*sis, or Centers for Excellence Programs do not appear to have been published.

The impacts and results presented below are extracted from an economic development report presented to the Legislative Fiscal Committees in Albany by Jim Denn, the Deputy Executive Director of NYSTAR, on February 15, 2006:

• Since its inception, NYSTAR has awarded over $316 million in funds to academic research institutions and not-for-profit organizations across the state. These investments have generated a credited impact of more than $4.4 billion. More specifically, NYSTAR's investments have resulted in 162 patent applications, 47 patents received, the establishment of 22 new companies, and more than $509 million in nonstate research funds to award recipients. The investments also have created and retained 13,484 jobs.

• Federal funding for research and development in New York state reached an all-time high, a recent National Science Foundation report revealed, exceeding $3.7 billion — an increase of more than 12 percent from the prior year.

• New York's universities and research centers were first in the nation in 2004 in licensing fees received, netting $305 million for their innovations, up 13 percent from the prior year, according to a study released by the Association of University Technology Managers. This was 55 percent more than California's $202 million and 70 percent more than Massachusetts' $179 million — two perennial powerhouses of academic research.

• The Capital Facility Program was awarded $95 million (half through NYSTAR and half through the SUNY Construction Fund) to fund eight Strategically Targeted Academic Research Centers and five Advanced Research Centers. These world-class facilities enable New York's researchers to be at the forefront of cutting-edge technology. To date, $47 million has been distributed. As a result of this investment, $274 million in impact has been generated, including the establishment of nine new companies and the receipt of $267 million in federal grants.

• The Faculty Development Program provides financial assistance to New York's leading research institutions to recruit and retain distinguished faculty who will develop and commercialize technologies that help expand New York's economy. To date, NYSTAR has provided over $22 million for grants made under this program. As a result of these investments, almost $55 million in impacts has accrued, including establishing seven new companies and $50 million in federal grants to the faculty's research team.

• The James D. Watson Investigator Program assists New York's leading institutions in recognizing, retaining and professionally developing early-career scientists in the life sciences or enabling life scientists who demonstrate leadership potential in their field and are anticipated to enhance economic activity in the state. To date, NYSTAR has provided over $7.2 million under this program. As a result of this investment, over $14 million in impacts have accrued, including the establishment of two new companies and $15 million in federal grants to the faculty's research team.

• The state budget has provided $5 million annually for the Matching Grants Leverage Program to leverage resources for efforts associated with high-tech economic development from federal or private sources, including the National Science Foundation, National Institutes of Health, businesses, industry consortiums, foundations, and other organizations. As part of that program, the Security through Advanced Research and Technology (START) initiative helps colleges and universities secure federal and other research funding for the emerging homeland security industry. Since 2000, NYSTAR has awarded nearly $46 million to match federal and private research grants received by New York State academic research institutions. These investments have leveraged $184 million in federal and other grants and led to the establishment of two new companies.

• The Center for Advanced Technology (CAT) program, established in 1983, works with industry to help solve near-term technological challenges, helping New York companies expand. Between 2000 and 2005, NYSTAR awarded $111 million to the 15 CATs located throughout the state. As a result of this investment, the CAT program generated over $2 billion in impact at New York companies including more than 2,700 new and retained jobs, $735 million in sales, $214 million in cost savings, $166 million in funds acquired, and $694 million in capital improvements.

• New York's Regional Technology Development Centers (RTDCs) program combines resources of two state programs — Industrial Technology Extension Service (ITES) and Technology Development Organization (TDO) — with support from the federal Manufacturing Extension Partnership (MEP) program to improve the competitiveness of New York's smaller manufacturers (typically those with less than 500 employees) and early-stage technology companies. Between 2000 and 2005, NYSTAR provided over $57 million in state and federal funds to the 10 RTDCs located throughout the state. As a result of this investment, the RTDCs have generated over $1.5 billion in impact at New York companies including 10,583 new and retained jobs, $699 million in sales, $127 million in cost savings, and $221 million in capital improvements.

• The Technology Transfer Incentive Program (TTIP) complements NYSTAR's other programs by providing short-term state assistance to accelerate the commercialization of intellectual property developed or enhanced at an institution of higher education working in conjunction with a New York company. To date, NYSTAR has awarded more than $18 million under this program, resulting in $57 million in economic impact including $13 million in sales, $17 million in cost savings, $9 million in funds acquired, and $5 million in capital improvements.

• In 2004, New York's high-tech small businesses were awarded a record $100 million in federal Small Business Innovation Research (SBIR) funds, beating the previous record of $79 million set in 2003. The SBIR program funds high-risk projects at the earliest stages of technology development — before companies can attract venture capital — and uses a three-phase approach to help companies move new technologies from idea to commercialization.

• Between 2001 and 2004, New York's ranking based on total SBIR dollars awarded rose from ninth to fifth place. During this same four-year period, the dollar value of New York's SBIR awards nearly tripled — the largest percentage increase among the top five SBIR states. New York received 251 SBIR awards in 2004, up 53 percent from 163 in 2001.

• New York universities ranked number one in the nation in revenue from licensing and patents, netting $305 million, up 13 percent from the prior year, according to the State Science and Technology Institute and the Association of University Technology Managers.

• The July 2005 issue of Business Facilities Magazine ranked New York second in the nation for biotechnology industry development.

• The May/June 2005 issue of *Small Times Magazine* ranked the State University of New York at Albany's Center of Excellence in Nanoelectronics first in the nation in nanotechnology facilities, as well as first in microtechnology and nanotechnology industry outreach.

• According to *Manufacturers' News,* manufacturing production and capacity in the state have grown, making New York the fourth-strongest manufacturing state in the nation. One primary reason for this is the incorporation of technology into the manufacturing process.

• According to the March 2005 issue of *Entrepreneur Magazine*, New York had three universities in the first tier of institutions recognized as leaders in entrepreneurial education — more than any other state — and 17 other New York universities and colleges were included in the ranking, up from 14 a year earlier.

• On January 3, 2006, Governor Pataki announced that a new $435 million Institute for Nanoelectronics Discovery and Exploration (INDEX) will be located at the Center of Excellence in Nanoelectronics at the University at Albany — one of only two in the nation, with the second being located in Silicon Valley. This center will partner with institutions including Harvard, Yale, and Georgia Institute of Technology. The Institute will focus on incorporating nanomaterials into electronic components and is a joint effort funded by the Semiconductor Industry Association (SIA) and Semiconductor Research Corporation (SRC).

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Appendix: Science, Technology and Academic Research Programs in New York

1. New York Office of Science, Technology and Academic Research (NYSTAR)

Funding Source: The Jobs 2000 Act (J2K), put into law in November 1999, created the New York Office of Science, Technology, and Academic Research. It provided funding for the NYSTAR Research Development Program, established by Section 209-p of Article 10-B of the Executive Law, to encourage and enhance the economic development role of academic institutions in New York state. Such programs are to include, but not be limited to, the faculty development program, capital facility program, the incentive program, and the centers for advanced technology development program. J2K also created the Advisory Council of New York Office of Science, Technology, and Academic Research to oversee NYSTAR.

Amount/Timeframe: The Jobs 2000 legislation provided NYSTAR with more than $120 million in new funds to implement a number of new programs and initiatives. These include:

- $95 million for the Capital Facility Program, which supports the construction and improvement of research and development facilities of six Strategically Targeted Academic Research (STAR) Centers and five Advanced Research Centers (ARCs). To be distributed over five years, disbursements began in early 2003 (Hamilton).
- $10 million for the CAT Development Program, which provided grants to five designated Centers for Advanced Technology for enhancing and expanding their activities.
- $7.5 million for the Faculty Development Program, which provided grants to assist colleges and universities in attracting and retaining the best research faculty.
- $4.65 million for the Technology Transfer Incentive Program, which supports the efforts of colleges and universities to commercialize high technology innovations.
- $350,000 for the creation of a NYSTAR-designated Science and Technology Law Center, which

provides a unique and critical resource for small and start-up technology companies as they look to succeed in an increasingly complex marketplace. The Law Center also will study the complex legal issues that surround science and technology (NYSTAR website).

Description/Purpose: Executive Law Article 10-b, L. 1999, c. 624, effective November 10, 1999. The legislative intent for chapter 624, known as the "Jobs two thousand for New York State (J2K) Act" recognizes that "research performed at an institution of higher education has played a valued and implicit role in the welfare and success of our economy. In addition it is recognized that in order to serve the best interests of higher education institutions and business in New York State, it is important to foster university industry relationships, and remove those barriers that impede or slow the development of these relationships" (New York, Ethics Commission).

NYSTAR's goals as articulated on their public website are:

• Spur economic development in New York state through academic research.

• Substantially increase the amount of federal research dollars that New York and its researchers obtain.

• Coordinate and organize New York's wide array of science and technology informational resources and provide access to these resources to the academic, business, and research communities.

• Develop and recommend policies to the governor and Legislature that will allow the state to take greater advantage of the tremendous economic power of its inherent science, technology, and academic research assets.

Further economic development legislation passed in 2001 created the Generating Employment through New York State Science (Gen*NY*sis) program (with funding of $225 million administered by the Dormitory Authority of the state of New York) and the Centers of Excellence Program (with funding of $250 million administered by the Urban Development Corporation). NYSTAR now functions in an advisory role for these programs, reviewing research, and focusing and coordinating research and development efforts with New York universities, research institutions, industry and NYSTAR programs (Hamilton).

Legal Structure: NYSTAR is a state agency overseen by the governor. It is headed by an executive director, appointed by the governor and confirmed by the state senate, which carries out the daily oversight and operation of the agency and its programs. NYSTAR is also overseen by an Advisory Council whose members are appointed by the governor, Senate majority leader, or speaker of the Assembly. The Advisory Council consists of 11 members: one trustee from the State University of New York (SUNY), one trustee from the City University of New York (CUNY), one member of the Council of Governing Boards of Independent Colleges and Universities, the Commissioner of Economic Development, and seven public members (Executive Law §209-b[1]). Members receive no compensation for their services, but are reimbursed for their expenses (New York, Ethics Commission, and NYSTAR, 2001).

Jim Denn, deputy executive director of NYSTAR, reported to the Legislative Budget Committees in Albany on February 15, 2006 that "NYSTAR will have a workforce of 30 positions in 2006-07. The Executive Budget includes $3.4 million to support the Agency's operating budget and $50.6 million in new funding for high-tech programs. The Agency's total budget, including re-appropriations, for 2006-07 is $205 million."

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2. Centers of Excellence

Funding Source: Administered by Empire State Development Corporation.

Amount/Timeframe: Created by section 3 of part T of chapter 84 of the Laws of 2002, State of New York. The 2002-03 budget of the state appropriated $250 million, funded from state debt, to be distributed over five years.

Description/Purpose: The Centers of Excellence (CoE) program supports major upgrades of research facilities and other high-technology and biotechnology capital projects, allowing colleges and universities and research institutions to secure research funding to generate job growth. The CoE Program focuses on industry-research connections and is intended to augment and work in tandem with the NYSTAR Strategically Targeted Academic Research (STAR) Centers. The plan anticipates a three-to-one match of industry, federal and other funds to state support.

The CoE Program includes the following operations:

• The Center of Excellence in Bioinformatics & Life Sciences at Buffalo seeks to decipher the structure of proteins and genes. The collaboration includes the University of Buffalo's Center for Computational Research, Roswell Park, the Hauptman Woodward Medical Research Institute, and private life science firms.

• The Infotonics Technology Center of Excellence, located in Canandaigua near Rochester, is devoted to helping create and support technology transfer and pilot fabrication facilities for high-resolution imaging and ultrafast communications devices that can be shared by center partners to accelerate product development. The collaboration includes industrial participants such as Corning Inc., Eastman Kodak Company, and Xerox Corporation. Academic participants include some 20 New York state colleges and universities, including the Rochester Institute of Technology and the University of Rochester. The center is operated by the Infotonics Technology Center Inc., a not-for-profit corporation.

• The Center of Excellence in Nanoelectronics at Albany is establishing a state-of-the-art 300-millimeter computer-wafer pilot-and-prototyping facility. The center's project is being developed in collaboration with IBM and the University of Albany and will lead to the state's emergence as a leader in the nanoelectronics industry.

• The Center of Excellence in Information Technology (IT) on Long Island will draw on area businesses' world-class expertise in information technology and software and top-flight local universities and colleges. Development of this center will provide a national and international platform for advanced research and growth in the commercialization of new IT applications and products.

• The Center of Excellence in Environmental Systems will house state-of-the-art labs and research facilities for the performance of cutting-edge research and development, highlighting Central New York's potential as a leader in environmental systems engineering. It represents a collaborative venture between the state, private industry, Syracuse University, the Metropolitan Development Association of Central New York, and other academic and research partners.

Legal Structure: The Empire State Development Corporation (ESDC) — formerly the Urban Development Corporation (UDC) — is a New York state public benefit corporation. It engages in four principal activities: economic and real estate development, state facility financing, housing portfolio maintenance, and privatization initiatives.

State economic development programs are administered by the Empire State Development Corporation working in conjunction with the Department of Economic Development. The corporation and department are distinct entities, but both are headed by the Commissioner of Economic Development and share senior managers. In addition, the corporation and department work closely with the New York Office of Science, Technology and Academic Research (NYSTAR), which was established in 1999 to foster technology-related job creation. The corporation had a workforce of 260 in 2005-06. From the corporation's central office in New York City, a chief operating officer is responsible for day-to-day operations.

The corporation is governed by a nine-member board of directors comprising two ex-officio members and seven members appointed by the governor with the consent of the Senate. The chair of the Empire State Development Corporation Board is selected by the governor and also serves as the Commissioner of Economic Development. Board members serve without compensation.

In conjunction with the Dormitory Authority, the corporation will continue to finance and administer the $1.45 billion Centers of Excellence, Empire Opportunity Fund, Gen*NY*sis, and RESTORE programs.

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3. Generating Employment through New York State Science (Gen*NY*sis) Program

Funding Source: Bonding through the Dormitory Authority of the state of New York.

Amount/Timeframe: The Generating Employment through New York Science Program as initially proposed by the Senate (legislation passed in 2001) was funded by $225 million in borrowing to be disbursed over three years (New York, Office of State Comptroller, 2002).

Legal Structure: Funding through the Dormitory Authority of the state of New York (New York, Office of State Comptroller, 2006). New York Office of Science, Technology, and Academic Research (NYSTAR) functions in an advisory capacity: consultation, coordination and review of research (Hamilton).

Description/Purpose: The Gen*NY*sis program is intended to maximize the research and development potential of life science research being conducted at public, not-for-profit and private research institutions in the state. The funds are intended to support the construction of high-tech and biotech research facilities throughout the state. The Gen*NY*sis funds are intended to leverage $3 billion in private financing.

Seventeen Gen*NY*sis centers are in various stages of development (NYSTAR website):

• Biomedical Research Laboratory, Albany Medical Center. The mission is to build new biomedical research laboratories that will accommodate 12 new researchers. Projects range from developing new vaccines for countering bioterrorism to exploring new cancer therapies.

• Biosurfaces Laboratory, Alfred University. The funds will be used to upgrade equipment in Alfred University's biosurfaces research laboratory and to help establish a Biomaterials Industrial Outreach Service Center that will provide unique services to the biotechnology industry, including fast turn-around bioengineering services and custom production of biomaterials critical to the manufacturers of biomedical devices and other applications of biotechnology.

• Advanced Biotechnologies Center, Binghamton University. A 63,000-square-foot center will be constructed and renovated and research in biomedicine and bioinformatics, bioengineering, materials engineering and material science, and applied health and environmental technologies will be supported.

• Broad Hollow Bioscience Park, Inc. is a nonprofit 63,500-square-foot biotechnology facility. The facility is devoted to supporting the development of biotech start-up companies by utilizing shared facility resources, the resources of the Farmingdale State campus, partnering with surrounding businesses and research institutions, and clustering the growing biotech companies into the Route 110 Bioscience Corridor. The facility is using a $20 million Gen*NY*sis grant to build a 50,000-square-foot incubator to support start-up biotechnology companies.

• Center for Assistive and Adaptive Technologies, Clarkson University. The center focuses on rehabilitation engineering and biomaterials. It will research and develop assistive and adaptive technologies, and work with the commercial sector for the creation of jobs in New York state. The Gen*NY*sis funding supports the creation of 11,000 square feet of laboratory and project workspace as well as advanced instrumentation. The new facility is designed to facilitate interdisciplinary research and technology transfer.

• Long Island Biotechnology Cluster, Cold Spring Harbor Laboratory. The mission is to create education programs to hone K-12 teacher skills, analyze biological data, create treatments for genetic illnesses, and research the use of high-powered brain imaging for diseases.

• Life Science Technology Center, Cornell University. The building will serve as the hub for functional genomics. It will hold labs for basic cell biology, biomedical engineering, biophysics, plant genomics, animal biology, and biological statistics and computational biology. It also will include state-of-the-art communication technology to provide links to businesses and other universities, medical schools and research laboratories in the state. It will create more than 1,000 jobs.

• Biotechnology Research Center, CUNY College of Staten Island. The focus is primarily on the interactions between molecules inside the human body, as well as drug design and cellular diseases research.

• The Institute for the Development of Education in the Advanced Sciences, Hofstra University. The institute focuses on cutting-edge issues in science and technology for the general public, local public- and private-school teachers and administrators, and college educators. The institute seeks to create public visibility and enhanced understanding of advances in science and technology. It further seeks to encourage greater interest in advanced study in the sciences and enhance the skills of precollege and college educators in science and technology education, hence encouraging a broader participation in science and technology.

• The Academic Center for Integrated Biological, Chemical and Technological Sciences, Niagara University. The center will include sophisticated, state-of-the-art bioinformatics research equipment in four new laboratories to conduct and investigate experiments involving anything that affects a cell's molecular biology.

• Center for Bioengineering and Medicine, Rensselaer Polytechnic Institute. The plan is to accelerate drug discovery and synthesis, create new biosensors and monitoring devices, and develop tissue repair and replacement technologies.

• Center for Biotechnology Education and Training, Rochester Institute of Technology. Its mission is to provide bachelor's and master's degrees in biotechnology. Degree recipients will become the workforce for the biotechnology industry in Rochester.

• Central New York Biotechnology Research Center, SUNY Upstate. The plan would establish a leading center for plant and animal biotechnology research.

• Center for Immunology Research, Trudeau Institute. The goal of the research is to understand the functions of the body's immune system, and to learn how to strengthen these functions to fight tuberculosis, cancer, AIDS-related infections, and other life-threatening diseases. The Gen*NY*sis money will be used to finance the renovations of laboratory and support facilities as well as scientific equipment.

• Gen*NY*Sis Center for Excellence in Cancer Genomics - University at Albany Foundation. The cancer research to be done at the center will be a cooperative effort that links private biotech businesses with academia and government to conduct groundbreaking research and development in state-of-the-art facilities.

• Biomedical Research Center - University of Rochester. Its mission is to build 380,000 square feet of biomedical space in two phases. Funding will help support new research labs and renovations, new equipment for the center, and expenses related to the new research space.

• Biotechnology Research Center - Yeshiva University. The plan is to build upon the college's already recognized strengths in biotechnology research and development.

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4. Rebuilding the Empire State Through Opportunities in Regional Economies (RESTORE) New York

Funding Source: Bonding through the Dormitory Authority of the state of New York.

Amount/Timeframe: RESTORE Program legislation was passed in 2001. It was funded by $150 million in debt in the 2002-03 budget.

Legal Structure: Dormitory Authority of the state of New York.

Description/Purpose: Another new program originating in the Assembly, Rebuilding the Empire State Through Opportunities in Regional Economies is not targeted specifically at academic research and linking research with industry. The program will provide project financing or assistance for the development and/or improvement of community and civic facilities that offer training, economic development, and educational benefits. Priority will be given to high-technology and biotechnology projects (New York, Office of the State Comptroller, p. 25).

The following are RESTORE programs:

- SUNY Downstate, Biotechnology Incubator.
- Rochester Institute of Technology, Biotechnology Worker Training.
- CUNY, Business Incubator Network.
- CUNY, New York University, Polytechnic University and Columbia University, High Tech Software Research and Design Institute (Commission on Independent Colleges and Universities, page 17).

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Biographical Profiles of the Authors

Dr. Dennis Hoffman

Dennis Hoffman, Ph.D., is a professor of economics at Arizona State University. He has published numerous academic articles and a book on the topics of macroeconomics and econometrics, and has chaired several Ph.D. committees. He received the Distinguished Faculty Research Award in 1992. His research has been funded by the National Science Foundation, a Fulbright Research Grant, and The Prochnow Foundation.

Dr. Hoffman holds the title of Dean's Council of 100 Distinguished Scholar, has won both undergraduate and graduate teacher of the year awards in the W. P. Carey School of Business, and was named Arizona professor of the year in 1997 by the Carnegie Foundation. Dr. Hoffman is the associate dean for research in the W. P. Carey School of Business, directing doctoral programs. He is the director of the L. William Seidman Research Institute as well as faculty director for the Center for Competitiveness and Prosperity Research, and administers the Office of the University Economist and the Productivity and Prosperity Project (www.asu.edu/p3).

In addition to academic research, Dr. Hoffman has participated in numerous applied research projects in Arizona, including the construction and maintenance of the tax revenue forecasting model used by the Executive Budget Office of the state of Arizona. Spanning six gubernatorial administrations, Dr. Hoffman has served in this capacity since 1982. Dr. Hoffman headed groups of economists who measured the economic impact of several fiscal initiatives for the state of Arizona in 1989 and 1990. The 1989 study was commissioned by Governor Mofford as an input to fiscal initiatives that were contained in her State of the State speech in 1989. The 1990 study was requested by the Joint Select Committee on Fiscal Reform of the Arizona Legislature. In 1996, Dr. Hoffman was appointed to the Joint Select Committee on Economic Incentives of the Arizona Legislature. Dr. Hoffman has served as the external advisor for the Arizona Legislature's tax and incentive committee, and for Governor Napolitano's Citizens Finance Review Commission. He has provided consulting expertise on Arizona economic and fiscal matters for various state agencies and municipal governments.

Dr. Kent Hill

Kent Hill, Ph.D., is a research professor working jointly in the Department of Economics and the L. William Seidman Research Institute of the W. P. Carey School of Business at Arizona State University. For the Department of Economics, he teaches an MBA course in global economics and undergraduate courses in international trade and finance, honors macroeconomics, and principles of macroeconomics.

Dr. Hill was an assistant professor at ASU from 1978 to 1983. After leaving the university for seven years, he returned in 1991 and has been teaching at ASU since that time. He also has taught economics at Clemson University, Southern Methodist University, and the American Graduate School of Management.

From 1984 to 1991, Dr. Hill worked in the research department of the Federal Reserve Bank of Dallas. His responsibilities included briefing the bank president and other officials on the state of the economy and contributing to and editing the bank's Economic Review. From 1992 to 1996, Dr. Hill served as a consultant to Arizona Public Service Corporation. His work at APS included preparing forecasts of regional energy demand and investigating the impact of deregulation on electricity rate structures. His activities at the Seidman Research Institute include tax analysis, economic impact analysis, and industry studies. Dr. Hill's research has been published in such professional journals as the *Journal of Political Economy, the Journal of International Economics,* and the *Journal of Development Economics.*

Dr. José Lobo

José Lobo, Ph.D., is a research scientist in the School of Sustainability at Arizona State University. He currently co-teaches a graduate seminar (jointly offered by the School of Sustainability and the School of Human Evolution and Social Change) on invention and innovation in cities and regions.

Dr. Lobo was an assistant professor at Cornell University between 1997 and 2002. After leaving Cornell he worked for a small high-technology consulting firm and then held visiting research positions at the Santa Fe Institute and the University of Modena and Reggio Emilia (Italy). He has been at ASU since March 2005.

In his present position at the School of Sustainability, Dr. Lobo participates in various multidisciplinary research projects which have as a common theme elucidating the role of knowledge-intensive industries in facilitating environmental, economic and social sustainability in urban areas, and quantifying the "environmental footprint" of urban economies having different industry mixes and socioeconomic characteristics. In collaboration with colleagues from the Harvard Business School, he is examining how salient features of social networks of inventors and the social, institutional, organizational and economic characteristics of metropolitan areas in the United States interact to generate "regions of innovation." In collaboration with colleagues from the Santa Fe Institute and Los Alamos National Laboratory Dr. Lobo is investigating the relationship between urban scale and innovation and the extent to which urban scaling mirrors biological scaling. Dr. Lobo's research has been published in such professional journals as the *Journal of Urban Economics, Journal of Economic Geography, Urban Studies* and *Research Policy.*

Dr. Alberta Charney

Alberta Charney, Ph.D., has been a faculty member in the Economic and Business Research Program at the University of Arizona since 1977. Her research focus is on the economy of the state of Arizona. She is considered an expert on tax analysis, econometric model building, regional economic forecasting, and impact analysis. She has built numerous revenue and economic forecasting models for Arizona and its substate areas, receiving funding for these projects from the Arizona Joint Legislative Budget Committee, the Arizona Department of Transportation, the City of Tucson, Pima County, Tucson Economic Development Corporation, the Chamber of Commerce, and the National Science Foundation.

Dr. Charney also has received funding for studies on tax policy, population estimation/projection methods, and impact studies from the Arizona Department of Economic Security, the Tucson Convention and Visitors Bureau, the Maricopa Association of Governments, the City of Tucson, the Arizona Legislature, the Arizona Joint Select Committee on Revenues and Expenditures, the University Medical Center, the Arizona Department of Commerce, the Governor's Strategic Partnership for Economic Development, Metropolitan Tucson Convention and Business Bureau, and the Governor's Arizona Science and Technology Council.

Her diverse academic publications deal with transportation, taxation, econometric model building, forecasting accuracy, water issues, migration, manufacturing location and entrepreneurship. They have appeared in *Land Economics, Journal of Regional Science, International Regional Science Review, Review of Public Data Use, Journal of Urban Economics, Logistics and Transportation Review, Quarterly Review of Economics and Business, Resources and Energy, American Journal of Agricultural Economics, Western Tax Review, Regional Studies, State and Local Government Review*, the *International Journal of Entrepreneurship Education*, and various book chapters.

Maile Nadelhoffer

Maile L. Nadelhoffer is a senior research economist in the Economic and Business Research Center at the University of Arizona's Eller College of Management. For the last 10 years, Maile has been a member of Center's Forecasting Project team which produces quarterly economic forecasts for Arizona and the Tucson and Phoenix metropolitan areas. These forecasts are recognized as among the most accurate in the western states. With Center faculty member Dr. Alberta Charney, Maile recently co-authored a program evaluation of the City of Tucson's Wired-for-Success workforce training program for the U.S. Department of Commerce. She currently is carrying out a workforce assessment study for the Town of Sahuarita. She also contributes analysis and editorial review to the Center's newsletter *Arizona's Economy.*

Prior to joining the Economic and Business Research Center's staff, Maile taught mathematics, statistics and economics at the University of Arizona. With a background in environmental economics, she carried out cost-benefit analyses of proposed environmental regulation for the Arizona Comparative Environmental Risk Project, a multidisciplinary task force prioritizing environmental risk in Arizona. Maile holds an M.A. in Economics and an M.S. in Mathematics, both from the University of Arizona.

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