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TECHNOLOGY TRANSFER AND COMMERCIALIZATION: THEIR ROLE IN ECONOMIC DEVELOPMENT

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TECHNOLOGY TRANSFER AND COMMERCIALIZATION:
THEIR ROLE IN ECONOMIC DEVELOPMENT

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Technology Transfer and Commercialization: Their Role in Economic Development

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Preface and Acknowledgements

To many in the field of regional economic development, the development and commercialization of advanced technology offers two complementary benefits—the warding off of economic instability and uncertainty driven by globalization and increases in personal income that reflect advanced technology's higher value-added. In light of this perception, cities, states, and public purpose organizations around the U.S. have very actively sought to capture these benefits through the creation of programs charged with facilitating the transfer of knowledge from innovating organizations, be they public or private, to commercializing firms. In recent years, in fact, there has been a veritable explosion of such programs, a "gold rush" of a sort.

This study has been prepared to aid and inform economic development practitioners seeking to promote technology transfer and commercialization. The objectives of the document are fourfold. First, it seeks to provide the context, globalization and increased competitiveness, that necessitates technology-focused activity. Second, as most development practitioners have little technology-related background, the report aims to increase practitioners' understanding of the breadth of technology transfer and commercialization activity, through providing a typology with numerous examples.

Third, the study endeavors to assist development practitioners in realistically assessing the potential for technology-based development in their respective areas. It seeks to answer questions such as: Where does technology development and commercialization activity take place in the United States and why? Are rural areas and smaller metro areas as likely to be homes to technology development and commercialization activity as larger metro areas? How important is the presence of public R&D (i.e., that carried out at universities, nonprofit research institutes, and federal laboratories) for technology-based development? Is it correct to assume that a new technology product will be produced in the location of its invention?

Fourth, the report aims to provide development practitioners with a sense of the technology transfer and commercialization program models and options and how their organizations might fruitfully interact with such programs. For a variety of reasons, the large majority of technology transfer and commercialization programs are managed outside of traditional economic development agencies. Fully utilizing the presence and possibilities of such programs is an important component of the technology-based development process.

The publication of this document represents the end of a remarkable journey, one notable for several reasons. First, the journey's arc covered quite a temporal landscape, from the high technology fever of the late 1990s through the subsequent technology swoon and, now, it appears, the slow re-emergence of a vibrant (and wiser) technology sector combined with the ongoing utilization of technology across all industrial sectors.

Second, the journey required the research team to use, and integrate the results of, a diverse array of research and analytic methodologies, including literature review, surveys, information collection via phone and on-line, telephone interviews, data analysis, and legal research. The effort also allowed the team to become familiar with a broad array of topics such as the processes of innovation and product development; global economic restructuring; the dynamics of regional economic development and industry clusters; public research and development; and organizational models and options for promoting technology transfer and commercialization. It has been fascinating to weave together the research results into what one hopes to be a coherent, instructive story regarding the role of technology transfer and commercialization in regional economic development.

Third, and most importantly, my traveling companions—my colleagues and clients—were extraordinarily dedicated, patient, helpful, and creative. Larry Icerman never ceases to amaze with his ability, on the one hand, to articulate in new ways the conceptual interface between technology and development, and, on the other, to gather and organize numerous factual details on both topics. His skills are evident in the frameworks of Chapter Two and comprehensiveness of Appendix A. Jan Youtie's focus, thoroughness, and analytic capacities are reflected in the 21 case profiles of Appendix C. Jan also expertly managed the project's Web-based survey of development practitioners.

Representing Georgia Institute of Technology, the grantee, David Roessner has shown extraordinary trust in agreeing to oversee this project and in allowing his project manager to shape and reshape the structure and nature of the effort. Dave has shown extraordinary patience and kindness throughout the project, as well as provided highly useful feedback. Susan Alice Silver, the project research assistant, put in many hours tracking down and calling up technology transfer and commercialization organizations across the country. Her efforts were crucial in the development of the program typology.

The staff of the Research and National Technical Assistance Division at the Economic Development Administration exercised a high degree of patience as well, coupled with periodic, well-deserved proddings. Many thanks go to John McNamee and his staff, including John Fieser, Margot Leydic-Boyd, and Kelly Robinson. John Fieser's skills in editing significantly improved this document, and his good humor was much appreciated.

While many hands contributed to this effort, the responsibility for any shortcomings in the final document rests with the project manager.

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Executive Summary

Background

Over the past several decades, the U.S. economy has been undergoing a series of substantial, sometimes exhilarating, sometimes wrenching, transformations. Industry structures are in constant churning—firms are merging, acquiring, leaving, dying, entering, growing, downsizing, outsourcing, and spinning off. At a faster and faster pace, the U.S. economy is experiencing the phenomenon the economist Joseph Schumpeter called "creative destruction."

The process of structural change shows no signs of abating. Markets and industries are far more competitive and volatile than before. With the availability of new production, transportation, and communication technologies, developing countries can effectively compete with industrialized ones in a number of markets. As the pace of technological innovation has exploded, leading to a stream of new goods and services, emerging firms and industries are constantly rising to challenge older ones.

The multi-decade process of radical economic change has significantly transformed regional economies across the United States. The ongoing series of industrywide downsizings and expansions and corporate mergers, acquisitions, failures, births, and relocations has led to major geographic redistributions of jobs and income.

While some regions have emerged in better shape than others, no region of any size has escaped the pain and uncertainty involved in the restructuring process. Even regions now dominant in high technology once experienced substantial job loss before their recent remarkable upturns. Moreover, as the process of creative destruction intensifies, the uncertainty of the future has become clear to all regions, regardless of their current status. No U.S. region can take its economic stability for granted.

To address pain and uncertainty, and to take advantage of opportunity, regions around the United States have created and implemented a diverse array of economic development strategies. While diverse in focus, these strategy elements have one key characteristic in common—they strive to support firms that increase the region's ***value added per worker***. They seek to add value to corporate operations through investing in a region's ***assets***, such as its ability to innovate, entrepreneurial base, workforce, physical facilities, and venture capital base. These assets have provided the foundation for the ongoing transformation of the U.S. economy. Experience suggests that, in the long run, those regions that prosper are the ones that have competed on the basis of value, investing in their assets, and not on cost alone.

In many regions, certain development tools aim to build value by encouraging the ***development and commercialization of new technologies***. While much attention is paid to successful innovations in high-technology industries, such as biotechnology and software, market opportunities for innovative technology-based products exist throughout all goods-producing industries, such as carpets and automotive parts, for instance. In fact, in 2001, less than 50 percent of the patents granted by the U.S. Patent and Trademark Office are for technologies in high-technology industries.

From an economic development perspective, the primary reward to a region in which successful technology development takes place may be, but is not necessarily, new employment directly resulting from the commercialization of that technology. In this age of geographically dispersed corporate functions and outsourcing of manufacturing, distribution, administrative, and service activities, the direct employment benefits of a successfully commercialized technology may be spread across many locales. Whatever the direct employment benefits, an important regional reward for successful technology development and commercialization is the enhanced capacity to attract additional well-paid jobs related to innovation. If an area is seen as having the human talent needed to enable successful technology development and commercialization, other firms, entrepreneurs, and researchers are attracted to the area, leading to "virtuous cycle" of additional successful technologies, waves of new technical staff, and a stream of new businesses.

Successful development and commercialization of innovative technologies is a difficult, multifaceted endeavor, and a variety of development tools exist to promote this activity. by far the most popular approach to directly promoting successful innovation is through ***technology transfer and commercialization programs***. For the most part, the state and regional organizations with primary responsibility for economic development do not manage these technology transfer and commercialization efforts, which usually require a level of technical expertise not found in traditional development agencies.

While the aim is to promote economic development, technology transfer and commercialization programs tend to operate in a "parallel universe" apart from, and often uncoordinated with, general purpose economic development organizations. The geography covered by place-based technology transfer and commercialization programs is often different from that covered by development agencies. While many economic development agencies cover only part of a region (e.g., a county), technology transfer and commercialization initiatives are rarely smaller than a multicounty region in geographic scope. Many are statewide in focus; a few are multistate.

Technology transfer occurs when a firm obtains technology from an ***external source*** (e.g., a university, a federal laboratory, another corporation, or an individual). All innovation builds on existing knowledge. So technology development very much depends on scientists and engineers knowing about and having access to other researchers' good ideas and discoveries. The greater the extent to which technical staff have knowledge of and access to other researchers' work, the more likely they will develop new technologies that can be the basis for successful products. Technology transfer is essential to technology development.

The potential economic development impacts of technology transfer are so compelling, in fact, that states and regions across the country with valuable repositories of technical information (e.g., universities, federal laboratories, and technology businesses), have created public and nonprofit technology transfer initiatives. These initiatives, numbering in the hundreds, aim to increase the supply of and access to unique local technical information in order to bolster the development of new technologies. Such programs are found in every state and in all types of economic areas, from the well-to-do to the less-well-off, from those rich in technology assets to those less so. These place-based technology transfer initiatives are diverse in nature. They differ greatly in the types of technical information offered, the means of providing it, sponsorship, industry breadth and focus, and impetus for creation.

Commercialization is the process of ***transforming new technologies into commercially successful products***. The commercialization process includes such efforts as market assessment, product design, manufacturing engineering, management of intellectual property rights, marketing strategy development, raising capital, and worker training. Typically, commercialization is a costly, lengthy process with a highly uncertain outcome. The costs of commercialization can run from between 10 and 100 times the costs of development and demonstration of a new technology. Moreover, success is rare—less than five percent of new technologies are successfully commercialized. Even when successful, technology commercialization does not happen quickly. On average, the commercialization of university research takes over six years. Commercialization of radically new technologies can take well over a decade.

Given the multiple resources required for successful commercialization of technology, it is not surprising to find a large number and variety of state and regional commercialization programs. Examples of such programs include technical assistance in product design and manufacturing engineering offered by public universities; access to market assessment and intellectual property experts through regional technology councils; and access to the equity capital needed to finance technology commercialization through public venture capital funds.

An Overview of Technology Transfer and Commercialization Activities

The process of technology development and commercialization takes place over three broad phases—the development of new science, the conversion of science to technology, and the conversion of technology to products. ***Science*** is knowledge regarding certain principles of nature (e.g. of lasers). ***Technology*** is the application of engineering to science, the use of our understanding of nature to develop a technical method (e.g., gas, solid state, and semiconductor laser technologies) for achieving a practical purpose. A ***product*** is the application of technology in a particular physical form (e.g., laser surgical instrument, laser welder, and DVD player), designed to carry out a specific set of functions.

Science, technology, and products are very rarely created in a vacuum, depending solely on internal expertise. In nearly every case, to a greater or lesser extent, scientists and engineers rely on technology transfer. For any particular technology-based product, one can trace the arc of science, technology, and product over time and from one set of scientists or engineers to the next. They draw on knowledge developed by others that they obtain through some combination of text (e.g., prior patents, journal articles, or working papers), legal permission (e.g., a patent license), and personal interaction (e.g., informal relationships, cooperative R&D, or technical assistance). Technology commercialization can be thought of as all the steps required to convert a technology into an economically successful product. In each trajectory of science, technology, and product, the process that unfolds is idiosyncratic, entirely dependent on context, individual and organizational capacities, and unique circumstances. A typology of technology transfer and commercialization activities is outlined below.

The Geographic Patterns and Impacts of Innovation

In exploring the geographic patterns of innovation, the primary units of analysis are R&D expenditures, patents, metropolitan areas, and units areas. Public R&D is that carried out by academic institutions, federal laboratories, and nonprofit research institutes (e.g., hospitals). Academic institutions provide about half of metro public R&D expenditures, federal laboratories provided 41 percent, and nonprofit research institutes provided nine percent. While problematic in some regards, patents are the best available proxy for technology development. Metropolitan areas include Consolidated Metropolitan Statistical Areas (CMSAs) and Metropolitan Statistical Areas (MSAs). Unit areas include Primary Metropolitan Statistical Areas (PMSAs) and MSAs. CMSAs are composed of two or more PMSAs. There are 276 metro areas and 331 units areas.

The pace of U.S. technology development activity has more than doubled in the past two decades. Industry performs the large majority of U.S. applied research and development, and so, not surprisingly, obtains the bulk of the patents. Universities, nonprofit research institutes, and the federal government carry out most of this country's basic research. Industrial R&D is primarily carried out by very large companies. Interestingly, the majority of patents are not in advanced technology industries.

At the state level, the level of patent activity is closely associated with the level of industrial R&D. To a lesser extent, the level of patent activity also is influenced by the presence of advanced technology industries. The level of patenting activity is not consistently related to the level of public R&D.

Technology development activity primarily takes place within larger metropolitan areas. While 84 percent of U.S. jobs are located in metropolitan areas, metropolitan areas receive 93 percent of U.S. utility patents and public R&D expenditures. Only 19 percent of U.S. metropolitan areas specialize in patenting (that is, have a patenting location quotient greater than 1.0); they receive 66 percent of patents and have 43 percent of jobs. The same pattern holds true for unit areas.

Unit area patenting rates correlate with three factors: the percent of the local economy devoted to advanced technology, the level of educational attainment, and the size of the metro area (MSA or CMSA) as measured by number of jobs. Differences in

Technology Transfer and Commercialization Activities

<u>Technology Transfer</u>

1) Cooperative research and development – business collaborates with one or more outside technology organizations
   a) Multi-firm strategic research alliances
   b) University-industry collaborations
   c) Nonprofit research institute-industry collaborations
   d) Federal agency or laboratory-industry collaborations

2) Licensing or sale of intellectual property
   a) Traditional licensing or sale – owner of technology transfers certain intellectual property rights to outside business in exchange for certain benefits, usually financial
   b) Startup spinoff – technology organization licenses intellectual property to the in-house developer of that technology, and so enables the developer to found a new business

3) Technical assistance – business utilizes outside organization to answer or solve a relatively narrow, well-defined question or problem
   a) Expert assistance – business utilizes outside experts
   b) User facilities – business utilizes equipment from outside organization for testing/evaluation

4) Information exchanges – business obtains access to existing technical information through exchanges such as markets, conferences, federal agencies, and professional networks
   a) Forms of information – printed material (e.g., articles, technical reports, or databases) and professional expertise (e.g., informal conversation, or new employees)
   b) Types of information access – freely available, exchange access fee (e.g., conference registration or corporate affiliate program membership), or direct purchase or hire

<u>Technology Commercialization</u>

1) Technical – technical effort required to transform technology into a viable and desirable product, and to produce the product in sufficient quantities and with adequate quality
   a) Product development or design
   b) Manufacturing engineering

2) Business management and market analysis
   a) Business planning
   b) Market characterization – determination of size and nature of market for product, potential profits, and return on investment
   c) Marketing strategy
   d) Manufacturing, supply chain, distribution, and service systems development
   e) Management of intellectual property rights

3) Factors of production
   a) Capital – equity capital or debt financing for product commercialization and business development
   b) Physical facilities – may include industrial parks, research parks, and incubators
   c) Skilled workforce

public R&D intensity (academic, nonprofit, and government R&D dollars per 100,000 jobs) have negligible explanatory power regarding differences in patenting rates. (Industrial R&D data are not available at the metro level.)

Metro size matters. Metro areas with more than 1 million jobs are far more likely to specialize in patenting (and have unit areas that specialize in patenting) than are metro areas with fewer jobs. Moreover, of the metro areas with less than 1 million jobs that specialize in patenting, 63 percent (24 of 38) are dependent on just two R&D organizations for at least half of their patents. In contrast, for patent-specializing metro areas with more than a million jobs, just 12 percent (four of 34) depend on two organizations for over half the patents.

High patenting rates for unit areas often are not sustained over time, particularly in areas dependent on older industries and one or two firms. Corporate size matters. In almost every metro and unit area that specializes in patenting, the top patenting organizations are Fortune 1000 firms.

Public R&D is even more geographically concentrated than patenting. Only 20 percent of metro areas specialize in public R&D, with 71 percent of metro R&D expenditures and only 29 percent of metro jobs. Moreover, over a quarter of metro areas have no public R&D. Federal intramural R&D expenditures are particularly concentrated geographically; academic/nonprofit R&D is concentrated, but much less so. Metro areas with over 2.5 million jobs have the highest academic/nonprofit R&D intensity. Interestingly, as metro size declines, the range of R&D intensity widens considerably, particularly for metro areas below 250,000 jobs. Few of these areas specialize in academic/nonprofit R&D; nearly half have no measurable academic/nonprofit R&D. At the same time, almost a tenth of the smallest metro areas are “university towns”, with R&D location quotients of over 3.0.

The presence of public R&D is not strongly correlated statistically with patenting activity. While it may be helpful, it often does not have a strong impact. Area size does positively affect the correlation.

Overall, only 12 percent of unit areas specialize in both patenting and academic/nonprofit R&D. Nearly half of areas that specialize in patenting do not specialize in academic/nonprofit R&D. Conversely, 58 percent of areas that specialize in academic/nonprofit R&D do not specialize in patenting. (However, 85 percent of areas that do not specialize in academic/nonprofit R&D do not specialize in patenting, so specialization in the former does boost likelihood of the latter.)

Metro size in terms of jobs greatly improves the likelihood that specialization in academic/nonprofit R&D is linked to specialization in patenting. In metro areas of over 1 million jobs specializing in academic/nonprofit R&D, 59 percent of unit areas specialize in patenting; for smaller metro areas that specialize in academic/nonprofit R&D, only 32 percent of unit areas specialize in patenting. However, clearly, metro size has a power independent of specialization in academic/nonprofit R&D. In larger metro areas that do not specialize in academic/nonprofit R&D, 47 percent of unit areas specialize in patenting; for smaller metro areas, the comparable figure is only 10 percent.

Findings regarding the relationship between federal R&D activity and patenting are similar to those for academic/nonprofit R&D.

Several observers have posited the value to technology development of the co-location of industrial R&D with graduate science and engineering (S&E) programs. The thought is that a steady local stream of S&E graduates yields a knowledgeable, motivated technical workforce available to carry out R&D in established firms and startups. As might be expected, S&E graduate student intensity (S&E graduate students per 100,000 jobs) is highly correlated with academic/nonprofit R&D intensity. Consequently, the pattern of impact of S&E graduate programs on patenting is quite similar to that of academic/nonprofit R&D.

These various results prompt the following observations:

- In general, metro areas with over 1 million jobs are more likely to have the critical mass of technology-focused industry, services, researchers, students, and amenities that stimulates and enables technology development.
- In the larger cities, the critical mass of academic/nonprofit R&D activity useful in supporting industrial technology development may be below the level of specialization.
- Because of their breadth of resources, larger metro areas can better enable the transfer of technology from academic/nonprofit institutions to local industry.
- Some smaller metro areas host patent activity for one or two large corporations with little need for access to local academic/nonprofit R&D.

For unit areas, wage levels are boosted by industrial R&D, patenting activity, metro size, and educational attainment. However, no factor other than educational attainment has a statistically significant impact on the expansion of regional job or wage base.

From a public policy perspective, the fundamental purpose of the promotion of technology development activity is to encourage improvement in regional economic performance. Four measures of economic performance are examined. Average annual wage and increase in average annual wage reflect trends in value added. Growth in jobs and wage and salary disbursements are proxies for regional economic expansion.

Three-quarters of differences in unit area average annual wage is explained by differences in number of patents, number of jobs (i.e., area size), patenting rate, and educational attainment (in order of importance). Academic/nonprofit R&D intensity and S&E graduate student intensity have slightly negative impacts. In statistical analysis at the state level, the substitution of industrial R&D intensity for patenting rate slightly increases the portion of average annual earnings explained.

For the increase in average annual earnings per job over the last decade, the statistical analysis yields approximately the same results. Two-thirds of the difference among unit areas in terms of increase in annual average earnings is explained by differences in average annual number of patents, average annual number of jobs, average annual patenting rate, and educational attainment. Again, at the state level, the substitution of industrial R&D for patenting rate slightly boosts the proportion of differences in earnings increase that can be explained. S&E graduate education intensity and academic/nonprofit R&D intensity again have slight negative impacts on wage levels.

Technology development activity—whether in the form of patenting, industrial R&D, and public R&D—appears to have negligible impact on two measures of regional economic growth—change in total jobs and total earnings (wage and salary disbursements). Educational attainment explains about a fifth the growth of wage and salary disbursements (by far the strongest impact of any of the variables); it has little explanatory power regarding the growth of jobs. The impact of metro size, academic/nonprofit R&D, and S&E graduate education are slightly negative.

Explaining the Geography of Innovation and Its Connection to Regional Development

To explain this geography of innovation, an examination of the literature in technology development and technology-based economic development was undertaken. This literature can be divided into three related realms: how innovative firms learn, where innovative firms locate in light of how they learn, and the nature of relations between public R&D organizations and firms.

In carrying out technology development, few firms can work alone. Many actively seek information from external sources, of the types and in the ways described earlier. Typically, this process of learning from external sources (technology transfer) is not a dramatic, high profile, highly logical effort, but rather an ongoing, incremental, often small-scale one that seldom leads to dramatic change. The learning process is not one of simply obtaining information. Rather it involves both obtaining and transforming information, which is factual, into useable ***knowledge***, which establishes generalizations and correlations between variables. Technology is a cumulatively aggregated pool of knowledge.

As Polanyi posits, knowledge is of two types, ***tacit*** and ***explicit***. Explicit (or codified) knowledge involves know-how that is transmittable in formal, systematic language and does not require direct experience of the knowledge that is being acquired. Explicit knowledge can be transferred through manuals and blueprints, for instance. On the other hand, tacit knowledge cannot be communicated in any direct or codified way, as it concerns direct experience. Tacit knowledge is intangible know-how acquired through learned behavior and procedures.

In general, the more tacit a specific piece of knowledge, the greater the time and effort required to learn the code and to transform the knowledge into a form that is firm-specific and commercially relevant. Given these complexities and the learning-by-doing nature of gaining tacit knowledge, the transfer of tacit knowledge is most effective through personal interaction with the holder of that knowledge. Therefore, tacit knowledge is most effectively transferred when the provider and seeker are in geographic proximity.

At the beginning of the life cycle for a particular technology, tacit knowledge is dominant. As a technology matures, more knowledge becomes codified. So the relative importance of tacit and explicit knowledge will shift over time as a technology moves along a trajectory. Thus, personal interaction and geographic proximity tend to be more important in the early stages of a technology life cycle.

Individual firms vary greatly in their abilities to learn. These abilities, in turn, appear to be a function of a number of factors. One is that of experience, in terms of internal R&D effort, learning, and external relationships (e.g., networks and alliances). A second factor is geographic proximity to potential sources of external knowledge.

A third factor relates to firm size. Small firms tend to have greater motivation to learn, greater openness to new ideas and willingness to let go of old ones, greater ability to make use of informal networks of firms, and greater flexibility and ability to manage change. Large firms tend to have greater R&D resources and specialization, more interfaces with the external environment, and more resources to devote to external knowledge accumulation. Evidence suggests that small, independent firms are more likely to seek external resources, formal and informal, than large firms due to relatively fewer internal resources. Thus, proximity is particularly attractive for small firms.

A firm's high outward orientation towards learning, particularly its ability to participate in widespread networks, can overcome the constraints of a peripheral location. Compared to other firms, the networks of active, extroverted firms tend to be wider and encompass more connections both within their own region and outside it. Telecommunications can substitute to some degree for remoteness, but active engagement in personal interaction locally or nonlocally are key to success.

The literature indicates that location in large metropolitan areas provides a number of important advantages to firm learning. In summary, these advantages are found in a depth of specialization, a breadth of diversity, and an access to important general economic resources that most smaller metro areas cannot match.

The advantages of specialization are revealed in the workings of industry *clusters*. Regional clusters provide two important advantages to firms—greater access to valuable knowledge and agglomeration economies of scale. The primary stimulant to greater access to valuable knowledge is geographic proximity. Proximity supports and encourages the development of business and social relations, of a variety of networks that include customers, goods and services suppliers, competitors, and public R&D institutions, often facilitated by mediating organizations such as trade associations and technology business councils. These connections facilitate the transfer of tacit technical knowledge.

Types of knowledge obtained through cluster connections include technical knowledge and tacit knowledge of a procedural sort. Such latter knowledge includes how to "transcode" new information, how to collaborate effectively with other researchers within and without one's own organization, and how to successfully interact with important nontechnical actors (e.g., financing organizations, government, training programs).

Firms are also attracted to the nonknowledge agglomeration economies of clusters. Clusters offer superior access to a variety of important inputs (e.g. technical and nontechnical workers, specialized services, supplies, training and degree programs).

Small firms in particular are attracted to locate in a cluster. New firms that spin off from existing firms in a cluster of course will find it easiest to remain where they are. Small firms, as noted, value networks more than larger firms for their knowledge sharing potential.

While innovative firms can experience substantial benefits from being in specialized clusters, research shows they also can gain significant advantage from being in a diversified environment. The argument is that local diversity increases the probability of combining different types of knowledge in innovative ways. A diversified city is likely to facilitate the transfer of know-how from one area of industry to others that are unrelated in terms of final products.

Large metropolitan areas provide a supportive context for innovation in part because of their greater diversity. In addition, through another set of agglomeration economies, large areas can provide access to a full array of important economic resources (e.g., financial services, an airport with excellent connections, temporary staffing agencies without limit, and quality-of-life elements) not specific to one industry.

Innovative clusters can begin in any setting. However, those clusters that grow to become world-class competitive tend to be located in large metropolitan areas, primarily the diversity and general economic resource assets of these areas better nurture and support the development of innovative technology in the early stages of its life cycle. Once a cluster in a large metro area reaches a critical mass, its growth can become reinforcing. Firms with a choice of locations locate there to garner the proximity benefits; the larger the cluster, the greater the proximity benefits, the more growth it attracts. The result is that any given industry has only a handful of major clusters, located almost always in large metropolitan areas.

Numerous authors suggest that regional differences in rates of innovation also can be attributed to differences in regional competencies for learning. These competencies are reflected in the nature of the regional corporate culture for information-seeking and –sharing; in the characteristics of regional public and private organizations that promote learning (e.g., trade associations, business councils, chambers of commerce, governments, universities); and in the presence of informal interfirm networks.

Researchers conclude that firms are much more likely to interact with sources of public R&D that are relatively close by. (Among the studies, the median distance is 75-100 miles.) University research, knowledge about how to apply university research, and knowledge about how to manage a relationship with a university are all relatively tacit, so proximity is preferred. However, while firms interested in using public R&D prefer proximity, they also find advantage in being near other firms in their industry, a diverse environment, and business services. Such needs are best met in larger cities. So while public R&D in any location can stimulate industrial innovation, its impact tends to diminish in smaller areas.

Regional history, in the development of organizations, technology, culture, and space, plays a critical role in economic development, for this history sets in place the trajectory down which places learn and apply that learning. This trajectory is "path-dependent," once history sets it in place, it is difficult to radically change. Moreover, once competitive advantage is in place, it is difficult for other regions to dislodge.

Regions "below best practice" can become positive environments for adapting (rather than creating) innovations, developing the ability to learn from innovative firms in other places. While these are not the best innovative environments, they can be economically competitive and provide well-paying skilled jobs.

Recent research indicates that the employment impacts of successful technology commercialization increasingly are spread geographically. While technology development may take place largely in innovation clusters, the various manufacturing, administrative, and distribution functions required for successful commercialization are more and more likely to occur elsewhere, in places with competitive advantage for those particular functions. Firms are more likely to outsource to other firms and to geographically fragment operating units, splitting key functions throughout the United States and abroad. The result is that regions that are not innovative clusters now have an opportunity to specialize in functions that support commercialization. (For instance, Louisville, Kentucky, has made a concerted effort to specialize in distribution.)

A Typology of Technology Transfer and Commercialization Programs

So that practitioners and policy makers may understand the breadth and variation of technology transfer and commercialization programs operating, this section provides a typology of such programs. As outlined in the box below, the typology is structured around four major categories concerning the nature of the organization sponsoring the program. Within each category, subcategories are provided; depending on the category, subcategories are organized by nature of activity, sponsoring organization, source of technology, or mission.

Typology Of Technology Transfer And Commercialization Programs

1) Programs sponsored by public R&D institutions to promote transfer of internally-held knowledge
   a) Cooperative R&D centers
   b) Technical assistance programs – some with dedicated technical staff; others matching businesses with appropriate technical expertise with public R&D organization
   c) Technology transfer offices – primary focus on licensing

2) Services at entrepreneurship and business development centers
   a) Small Business Development Centers – supported by U.S. Small Business Administration
   b) University-based entrepreneurship & business development centers
   c) Independent entrepreneurship and business development centers
   d) Industry-specific technology business development organizations

3) External technology transfer and commercialization intermediaries
   a) Intermediaries working with technologies from all sources
   b) Federal technology transfer intermediaries – focus on transferring technology from federal laboratories
   c) Federal technology contract intermediaries – focus on assisting businesses in obtaining Small Business Innovation Research and Small Business Technology Transfer contracts

4) Technology business membership organizations
   a) Technology-based regional development councils – businesses and development agencies working together to promote technology-led development
   b) Technology business councils – technology business advocacy groups
   c) Technology entrepreneur networks
   d) Industry-specific associations and networks
   e) Professional associations and user groups

This typology is offered as a descriptive, not an evaluative or prescriptive, tool. Relatively few independent evaluations of such programs have been carried out, and the literature as yet does not offer comparative evaluations. Moreover, it should be recognized, different models and options are likely to be appropriate in different economic and institutional circumstances. Essentially, the nature of the programs developed needs to fit the nature of the opportunities present and the market barriers to taking advantage of these opportunities. The relationship between opportunities, barriers, and program design is deserving of further research.

In contradiction to findings of the previous sections, many regional and state technology transfer and commercialization programs appear to assume that

- technology transfer and commercialization are linear, mechanical processes that are quite often successful;
- location is not a major factor in the probability of success;
- technology-developing firms are not likely to relocate;
- technology-developing firms can locally obtain commercialization resources needed to be successful; and
- the corporate functions that grow out of commercialization (manufacturing, distribution, administration, service) are likely to be sited in the same locale as technology development.

That a significant number of programs originally identified during the research phase of this project no longer exist may speak, in part, to the inaccuracy of these assumptions.

However, that these assumptions are incorrect should not be taken to mean it is fruitless to create technology transfer and commercialization programs for rural and smaller metro areas. But it may mean that technology transfer efforts and commercialization efforts should be separate programs, given that the geographic dynamics of each phase are quite different. Any future research agenda should include an examination of which types of programs are appropriate for economic regions of varying size and location.

It is also helpful to understand that the efficacy of any technology transfer and commercialization program is improved to the extent its design and operations are consistent with a thoughtful regional development strategy. Practitioners and policy makers often confuse economic development tools with strategies. Technology transfer and commercialization programs are tools; strategy is determining how these tools are best used, independently and in conjunction with other tools promoting development.

Technology Transfer and Commercialization Programs and Economic Development Agencies

Technology transfer and commercialization programs for the most part operate outside of mainstream economic development agencies. Development agencies tend to be generalists, responsible for developing and implementing broad strategies, and marketers and facilitators, helping businesses find the resources (e.g., land, labor, or capital) needed to be successful and contribute to the local economy. Few have staff with the technical training needed to manage technology transfer and commercialization. Moreover, the geography covered by place-based technology transfer and commercialization programs is often different from (usually larger than) that covered by development agencies.

That both types of efforts share a similar economic development mission strongly suggests that there should be significant linkage between the two worlds. However, a project survey and field experience suggests that coordination and cooperation between these programs and agencies are not optimal. Many development practitioners do not have a full understanding of the ways in which they might fruitfully interact with technology transfer and commercialization programs. While some agency staff say they are adept at taking advantage of these programs, and a few have played a role in their creation and operation, these are the exception rather than the rule. A number even say that they are not aware of the full array of such programs in their area. Many, even those who work with these programs, say they do not completely understand the processes of technology transfer and commercialization and need to learn more.

To overcome the gap in the literature regarding how development agencies work with technology transfer and commercialization programs, a series of 21 case profiles were carried out. Each profile (available in the Appendix C) provides background regarding the region or state, an overview of the technology transfer and commercialization program, a discussion of how the program works with local development agencies, and a summary of lessons learned. The set of organizations was selected for geographic and programmatic diversity.

The case profiles suggest that state and regional economic development agencies play two major roles regarding technology transfer and commercialization organizations. One is a ***leadership*** role, with subroles that can include catalyzing the creation of the technology transfer and commercialization organization (either within or outside the development agency), managing that organization, and providing financial support. The second role is ***cooperating*** with the technology transfer and development programs in development-related efforts. Possible subroles include referring clients, being assisted on particular projects, co-investing in business and technology development facilities, and coordinating activities through participating on the boards, committees, and working groups of the other organization.

The case profiles make clear the variety of interactions that can take place between development agencies and technology transfer and commercialization organizations, and identifies several broad lessons learned.

First, adequate ***education*** is paramount. Development agencies and technology transfer and commercialization organizations need to be active, extroverted learners. Development agencies need to understand the realities of the technology development and commercialization process, and not get caught up in unrealistic thinking. They also need to become aware of the types of services that technology transfer and commercialization organizations offer, or could offer. On the latter point, they need to become more cognizant of models and options for technology transfer and commercialization as implemented in various regions around the United States, so that they might press for appropriate services in their respective areas.

Conversely, technology transfer and commercialization organizations need to better understand the breadth of economic development agency mission and services, and the incentives under which they operate, so that they might better meet agency needs. Moreover, they need to more fully comprehend the role that technology can and cannot play in the larger economy, and recognize that other sectors are important as well.

Second, good ***communication*** is key. Each organization needs to regularly update the other regarding its activities, services, results, and clients. Good communication allows each organization to better determine when to call on the other for assistance, or provide a referral.

The third lesson is ***collaboration***. The organizations need to move beyond understanding to action on particular projects. Each can benefit from the other's resources, expertise, and perspective, whether working with clients, developing new programs, or building new infrastructure.

The fourth lesson is the need for ***coordination***. The policy and strategy of each organization needs to recognize, and to the extent possible, be consistent with the other. Cross-representation on boards and committees facilitates coordination.

The final lesson is the need for ***leadership***. Through the leadership of a handful of individuals, a number of development agencies were responsible for creating a new technology transfer and commercialization organization. Good leadership brings about education, communication, collaboration, and coordination. It is the "meta" characteristic without which the others would not exist.

These lessons hold even if, as is so often the case, the technology organization covers a larger area than the development organization. In such instances, the local development agencies may be more dependent on the technology organization than vice versa. However, if a technology organization has statewide coverage, the state development agency should be actively working with it as well in the realms of education, communication, collaboration, and coordination.

Concluding Remarks

In light of the geographic patterns of technology transfer and commercialization, perhaps states and regions should be advised to separate technology transfer efforts from commercialization efforts, and to have a difference in emphasis and orientation that realistically reflects the local opportunities offered by each. Significant technology transfer programs are appropriate where innovation clusters currently exist, or appear possible. Other regions certainly should take steps to promote technology transfer, but they need to be more strategic and realistic about what can be accomplished. All regions, but the latter in particular, might do well to explore ways to facilitate increased local firm access to technology developed elsewhere. That is, they should explore the ways in which technology transfer efforts can emphasize "demand-pull" rather than "supply-push." The primary focus in some regions on transferring technology from a local public R&D institution seems misplaced.

Similarly, states and regions should consider adjusting the nature of their commercialization strategies from ones emphasizing the commercialization of locally developed technologies to ones emphasizing aiding the successful commercialization of technologies developed elsewhere. With the geographic fragmentation of the outcomes of commercialization, regions that do not contain major innovation clusters have an opportunity to implement some aspect of commercialization (e.g., manufacturing, distribution, marketing, service, administration) in which they excel.

In adjusting technology transfer and commercialization tools and strategies in light of experience and new economic realities, regions would benefit from studying efforts in other regions that have proven effective in circumstances similar to theirs. The field of technology transfer and commercialization program development itself suffers from inefficiencies in knowledge transfer. Too often, it appears (and is often the case in economic development generally), a particular tool is widely copied without full understanding of the appropriateness of such a tool in a local setting and, if appropriate, how to manage it effectively.

With increased globalization, the need for regions to develop and protect higher value-added industries only grows. To respond, regions must have a thoughtful, strategic, quick-acting economic development process; to be effective, such a process must involve collaboration among all relevant parties, including those involved in technology development and commercialization. To a significant extent, technology transfer and commercialization programs operate with insufficient linkage to regional economic development agencies.

Even so, as the primary facilitators of overall regional strategy, economic development agencies have a responsibility to identify the need for and proper design of local technology transfer and commercialization efforts, to see that any programmatic gaps are filled (even if by state programs), and to ensure that representatives of such efforts are active partners in strategic planning and implementation.

In economic development, the widespread optimism of the 1990s is giving way to a more somber realism that there are no "magic bullets." Technology transfer and commercialization are difficult processes with uncertain endings. Thus, it becomes clear that regional economic well-being is best served if development agencies work hard to educate themselves about the art of the possible in technology transfer and commercialization, and actively work with relevant partners so that those possibilities can become realities.

Chapter One: Background and Introduction

1.1 In a Time of Radical Economic Change

Over the past several decades, the U.S. economy has been undergoing a series of substantial, sometimes exhilarating, sometimes wrenching, transformations. Low-wage, low-skilled commodity industries—such as shoes, apparel, and textiles—have gone off-shore to take advantage of far lower labor costs; plants that produce commodity durables, such as electric motors and generators, are following. High-wage industries, such as iron and steel, that could not compete in terms of productivity provide far fewer jobs than they once did. Industries difficult to imagine a few decades ago—such as software, Web-based services, and biotechnology—have blossomed, and traditional technology industries—such as telecommunications and pharmaceuticals—are regularly being reinvented and transformed. Advanced manufacturing technologies have greatly reduced the number of production workers needed. Industry structures are in constant churning—firms are merging, acquiring, leaving, dying, entering, growing, downsizing, outsourcing, and spinning off. At a faster and faster pace, the U.S. economy is experiencing the phenomenon the economist Joseph Schumpeter called "creative destruction."[1]

Table 1.1 offers examples of the radical transformation of the U.S. economic structure. While the total number of jobs in the economy more than doubled between 1960 and 2001, jobs in farming, traditional manufacturing, and railroads have declined greatly, and those in service industries and high technology have grown several times over.

What are the sources of these changes? The answers, well known to most practitioners in economic development (and illustrated in Table 1.2), include

- major shifts in the composition of the U.S. workforce, including significant advances in educational attainment (enabling innovation, greater productivity, and the staffing of emerging industries);
- a tripling of real investment in research and development (R&D), the results of which create whole new industries and transform others;
- large-scale investment in capital equipment, greatly increasing productivity, reducing physical labor requirements, and increasing flexibility;

[1] Schumpeter uses this term in his 1942 book *Capitalism, Socialism and Democracy*. He tells us that the notion of "creative destruction" has been integral to capitalism since its beginnings: "The opening up of new markets, foreign or domestic, and the organizational development from the craft shop and factory to such concerns as U.S. Steel illustrate the . . . process of industrial mutation . . . that incessantly revolutionizes the economic structure *from within*, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism. It is what capitalism consists in and what every capitalist has got to live with." (Harper Torchbooks, 1976, p. 83)

- a massive expansion in the productive capacity of developing nations, the levels of international trade, and the mobility of capital around the globe; and
- substantial increases in corporate restructuring, including business formations, business failures, and mergers and acquisitions.

Table 1.1: Wage and Salary Jobs, Selected Industries, 1960–2002

	1960	2002	% Change
Leather and leather products	363,400	55,500	-84.7%
Railroads	885,300	228,800	-74.2%
Apparel	1,233,200	520,700	-57.8%
Coal mining	186,100	79,700	-57.2%
Farming[a]	1,907,000	870,000	-54.4%
Textiles	924,400	431,800	-53.3%
Primary metals	1,184,800	592,000	-50.0%
Communications	839,700	1,613,800	92.2%
Computer and office equipment	143,500	303,700	111.6%
Total nonfarm jobs	54,189,000	130,790,000	141.4%
Pharmaceuticals	79,600	255,500	221.0%
Hotels	530,800	1,730,700	226.1%
Colleges and universities	426,900	1,426,700	234.2%
Transportation by air	191,000	1,161,500	508.1%
Health services	1,547,600	10,673,000	589.6%
Business services[b]	655,700	9,304,500	1,319.0%

Source: Current Employment Statistics, U.S. Bureau of Labor Statistics, except as noted.

[a] Farming figures from U.S. Bureau of Economic Analysis. The figure in the 2002 column is for 2001.
[b] In 2002, the primary components of business services were personnel supply (temporary employment agencies), 34 percent; computer programming and data processing, 24 percent; miscellaneous, 19 percent; other (e.g., advertising, copy services, equipment rental), 13 percent; and building services, 11 percent.

The radical economic restructuring stimulated by these various forces have brought about, in general, a vast improvement in the economic well-being for Americans. As indicated in Table 1.3, increases in human capital, innovation, productivity capital mobility, and corporate restructuring have led to substantial improvements in real earnings per worker and per capita income.

It has become clear that the economic advantage of the United States, and the source of its growing wealth, lies in competing on ***value***, not on cost alone. Competing on value requires innovation, creating products and services with unique performance characteristics; investment in a workforce with high skills and in capital equipment; and flexibility in corporate structures, strategies, and operations.

Table 1.2: Fundamental Sources of Change in the U.S. Economy, 1960–2001			
	1960	**2001**	**% Change**
Workforce Composition[a]			
College graduates	7.7%	25.5%	
Managerial, professional, technical workers	22.1%	33.7%	
Production workers, material movers, laborers	44.4%	23.7%	
Women	32.3%	46.3%	
Capital Investment[b]			
Equipment and software per worker, private sector (2001$)	$12,769	$38,305	200.0%
Per worker in manufacturing (2001$)	$15,037	$59,314	294.5%
Innovation			
R&D expenditures (2001$, millions)[c]	$67,600	$281,800	317.0%
Industry contribution (2001$, millions)	$22,300	$192,900	765.0%
Patents issued[d]	47,200	166,000	252.0%
Entrepreneurship and Corporate Restructuring			
Business formations[e]	182,713	800,874	337.6%
Business failures[e]	15,445	83,384	439.9%
Mergers and acquisitions[f]	814	7,610	834.9%
Productivity			
Nonfarm business output per worker hour (1992=100)[g]	51.9	123.0	137.0%
Manufacturing output per worker hour (1992=100)	41.8	142.2	240.2%
Gross Domestic Product (GDP) per FTE worker (2001$)[h]	$45,962	$81,022	76.3%
Value added per production worker (2001$)[i]	$70,313	$165,012	134.7%
Trade[j]			
Exports (2001$, millions)	$57,600	$718,762	1,247.9%
As % of GDP	3.7%	7.1%	
Imports (2001$, millions)	$62,451	$1,145,927	1,834.9%
As % of GDP	2.8%	11.4%	

[a] U.S. Bureau of the Census. College graduates given as percentage of adults 25 years and older.
[b] U.S. Bureau of Economic Analysis
[c] National Science Foundation
[d] U.S. Patent and Trademark Office
[e] Dun & Bradstreet. Figure in the 2001 column is for 1997, when series was discontinued.
[f] U.S. Census Bureau, *U.S. Statistical Abstract*. Figure for 2000 was 11,169.
[g] U.S. Bureau of Labor Statistics.
[h] U.S. Bureau of Economic Analysis
[i] U.S. Bureau of the Census. The figure in the 1960 column is for 1963.
[j] Council of Economic Advisers, *Economic Report of the President*, February 2003.

Table 1.3: Economic Well-Being, 1960–2001			
	1960	**2001**	**% Change**
Per capita net stock of residential fixed assets (2001$)[a]	$19,641	$39,793	102.6%
Per capita income (2001$)[a]	$11,366	$30,511	168.4%
Real compensation per nonfarm business worker hour (1992=100)[b]	62.6	110.5	76.5%
Average wage and salary accruals per FTE worker (2001$)[a]	$24,014	$39,784	65.7%

Source: U.S. Bureau of Economic Analysis

[a] U.S. Bureau of Economic Analysis. Per capita income includes work earnings, investment income, and transfer payments.
[b] U.S. Bureau of Labor Statistics

The process of structural change shows no signs of abating. Markets and industries are far more competitive and volatile than before. With the availability of new production, transportation, and communication technologies, developing countries can effectively compete with industrialized ones in a number of markets. As the pace of technological innovation has exploded, leading to a stream of new goods and services, emerging firms and industries are constantly rising to challenge older ones.

1.2 Economic Restructuring

The multi-decade process of radical economic change has significantly transformed regional economies across the United States.[2] The ongoing series of industrywide downsizings and expansions and corporate mergers, acquisitions, failures, births, and relocations has led to major geographic redistributions of jobs and income. For instance, the decline of traditional durables manufacturing and a spate of mergers and acquisitions has hurt old industrial cities in the Northeast and Midwest; the rise of information technology industries has enormously benefited Austin, Boston, Denver, Seattle, and Silicon Valley; and substantial increases in disposable income have led to new service industries in states once considered far out of the way, such as Arizona, Colorado, Florida, Nevada, and Vermont.

Not only have businesses and populations shifted geographically, relative incomes have as well, as Table 1.4 indicates. Between 1980 and 2001, annual pay per job as a percent of the U.S. average has climbed in areas with a focus on high technology and other growing high-value-added industries; declined in areas with high dependence on natural resources and traditional industries; and had a down-up pattern in regions hurt in the 1980s by reliance on older industries, but able to build on new industries (e.g., Seattle) or reinvigorate traditional ones (e.g., Detroit) in the 1990s.

[2] For the purposes of discussion, a region is an economically coherent set of political subdivisions (e.g., a metropolitan area or a contiguous group of rural counties).

While some regions have emerged in better shape than others, no region of any size has escaped the pain and uncertainty involved in the restructuring process. Even regions now dominant in high technology once experienced substantial job loss before their recent remarkable upturns. Moreover, as the process of creative destruction intensifies, the uncertainty of the future has become clear to all regions, regardless of their current status. No U.S. region can take its economic stability for granted.

Table 1.4: Average Annual Pay per Job as a Percent of the U.S. Average, Selected Years

	1980	1990	2001
Real average annual pay (2001$), U.S.	$27,776	$29,840	$35,550
Moving ahead:			
New York, New York	120.8%	144.5%	164.0%
San Jose, California	118.6%	138.5%	183.5%
Seattle, Washington	118.2%	110.3%	127.5%
Boston, Massachusetts	97.5%	114.4%	126.6%
Boulder, Colorado	93.4%	95.6%	121.6%
Austin, Texas	88.0%	93.1%	113.2%
Loss and partial recovery:			
Detroit, Michigan	127.8%	117.7%	118.4%
Houston, Texas	122.7%	112.2%	118.7%
Boise, Idaho	92.1%	85.9%	87.7%
Falling behind:			
Gary, Indiana	121.3%	98.9%	88.2%
Toledo, Ohio	108.8%	97.8%	89.2%
Pittsburgh, Pennsylvania	106.2%	96.5%	97.2%
Non-metropolitan West Virginia	97.2%	84.0%	72.6%
Redding, California	97.1%	89.8%	78.8%
Pueblo, Colorado	96.2%	88.9%	75.3%
Non-metropolitan Washington	95.2%	78.6%	75.2%
Pensacola, Florida	90.4%	87.6%	81.2%
Non-metropolitan Louisiana	86.5%	75.2%	69.6%

Source: U.S. Bureau of Economic Analysis

1.3 Economic Development Strategies in Response to Change

To address pain and uncertainty, and to take advantage of opportunity, regions around the United States have created and implemented a diverse array of economic development strategies. Some strategy elements aim to develop emerging industries, others seek to attract new branch plants, and others attempt to improve the competitiveness of firms in traditional industries. While diverse in focus, these strategy elements have one key characteristic in common—they strive to support firms that increase the region's ***value added per worker***.

Value added, the difference between the cost of materials and the price of the final product or service, is a measure of wealth creation—it represents the amount of money available to be shared by workers and owners. The attractiveness of increased wealth and the difficulties in retaining low-value-added industries have combined to strongly encourage regions to move their industries up the ladder of value-added jobs.

While all regions want to increase value added per worker, the tools they use to achieve this goal can differ considerably. Similar to corporations, regions' development tools can emphasize cost or value. Tools that aim to cut corporate costs (e.g., tax incentives, industrial development bonds, and low-interest loans) do not aim to alter how a firm does business.

On the other hand, certain tools seek to add value to corporate operations through investing in a region's ***assets***, such as its ability to innovate, entrepreneurial base, workforce, physical facilities, and venture capital base. These assets have provided the foundation for the ongoing transformation of the U.S. economy. Experience suggests that, in the long run, those regions that prosper are the ones that have competed on the basis of value, investing in their assets, and not on cost alone.

1.4 Technology Development, Transfer, and Commercialization

In many regions, certain development tools aim to build value by encouraging the ***development and commercialization of new technologies***. (A technology may be defined as the technical application of scientific principles and knowledge to achieve a practical purpose. Commercialization is the process of applying technology to create a product. These terms are discussed in greater depth in Chapter Two.)

While much attention is paid to successful innovations in high-technology industries, such as biotechnology and software, market opportunities for innovative technology-based products exist throughout all goods-producing industries, such as carpets and automotive parts, for instance. In fact, in 2001, less than 50 percent of the patents granted by the U.S. Patent and Trademark Office are for technologies in high-technology industries.[3]

From an economic development perspective, the primary reward to a region in which successful technology development takes place may be, but is not necessarily, new employment directly resulting from the commercialization of that technology. In this age of geographically dispersed corporate functions and outsourcing of manufacturing, distribution, administrative, and service activities, the direct employment benefits of a

[3] Based on analysis of U.S. Patent and Trademark Office patent data by class, using concordance with advanced technology industries, as defined in Milken Institute, "America's High-Tech Economy: Growth, Development, and Risks for Metropolitan Areas," July 1999.

successfully commercialized technology may be spread across many locales.[4] For products with high value and low shipping weight, the direct, immediate employment impacts in the locale in which the technology was developed may be relatively small. Once in a great while, technology development and commercialization by one company, such as Microsoft Corporation or Dell Computer Corporation, can provide enormous direct job benefits to a region, but this is the rare exception rather than the rule.

Whatever the direct employment benefits, an important regional reward for successful technology development and commercialization is the enhanced capacity to attract additional well-paid jobs related to innovation. If an area is seen as having the human talent needed to enable successful technology development and commercialization, other firms, entrepreneurs, and researchers are attracted to the area, leading to "virtuous cycle" of additional successful technologies, waves of new technical staff, and a stream of new businesses. From an economic development perspective, the people and organizations devoted to innovation is itself a key high-value-added cluster. If new manufacture, supply, and distribution operations are established locally, these are a bonus in terms of employment.

Successful development and commercialization of innovative technologies is a difficult, multifaceted endeavor, and a variety of development tools exist to promote this activity. One approach is ***indirect***, aiming to create the proper environment within which innovation and commercialization can take place. For example, technical expertise is encouraged through investing in university science and engineering degree programs; physical plant is developed through building research parks, business incubators, and advanced telecommunications infrastructure; financing is provided through R&D tax credits; and innovative firm development is encouraged though entrepreneurship programs and industry cluster organizations.

A second, complementary, approach is ***direct*** in nature—seeking to facilitate and support the development and commercialization of specific technologies. For example, through targeted investments, public venture capital funds support successful technology innovation and corporate development. However, by far the most popular approach to directly promoting successful innovation is through ***technology transfer and commercialization programs***. For the most part, the state and regional organizations with primary responsibility for economic development do not manage these technology transfer and commercialization efforts, which usually require a level of technical expertise not found in traditional development agencies. While the aim is to promote economic development, technology transfer and commercialization programs tend to operate in a "parallel universe" apart from, and often uncoordinated with, general purpose economic development organizations.

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[4] Paul Sommers and Daniel Carlson, "What the IT Revolution Means for Regional Economic Development," The Brookings Institution, February 2003.

1.4.1 Technology Transfer Programs

Technology transfer occurs when a firm obtains technology from an ***external source*** (e.g., a university, a federal laboratory, another corporation, or an individual). All innovation builds on existing knowledge. So technology development very much depends on scientists and engineers knowing about and having access to other researchers' good ideas and discoveries. The greater the extent to which technical staff have knowledge of and access to other researchers' work, the more likely they will develop new technologies that can be the basis for successful products. Technology transfer is essential to technology development.

Technical information can come in many forms. Examples include journal articles, technical assistance from experts, the licensing of patented technology, the results of cooperative R&D, access to another organization's unique technical facilities, conference presentations, and conversations during the social hour after those presentations.

To a large extent, access to technical information can be gained through the natural workings of the marketplace. Consulting firms offer technical advice for a fee. Publishing companies distribute thousands of technical journals and magazines. Companies carry out joint R&D with universities and other firms. Nonprofit associations facilitate the exchange of technical information within a profession or an industry. Patent owners hire agents to facilitate agreements with licensees.

Even so, the marketplace for technical information, left to its own devices, is not as "efficient" as it might be. Technical staff may not know who, if anyone, is able to provide needed information. They may not know how to search for that information, or may lack the resources to conduct a search. They may know who has the information, but may be denied access because of intellectual property issues or lack of funds. Sometimes the information needed is not "know-what" (such as facts and formulas) but "know-how," expertise developed through hands-on experience or learning-by-doing. Know-how often is best transmitted through interpersonal contact, which may be difficult to arrange for reasons of distance, expense, or schedule. Technical staff in small and medium-size enterprises (SMEs) are often at a particular disadvantage in gaining access to technical information as they typically do not have the same information-gathering resources as larger firms.

The ability of technical staff to find valuable technical information depends in no small part on the interest of the suppliers of technical information in promoting access. Historically, government and nonprofit research institutions (e.g., federal laboratories and universities) have not been highly active in transferring research findings to individual companies for use in the technology development process. In recent years, however, their behavior has changed significantly. For example, in response to the pressures of international competition, Congress has passed a series of laws to motivate federal laboratories and their staff to transfer technology. The substantial stream of royalties earned by major research organizations, such as Stanford University and the

Massachusetts Institute of Technology, has spurred many research universities across the country to expand technology transfer efforts as a means of raising revenues.

The potential economic development impacts of technology transfer are so compelling, in fact, that states and regions across the country with valuable repositories of technical information (e.g., universities, federal laboratories, and technology businesses), have created public and nonprofit technology transfer initiatives. These initiatives, numbering in the hundreds, aim to increase the supply of and access to unique local technical information in order to bolster the development of new technologies. Such programs are found in every state and in all types of economic areas, from the well-to-do to the less-well-off, from those rich in technology assets to those less so.

These place-based technology transfer initiatives are diverse in nature. They differ greatly in the types of technical information offered ("know-what," "know-how") and the means of providing it (e.g., licensing, technical assistance, cooperative R&D, or conferences). They are diverse in sponsorship as well. Some are located at research institutions (e.g., universities or federal laboratories) seeking to transfer internally developed technologies. Others are operated by technology transfer intermediaries seeking to match technical information providers with users. Intermediaries include entrepreneurship/business development centers, regional technology-based economic development organizations, and technology business advocacy organizations (such as technology business councils). While some technology transfer programs promote technology transfer in multiple industries, others are industry-specific (e.g., the Pittsburgh Biomedical Development Corporation). Many programs were created in response to economic pain, while others were established proactively, in an effort to seize future opportunities.

Though place-based technology transfer programs are quite diverse, almost all are motivated by a mission of economic development. At the same time, the large majority of these initiatives are performed outside of the agencies primarily responsible for economic development. Development agencies tend to be generalists, responsible for developing and implementing broad strategies, and marketers and facilitators, helping businesses find the resources they need (e.g., land, labor, or capital) to be successful and contribute to the local economy. Few have staff with the technical training needed to manage technology transfer.

The geography covered by place-based technology transfer programs is often different from that covered by development agencies. While many economic development agencies cover only part of a region (e.g., a county), technology transfer initiatives are rarely smaller than a multicounty region in geographic scope. Many are statewide in focus; a few are multistate.

1.4.2 Technology Commercialization Programs

Commercialization is the process of ***transforming new technologies into commercially successful products***; it is "to cause something having only a potential income-producing value to be sold, manufactured, displayed, or utilized so as to yield income or raise capital."[5] Commercialization encompasses a diverse array of important technical, business, and financial processes that together aim to transform a new technology into a profitable product or service. These processes include such efforts as market assessment, product design, manufacturing engineering, management of intellectual property rights, marketing strategy development, raising capital, and worker training.

Typically, commercialization is a costly, lengthy process with a highly uncertain outcome. The costs of commercialization can run from between 10 and 100 times the costs of development and demonstration of a new technology.[6] Moreover, success is rare—less than five percent of new technologies are successfully commercialized.[7] Even when successful, technology commercialization does not happen quickly. On average, the commercialization of university research takes over six years.[8] Commercialization of radically new technologies can take well over a decade.

In addition, as noted, the direct employment benefits of successful commercialization are often geographically dispersed, particularly for products that are high in value added and low in shipping weight. It is not unusual for a technology firm to contract out the manufacturing of its new product to plants in a different part of the country or the world. Whatever the direct local benefits, successful commercialization also can lead to a region's specializing in the commercialization process in a particular industry, encouraging the development of additional high-value-added firms, entrepreneurs, and jobs.

The marketplace provides access to the diverse array of inputs (e.g., capital, design engineering, real estate, machinery, and worker training) that firms need to commercialize new technologies. However, these services do not come inexpensively, and many innovating firms, SMEs in particular, do not have the requisite financial resources.

From a regional economic perspective, unsuccessful commercialization due to lack of resources is seen as a loss of possible jobs and incomes. As a result, numerous public and nonprofit initiatives have been created at the state and regional level to facilitate the technology commercialization process, particularly for SMEs.

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[5] *Webster's Third New International Dictionary*, Encyclopedia Britannica, 1986, p. 457.

[6] Gene Allen and Rick Jarman, *Collaborative R&D: Manufacturing's New Tool*, John Wiley & Sons, 1999, p. 16.

[7] Robert E. Spekman and Lynn A. Isabella with Thomas C. MacAvoy, *Alliance Competence: Maximizing the Value of Your Partnerships*, John Wiley & Sons, 2000, p. 243.

[8] Edwin Mansfield, "Academic research and industrial innovation: an update of empirical findings," *Research Policy*, Vol. 26, pp. 773–776, 1998.

Given the multiple resources required for successful commercialization of technology, it is not surprising to find a large number and variety of state and regional commercialization programs. For example, assistance in product design and manufacturing engineering is available through university engineering schools, manufacturing extension programs, and local trade associations. Venture capital funds, revolving loan funds, small business incubators, and research parks have been established. Management assistance regarding the commercialization process is provided through entrepreneurship/technology business centers at universities and state and regional nonprofit organizations (e.g., the Connecticut Entrepreneurial Resources for Technology). Several states (e.g., Kansas and Oklahoma) have established statewide networks of nonprofit commercialization centers providing access to multiple services.

Many state and regional programs provide assistance in both technology transfer and commercialization. Some states (e.g., Pennsylvania) have nonprofit, public, or university-based programs with a charge to promote technology transfer and commercialization statewide. Some university technology transfer offices go well beyond the traditional mission of selling licenses and aim to promote regional technology transfer and commercialization for economic development purposes (e.g., the Cornell Office of Technology Assessment and Business Assistance). And there are industry-specific technology transfer and commercialization programs in a number of states and metropolitan areas (e.g., biotechnology in Maryland and Ohio).

As with technology transfer, the large majority of place-based technology commercialization program services are not delivered through economic development agencies. Though some agencies do operate loan funds or industrial parks, most leave to other organizations—such as technology agencies, universities, workforce development agencies, venture capital firms, and real estate management companies—the functions that provide highly specialized, highly technical services to individual businesses. And as with technology transfer programs, the geography covered by technology commercialization programs often is broader that covered by development agencies.

1.5 Purpose and Structure of Research Report

Clearly, the promotion of technology transfer and commercialization are very attractive components for regional value-added economic development strategies. However, for several reasons, many economic development organizations are unable to effectively facilitate technology transfer and commercialization as they pursue their traditional economic development mission.

First, a comprehensive, accessible framework of technology transfer and commercialization activities has not been available, even to those in the field. As a consequence, economic development practitioners have not been educated about the breadth and variety of technology transfer and commercialization efforts.

Second, the U.S. geography of technology development and commercialization is poorly understood. As a result, it is not unusual for regional development practitioners to overestimate the possibility that their respective communities can become "the next Silicon Valley". While much literature exploring the geographical location of R&D and patenting has been published in the last three years, it has not been well integrated or publicized. Moreover, gaps in the research exist, particularly regarding the dynamics of innovation in metropolitan areas, in which nearly all patenting and public R&D take place. The new geography of the commercialization process, reflecting increased spatial fragmentation and outsourcing, is not well understood. Better knowledge regarding these dynamics would allow practitioners to more effectively focus their activities.

Third, a comprehensive typology and inventory of local, state, and multistate technology transfer and commercialization programs has not been available. As a result, economic development practitioners do not have a full sense of program models and options.

As noted earlier, the large majority of technology transfer and commercialization programs are managed outside of traditional economic development agencies. Experience suggests that in many local areas, coordination and cooperation between these programs and agencies are not optimal. As the final issue then, many development practitioners do not have a complete understanding of the ways in which they might fruitfully interact with technology transfer and commercialization programs.

The purpose of this research report is to promote the more effective integration of technology transfer and commercialization components into regional economic development strategies by addressing each of these concerns in depth. The structure of the report is as follows:

- In some detail, Chapter Two explores a framework of four categories of technology transfer activities and three categories of commercialization activities.
- Chapter Three looks at the geography of innovation (scientific research and technology development) in the United States. First, recent trends in the geographic locus of patenting and public R&D, and impacts of these activities on regional development, are examined. Second, findings of recent literature are use to explain these trends. The challenges and possibilities of successful technology development and commercialization, particularly in regions outside the top-tier high-technology ones, are explored.
- Chapter Four reviews the models and options for state and local technology transfer and commercialization programs, with numerous examples.
- On the basis of 21 case studies, Chapter Five discusses the possibilities for fruitful interaction between economic development agencies and technology transfer and commercialization programs.

- Synthesizing the findings of previous chapters, Chapter Six offers reflections on the possibilities of promotion of technology transfer and commercialization by economic development agencies.
- Appendices include a summary of federal technology transfer and commercialization legislation, metropolitan area data related to innovation, and the 21 case studies.

To illustrate types of technology transfer and commercialization activities and programs, Chapters Two and Four provide numerous specific examples. Readers should be aware that these examples have not been evaluated in terms of their effectiveness and are not offered as instances of “best practice.” They have been chosen solely because their intent and structure are illustrative of a particular category of activity or program.

Chapter Two: An Overview of Technology Transfer and Commercialization Activities

This chapter begins by discussing the context in which technology transfer and commercialization take place. Section 2.1 reviews the general process of the transformation of science into technology and technology into products, the place of technology transfer in that process, and the notion of intellectual property.

The chapter then guides the reader through a framework of technology transfer and commercialization activities in which technology businesses are involved. Section 2.2 reviews four categories of technology transfer activity—cooperative research and development (R&D); licensing or sale of technology, patents, or technical know-how; technical assistance; and nonproprietary information exchanges. Section 2.3 explores three categories of commercialization activity—technical, business analysis and management, and key factors of production. Throughout the chapter, sidebar examples are provided to illustrate types of activity. Appendix A offers an overview of federal legislation regarding technology transfer and commercialization.

2.1 Science, Technology, and Products

The process of technology development and commercialization takes place over three broad phases—the development of new science, the conversion of science to technology, and the conversion of technology to products.

Science is knowledge regarding certain principles of nature. For instance, the underlying scientific principle of lasers is that the emission of light can be stimulated by incoming photons with certain characteristics (light amplification by stimulated emission of radiation).

Technology is the application of engineering to science, the use of our understanding of nature to develop a technical method for achieving a practical purpose. Continuing with our example, three types of laser technology exist (gas, solid state, and semiconductor), each with a variety of practical applications. For instance, laser technology can be used to heal the human body, process industrial materials, measure distance, and record, read, and transmit digitally encoded information.

A ***product*** is the application of technology in a particular physical form, designed to carry out a specific set of functions. Specific laser products have been developed for the various applications mentioned above, such as laser surgical instruments, laser welders, laser distance measuring instruments, CD and DVD players, and laser-based telecommunications switches.

The development of science and its transformation to technology and products is an ongoing, never-stagnant process that unfolds over years. New science, technology, and products can range from the radically new (e.g., the scientific principles underlying the transmission of sound via radiowaves, the technology for wireless transmission and reception, the first radio) to major improvements (e.g., the portable transistor radio) to minor improvements (e.g., a waterproof portable radio). The discovery of radically new science is a foundation event from which radically new technologies and products can come. It is not unusual for a string of new technologies based on new science to be invented, not at one point in time, but over a period of decades. On some occasions, a technology is discovered first, either through trial and error (e.g., light bulb, airfoil) or accident (e.g., penicillin), then the underlying scientific principles are determined.

Once a new technology is created, it may take years for products based on that technology to be offered commercially, and some years after that for commercial success to be achieved. For instance, radio technology was first demonstrated in 1895, but did not come in to general commercial use until 1925; computer games were first created in the 1960s (for mainframes), but did not become commercially popular until the 1980s (with the advent of the personal computer). Often, commercial success for one product requires additional technologies and products to be developed. For example, commercial success of computer games required the development of the personal computer.

After the development of radically new science, technology, and products, incremental improvements continually take place. Sometimes, incremental improvements in science can lead to radically new technologies. For instance, improvements in the science of superconductivity (i.e., ability to transmit electricity without loss) allowed the development of a series of new technologies (e.g., superconducting magnets). Also, incremental improvements in technology can lead to radically new products. For example, improvements in laser technology allowed the invention of the CD player.

For any particular technology-based product, one can trace the arc of science, technology, and product over time and from one set of scientists or engineers to the next. (See box, for the example of laser eye surgery.) It is very rare for any one individual to be involved from the discovery of the basic science through product development. Individual scientists and engineers can enter and exit at any point in the process. In each trajectory of science, technology, and product, the process that unfolds is idiosyncratic, entirely dependent on context, individual and organizational capacities, and unique circumstances.

In order to promote the investment of money, time, and talent in the process of technology development and commercialization, unique technical knowledge developed through that process is eligible for designation as ***intellectual property***, with legal protections that prevent the ability of others to appropriate that technology without permission. In the realm of technology development and commercialization, the three major types of intellectual property (IP) are patents, trade secrets, and copyrights. (See box for definitions.)

Lasers for Eye Surgery – From Science to Technology to Product	
1958	Development of scientific principles of lasers at Bell Laboratories
1960	Demonstration of first laser technology, using a ruby crystal, at Hughes Aircraft
1961	Invention of gas laser technology, using a helium neon mixture, at Bell Laboratories
1970	Development of scientific principles for excimer lasers, a new class of gas lasers that produces light of a shorter wavelength (ultraviolet), at the Lebedev Physical Institute in Moscow
1975	Demonstration of excimer laser technology by two federal and two private research laboratories in U.S. (Naval Research Laboratory, Sandia National Laboratories, Avco Everett Research Laboratory, Northrop Research and Technology Center)
1977	Development of first commercial excimer laser by Lambda Physik
1983	Potential for use of excimer laser for eye surgery identified by Columbia University ophthalmologist Steven Trokel
1986	VISX founded by Trokel and laser industry professionals to develop excimer laser for vision correction; carried out cooperative R&D with Louisiana State University
1988	First clinical trials for photorefractive keratectomy (PRK) eye surgery
1991	First clinical trials for laser in-situ keratomileusis (LASIK) eye surgery
1992	VISX granted patent for excimer laser technology. VISX manufactures laser systems for purchase. Eventually, seven licenses offered to other manufacturers
1996	Twenty thousandth laser eye surgery performed in U.S.
1999	One millionth laser eye surgery performed in U.S.
2000	Two millionth laser eye surgery performed in U.S. Annual U.S. industry revenues, $2.2 billion
2001	VISX licenses a surgical waterjet technology from MedJet
2002	Over the ten years after the original patent, VISX is granted 45 additional patents regarding laser eye surgery technology
Note: VISX has a 70 percent share of the laser eye surgical instrument market. Summit Technologies is the other major developer of laser eye surgery technology.	

For the most part, IP is generated in the process of converting science to technology. Patents and trade secrets protect new embodiments of physical principles.[9] There is no standard point in the technology development process at which new knowledge becomes eligible for IP protection. For any one technology, the moment could be early in the process, late, or at various points along the way. In any case, to maintain competitive advantage, a firm needs adequate IP protection before it begins the process of converting technology to products. In the laser example, VISX, Inc. patented the new technology prior to developing and marketing its product line.

Knowledge is very rarely created in a vacuum, depending solely on internal expertise. In nearly every case, to a greater or lesser extent, scientists and engineers rely on ***technology transfer***. They draw on knowledge developed by others that they obtain through some combination of text (e.g., prior patents, journal articles, or working papers), legal permission (e.g., a patent license), and personal interaction (e.g., cooperative R&D or technical assistance).

[9] Copyright, taken out on software products, is relevant to commercialization, not technology development.

Major Forms of Intellectual Property Protection

Patent: a contract between society and the inventor of a technology that is new or novel, useful, and not obvious. Under the terms of this social contract, the inventor is given the exclusive right to prevent others from making, using, and selling a patented invention for a fixed period of time (typically 17 years in the United States.) in return for the inventor's disclosing the details of the invention to the public. Thus, patent systems encourage the disclosure of information to the public by rewarding an inventor for his or her endeavors. In the U.S., patents are granted by the U.S. Patent and Trademark Office.

Trade secret: information that is secret or not generally known in the relevant industry and that gives its owner an advantage over competitors. Trade secret protection exists as long as the information has value, is kept secret or confidential by its owner, and is not lawfully and independently obtained by others. Examples of trade secrets include product formulas (e.g., Coca-Cola), patterns, methods, techniques, manufacturing processes, and compilations of information that provide a business with a competitive advantage. Trade secrets are protected under state law. Unlike patents, trade secret protection has no time limit and is in place as long as the information is kept secret.

Copyright: an exclusive right to reproduce an original work of authorship fixed in any tangible medium of expression, to prepare derivative works based upon the original work, and to perform or display the work in the case of musical, dramatic, choreographic, and sculptural works. In the realm of advanced technology, the intellectual property underlying computer software is commonly protected by copyright. Copyright protection lasts 100 years.

Source: Adapted from L. Hefter and R. Litowitz, "What is Intellectual Property?", available at infoUSA, U.S. Department of State, http://usinfo.state.gov/products/pubs/intelprp/.

In the laser eye surgery example, we see a number of instances of technology transfer:

- Each iteration of laser technology (from ruby to gas to excimer to eye surgery excimer) is built, in part, on the technical methods developed beforehand.
- The VISX patent application cites 16 prior patents granted to others and four journal articles as building blocks for its technology.
- VISX developed its technology in collaboration with Louisiana State University.
- Once the firm patented its technology, it licensed that technology to a number of firms, who then developed their own products.
- VISX licensed another company's technology for incorporation into its own products.

One way or another, technology transfer plays a role in virtually every instance of technology development. For the purposes of economic development, the question becomes: how might technology transfer facilitate effective technology development?

This chapter explores the answers to this question, beginning with systematically examining the four major types of technology transfer in the next section.

Technology commercialization involves all the steps required to convert a technology into an economically successful product. This process includes, but is not limited to, the conversion of technology to a technically feasible product. As will be discussed in Section 2.3, economic success also requires market analysis, business management, and access to factors of production, such as physical facilities, a trained workforce, and financial capital.

2.2 Technology Transfer

2.2.1 Cooperative Research and Development

Cooperative R&D involves a collaborative effort between a business and one or more research organizations to develop new technology (and, in certain instances, new science as well). Cooperative R&D takes place in four basic arrangements—multi-firm strategic research alliances, university-industry collaborations, nonprofit research institute-industry collaborations, and federal agency or laboratory-industry collaborations.

Multifirm strategic research alliances have become quite popular in recent years. The reasons that firms work with corporate research partners include the greater complexity and cost of technology development; increased competitive pressure for new products; more willingness to use technical expertise outside the firm; and improvements in communications technology that facilitate collaboration. The growth in strategic research alliances is part of a larger trend toward interfirm alliances of many types, include production, marketing, sales, and distribution.[10]

Strategic research alliances can take a number of forms, including (in descending order of scope and permanence) equity joint ventures, research consortia, non-equity research alliances, and contract R&D:

- ***Equity joint ventures*** — research corporations in which multiple corporate partners hold equity. A joint venture may involve research and manufacturing. For example, in 2000, Lucent Technologies and DiCon Fiberoptics formed LD Fiberoptics LLC as an equity joint venture to develop and produce integrated passive optical components.

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[10] Robert E. Spekman and Lynn A. Isabella with Thomas C. MacAvoy, *Alliance Competence: Maximizing the Value of Your Partnerships*, John Wiley & Sons, 2000. According to Accenture (www.accenture.com), alliances accounted for 26 percent of Fortune 500 company revenues in 1999.

Technology Transfer and Commercialization Activities

Technology Transfer

1) Cooperative research and development – business collaborates with one or more outside technology organizations
   a) Multi-firm strategic research alliances
   b) University-industry collaborations
   c) Nonprofit research institute-industry collaborations
   d) Federal agency or laboratory-industry collaborations

2) Licensing or sale of intellectual property
   a) Traditional licensing or sale – owner of technology transfers certain intellectual property rights to outside business in exchange for certain benefits, usually financial
   b) Startup spinoff – technology organization licenses intellectual property to the in-house developer of that technology, and so enables the developer to found a new business

3) Technical assistance – business utilizes outside organization to answer or solve a relatively narrow, well-defined question or problem
   a) Expert assistance – business utilizes outside experts
   b) User facilities – business utilizes equipment from outside organization for testing/evaluation

4) Information exchanges – business obtains access to existing technical information through exchanges such as markets, conferences, federal agencies, and professional networks
   a) Forms of information – printed material (e.g., articles, technical reports, or databases) and professional expertise (e.g., informal conversation, or new employees)
   b) Types of information access – freely available, exchange access fee (e.g., conference registration or corporate affiliate program membership), or direct purchase or hire

Technology Commercialization

1) Technical – technical effort required to transform technology into a viable and desirable product, and to produce the product in sufficient quantities and with adequate quality
   a) Product development or design
   b) Manufacturing engineering

2) Business management and market analysis
   a) Business planning
   b) Market characterization – determination of size and nature of market for product, potential profits, and return on investment
   c) Marketing strategy
   d) Manufacturing, supply chain, distribution, and service systems development
   e) Management of intellectual property rights

3) Factors of production
   a) Capital – equity capital or debt financing for product commercialization and business development
   b) Physical facilities – may include industrial parks, research parks, and incubators
   c) Skilled workforce

- ***Research consortia*** — industry membership organizations carrying out early-stage (pre-competitive) research. The first industry-led research consortium in the U.S. was the Electric Power Research Institute, founded in 1973. As of 1998, 741 research consortia were registered with the federal government. Well-known examples of consortia include Semiconductor Manufacturing Technologies (SEMATECH), the Microelectronics and Computer Technology Corporation (MCC), the Semiconductor Research Corporation (SRC), the Textile/Clothing Technology Corporation (see box), and the U.S. Advanced Battery Consortium (USABC). The federal government has organized a number of national research consortia. Some consortia operate their own dedicated facilities, while others use member facilities. While Fortune 500 firms dominate some consortia, the majority of industry participants in research consortia appear to be privately-held small and medium-size firms.[11] University and government participation is not unusual.
- ***Non-equity research alliances*** — firms forming joint R&D agreements without setting up new organizations. Non-equity research alliances are highly focused efforts to develop (and, usually, commercialize) new technology. Typically, when the goal as been reached, the alliance is disbanded. Non-equity alliances are the most common form of strategic research alliance. As an example of a non-equity research alliance, Sony has been working with General Instrument to develop digital set-top boxes for cable operators. While most such alliances are initiated by the firms involved, some are encouraged by the federal government through the Advanced Technology Program, which can fund corporate teams for pre-commercialization applied research.[12]
- ***Contract R&D*** — purchase of R&D services by one firm from another. There are hundreds of contract research firms in the U.S., particularly in the biomedical field. While the participants in the other forms of strategic research alliances have some IP rights to the research results, the contractor typically gives up IP rights in contract R&D arrangements.

Studies indicate that participation in multifirm alliances facilitates learning and growth. Alliance management is an extensive and tedious process, so firms must invest considerable time and management attention to make the relationship successful and achieve a useful transfer of knowledge. In general, larger firms have superior managerial resources and capabilities to exploit the learning potential of alliances.[13]

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[11] Nicholas S. Vonortas, "Research Joint Ventures in the U.S.," *Research Policy* 26 (1997), p. 589.
[12] See www.atp.nist.gov.
[13] See, for example, Paul Almeida, Gina Dokko, and Lori Rosenkopf, "Startup Size and the Mechanisms of External Learning: Increasing Opportunity but Declining Usefulness?," working paper, Mack Center for Technological Innovation, Wharton School, University of Pennsylvania, February 27, 2001.

Example of a Research Consortium: Textile/Clothing Technology Corporation

In response to the rapid loss of apparel market share to foreign competitors, U.S. clothing manufacturers formed the Tailored Clothing Technology Corporation (TC2) in 1981, with support from the U.S. Department of Commerce. The purpose of the organization was to undertake joint R&D that would benefit all members. In 1985, TC2's mission was expanded to include technology demonstration and education, and the name was changed to the Textile/Clothing Technology Corporation.

At present, TC2 has more than 200 members and associate members. Current TC2 R&D efforts include development of mass customization technologies, a full-length, three-dimensional body measurement system; and the digital printing of fabric. In addition, TC2 provides technical assistance and training in quality improvement, operations, and supply chain management. TC2 has a staff of 40 and is located in Cary, North Carolina.

University-industry collaborations have been growing at a rapid pace. Between 1975 and 2002, industry contributions to university R&D activity rose 618 percent in 2002 constant dollars, from $326 million to $2.34 billion. The portion of academic R&D funded by industry steadily increased from 3.3 percent in 1975 to peak of 7.7 percent in 2000, but then declined to 6.2 percent as of 2002.[14]

The majority of industry funding for academic R&D is for "sponsored research." Most sponsored research looks much like contract R&D—a firm or group of firms funds a university research project and has certain, if not exclusive, rights to the results. Sponsored research can be carried out by individual professors (typically with student assistance), teams of professors, or specialized research centers with dedicated facilities and staff. Often, complementary research is carried out in firm laboratories.

Many university research centers are specifically chartered to host university-industry collaborations. In 1990 (the last time a count was made), there were more than 1,000 university-industry research centers (UIRCs) in the United States, most of which were less than a decade old. On average, each center had 17 member companies. Half of industry support for academic R&D went through UIRCs.[15] A number of UIRCs are financially supported by the National Science Foundation (NSF) (see box).[16]

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[14] National Science Foundation, "Slowing R&D Growth Expected in 2002," *Infobrief*, NSF 03-307, December 2002, and *National Patterns of R&D Resources: 2000 Data Update* (NSF 01-309), March 2001. The constant dollar figure for 2002 is slightly below that for 2000, reflecting the economic downturn.

[15] Wesley Cohen, Richard Florida, and Richard Goe, "University-Industry Research Centers in the United States," mimeo, Carnegie-Mellon University, 1994.

[16] NSF currently funds 135 UIRCs, including Industry-University Cooperative Research Centers (57, with 630 industrial members), State/Industry/University Cooperative Research Centers (12, with 280 industrial members), Engineering Research Centers (20, with 708 industrial members), Materials Research Science and Engineering Centers (29), and Science and Technology Centers (17). Programs typically require centers to become self-sufficient after a period of time. Currently, for instance, there are 16 self-sustaining Engineering Research Centers.

Example of a University-Industry Research Center

The University of Colorado's Center for Pharmaceutical Biotechnology is a joint effort of the College of Engineering and Applied Sciences and the School of Pharmacy. The Center's aim is to partner with biotechnology companies in product development. Founded in 1997, the Center has had research relationships with 20 local and global pharmaceutical and biotechnology firms. The Center had its new drug delivery technology licensed, leading to the founding of a new Colorado company called RxKinetix, Inc.

Industry/University Cooperative Research Centers Program at the National Science Foundation

NSF currently funds 57 Industry/University Cooperative Research Centers (I/URCs) at U.S. academic institutions. I/URCs are partnerships between universities and industry aimed at pursuing industrially relevant fundamental research and the direct transfer of university-developed ideas, research results, and technology to U.S. industry. Categories of I/URC focus include materials and materials processing; biotechnology and health care; energy, power, and infrastructure; manufacturing; agricultural and environmental sciences; electronics, computing and communication; and chemical, mechanical, and transport systems.

Each center has an Industrial Advisory Board (IAB), which advises on all aspects of center operations, from research project selection and evaluation to strategic planning. All IAB members have common ownership of the entire I/UCRC research portfolio; however, individual firms can provide additional support for specific "enhancement" projects. On average, each center has 11 industrial members. In 2000, industrial members provided about $2 million per center, on average. Examples of success stories include the following:

- A professor at a communications-oriented I/UCRC started a company to design a specialized switch; the firm has 35 employees.
- A center is exploring advanced materials and processes for the manufacture of more reliable automotive electronics. An automotive controller with silica-filled epoxy has been developed, and is planned for mass production in 2004.
- Fouling is a problem in the use of membranes in liquid separation processes such as water treatment. A center has developed an analytical tool to non-invasively monitor the condition of membrane modules during operation; a commercial product is being developed.

The I/UCRC Program initially offers five-year awards to centers. This five-year period allows for the development of a strong partnership between the academic researchers and their industrial and government members. After five years, centers that continue to meet the I/UCRC Program requirements may apply for a second five-year award. These awards allow centers to continue to grow and diversify their non-NSF membership. After ten years, the centers are expected to be fully supported by industrial, other federal agency, and state and local government partners.

At a typical UIRC, each corporate member pays an annual fee, which, depending on the center, can vary from a few thousand dollars to over $100,000. Membership fees, plus any contributions from the university, the federal government, state government, or foundations, fund "core" or "fundamental" research, the results of which are available to all members. Individual members have the option of providing additional financial contributions to sponsor research to which they typically have particular rights.

The costs of becoming a member of an UIRC do favor larger and more sophisticated corporate R&D laboratories. Corporate laboratories that belong to UIRCs are 2.5 times larger and more science-oriented than are non-members.[17]

Experience suggests that, for the most part, UIRC membership increases technology transfer and improves firm product and process development. A recent study of UIRCs funded under two NSF programs indicate that about three-quarters of members find the benefits of membership equal or exceed the costs.[18]

Cooperative R&D between industry and universities can take place through means other than sponsored research or UIRCs. Often, corporations participate in multi-university research consortia (e.g., the University Corporation for Advanced Internet Development). Conversely, universities participate in some industry-led research consortia.[19] In addition, universities and industries engage in personnel exchanges in which research staff from a university temporarily locate at a corporate research facility, and vice versa, to perform collaborative research. NSF offers financial support to facilitate such exchanges.[20]

A significant amount of cooperative R&D takes place in ***nonprofit research institute-industry collaborations***. The large majority of these research institutes are in the health care field (e.g., the Massachusetts General Hospital, the Mayo Clinic, and the Cleveland Clinic). Others focus on disciplines such as oceanography (Woods Hole Oceanographic Institute), wood products (Institute of Paper Science and Technology), and polymer science and technology (Michigan Molecular Institute). Some are multidisciplinary institutes (e.g., Battelle Memorial Institute in Ohio, Southwest Research Institute in Texas, and SRI International in California). Several multidisciplinary centers are linked to, but independent of, area universities (e.g., the Houston Advanced Research Center and the University City Science Center in Philadelphia). Fraunhofer USA, a subsidiary of a German independent research organization, operates seven discipline-specific institutes (e.g., coatings and laser applications, molecular biotechnology) in six states; some are university-linked.

Industry is an important source of funding of R&D at independent nonprofit research institutes. In 2002, industry provided $1.2 billion in funding to these organizations. Since 1975, industry share of independent research institute R&D funding

[17] James Adams, Eric Chiang, and Katara Starkey, "Industry-University Cooperative Research Centers," National Bureau of Economic Research, Working Paper 7843, August 2000.
[18] David Roessner, "Outcomes and Impacts of the State/Industry-University Cooperative Research Centers Program," SRI International, October 2000, report to the National Science Foundation.
[19] In 1995, 13 percent of 575 industry-led research joint ventures had university members. Vonortas, *op. cit.*
[20] Grant Opportunities for Academic Liaison with Industry (GOALI).

has ranged from a low of 10.3 percent in 1991 to a high of 12.4 percent in 2000, before falling back to 10.3 percent in 2002 (again, reflecting the change in industry fortunes). Industry funding to independent research institutes is not insignificant, about one-half of the amount industry provides to universities.

Cooperative R&D at the Houston Advanced Research Center

The Houston Advanced Research Center (HARC) is a nonprofit research institution located outside of Houston, Texas. Examples of cooperative R&D at HARC include:

- The Center for Fuel Cell Research and Applications is carrying out a fuel cell research project with two utility companies, an energy company, and a supplier of engine components and automotive products.
- The DNA Technology Laboratory is working with a biotechnology firm to develop a DNA chip to detect the presence of alterations in genes.
- The Industry Affiliates Program houses small- and medium-size enterprises in an on-site incubator and provides access to HARC researchers for contract R&D.

The fourth form of cooperative R&D is ***federal government-industry collaborations***. To carry out a wide range of research in the national interest, the federal government funds over 500 federal laboratories under the auspices if 17 federal departments and independent agencies.[21] In 2002, federal laboratories spent $32.0 billion on R&D (40 percent of the federal R&D budget and 11 percent of nationwide R&D expenditures).[22] Eighty-nine percent of funding goes to federal laboratories run by four federal departments with important national missions: Department of Defense, Department of Health and Human Services, National Aeronautics and Space Administration (NASA), and Department of Energy (DOE).[23] Federal laboratories employ approximately 100,000 workers.

While the federal laboratory system dates back to the late 19th century, most of the system's growth occurred after World War II. Through the 1970s, technology transfer was not a primary focus of federal laboratory activity (with the exception of NASA). In response to greater global competition and the perception of untapped commercial opportunities for federally developed technology, beginning in 1980 Congress has passed a series of laws actively encouraging the transfer of technology from federal laboratories

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[21] While the large majority of federal laboratories are government-operated, 36 are operated by academic and private contractors such as the University of California and Lockheed Martin Corporation. The contractor-operated facilities are known as Federally Funded Research and Development Centers (FFRDCs). For a complete list of laboratories, see the Federal Laboratory Consortium Web site at www.federallabs.org. For a list of FFRDCs only, see the NSF Web site at http://www.nsf.gov/sbe/srs/nsf01304/ location.htm.

[22] National Science Foundation, "Slowing R&D Growth Expected in 2002," *Infobrief*, NSF 03-307, December 2002.

[23] National Science Foundation, "Changing Composition of Federal Funding for Research and Development and R&D Plant Since 1990," *Infobrief*, NSF 02-315, April 2002.

to private industry. (Appendix A provides an overview of federal technology transfer legislation.)

In particular, legislation passed in the 1980s makes it possible for federal laboratories to enter into cooperative research and development agreements (CRADAs) with the private sector and universities. Federal laboratories can contribute personnel, property, and services, but not funds, to a cooperative research project; private parties can contribute personnel, property, services, and funding. Laboratories that enter into CRADAs do not have to comply with normal Federal acquisition regulations. To safeguard proprietary information of the industry partner, CRADAs are exempt from Freedom of Information Act requirements.

Under a CRADA, title to, or licenses for, inventions made by a laboratory employee may be granted in advance to the participating firm by the director of the laboratory. In addition, the laboratory director can waive any right of ownership the federal government might have to inventions resulting from the collaborative effort. The federal government retains the ability to use the resulting technology, royalty-free, for its own purposes.

Since CRADAs were first authorized, the number of active CRADAs has grown exponentially, from 34 in Fiscal Year (FY) 1987 to 731 in FY 1991 to a record 3,603 in FY 2001. In each of FYs 1997 through 1999, over 1,000 new CRADAs were initiated; 926 were created in FY 2001.[24]

Outside of CRADAs, federal laboratories also are available to commercial firms for contract research. For instance, DOE's Work for Others program offers access to the technical staff of DOE laboratories on a contract basis. Such work must pertain to the mission of the laboratory, not conflict with DOE program requirements, and not directly compete with the domestic private sector. Customers pay on a full-cost recovery basis and, typically, retain rights regarding IP developed.

Federal laboratories also sponsor personnel exchange programs with industry. Employees of a private company work at a federal laboratory for a limited period on specific technical inquiries or focused cooperative projects; the employer pays its employee's salary, and the federal laboratory provides services and supplies.

A survey of 220 corporate laboratories finds that 28 percent have had a CRADA, 33 percent have hosted federal researchers in a personnel exchange, and 16 percent have assigned corporate researchers to temporarily work in a federal laboratory. The study also finds that the patent productivity (patents per $1 million R&D) of corporate laboratories involved in CRADAs is 122 percent greater than that of other laboratories.[25]

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[24] Office of the Secretary, U.S. Department of Commerce, *Summary Report on Federal Laboratory Technology Transfer: Agency Approaches; FY 2001 Activity Metrics and Outcomes (2002 Report to the President and the Congress under the Technology Transfer and Commercialization Act)*, September 2002.
[25] James D. Adams, Eric P. Chiang, and Jeffery L. Jensen, "The Influence of Federal Laboratory R&D on Industrial Research," National Bureau of Economic Research, Working Paper 7612, March 2000.

Examples of Federal Laboratories and CRADAs

Gulf Ecology Division, National Health and Environmental Effects Research Laboratory (Pensacola, Florida), Environmental Protection Agency

Focus: physical, chemical, and biological dynamics of coastal wetlands and estuaries, including assessment and remediation.

Under a CRADA with SBP Technologies (Pensacola, Florida), researched the use of hydro-filtration technology for removing toxic chemicals from ground water.

Air Force Research Laboratory Materials and Manufacturing Directorate (Dayton, Ohio), Air Force Research Laboratory, Department of the Air Force

Focus: materials, manufacturing technology, avionics, flight dynamics, solid-state electronics, aero propulsion and power, armament.

Under a CRADA with Gauge & Measurement Technologies, Ltd. (GMT) of Dayton, Ohio, developed Tunnel Gauge, a laser-based device for measuring interior dimensions of tubular or hollow structures. GMT has received numerous inquiries about the Tunnel Gauges from manufacturers of extruded hose and tubing, naval cannon barrels, aircraft engine bellows, automobile brake calipers, cold-rolled metal tubing and others. GMT estimates a $20 million market for Tunnel Gauge over five years.

Lawrence Berkeley National Laboratory (Berkeley, California), Department of Energy.

Government-owned, contractor-operated by the University of California. Focus: energy efficiency and renewable energy, environmental management, civilian radioactive waste management, and other energy programs.

Under a CRADA with Sunsoft Corporation of Albuquerque, New Mexico, developed two biocompatible materials for contact lenses. Sunsoft is using these materials to develop continuous-wear contact lenses.

2.2.2 Licensing or Sale of Intellectual Property

The second form of technology transfer is the ***licensing or sale*** of IP, including patents and trade secrets. A licensing agreement is a legal contract between two organizations that grants one either an exclusive or nonexclusive right to use the other's IP. The technology transfer occurs as the licensor provides the knowledge and legal permission necessary for the licensee to fully utilize the technology, in exchange for payment (which may be some combination initial fee and royalty). The licensee also may have permission to sublicense the technology to other organizations, under certain conditions. In a sale, the seller transfers all IP rights to the buyer. Firms, universities, and the federal government are active licensors; when IP is sold, the seller is usually a private firm.[26] A patent license can last only as long as the patent is valid. In contrast, trade secrets can be licensed in perpetuity.

Firms seeking technologies often turn to licensing or purchase once developing technology internally has been ruled out. In particular, small and medium-size enterprises choose to license or purchase technology to make up for the lack of internal R&D capacity, to gain rapid entry into the market, or to develop expertise in needed areas.

Also, some number of licensees are startup firms that are spinoffs of the research organization.[27] Corporate spinoffs often are created as part of corporate strategy. In the typical spinoff process from a university, nonprofit research institute, or government organization, a researcher (or research team) recognizes the commercial potential of the discovery, forms a firm (often with business-savvy partners) to exploit that potential, and licenses the relevant technology from the research organization, which holds the patent.

Over the last decade, U.S. licensing revenues have increased at a far greater pace than patenting itself. Between 1990 and 1999, the annual number of patents granted rose 74 percent. At the same time, it is estimated, licensing revenues rose from $15 billion to over $110 billion, over 600 percent.[28]

In 2001, ***for-profit corporations*** received 77 percent of all patents assigned to U.S. inventors, independent inventors received 17 percent, universities four percent, the federal government one percent, and nonprofit R&D institutes less than one percent.[29,30] It is no surprise, then, that for-profit firms are by far the most active players in patent licensing and sales.

It is highly unusual for any organization other than a for-profit corporation to license trade secrets. Because the sharing of trade secret information outside the company

[26] As noted in the previous section, licenses also can be distributed to participants in cooperative R&D. For example, the industry partner in a CRADA gets a license to technology developed by federal researchers.
[27] For the purposes of this report, a startup "spinoff" is a new company formed to commercialize licensed or purchased patented technology, with the significant involvement of researchers or former managers from the organization that originally developed the technology.
[28] Kevin Rivette and David Kline, "Protect and Serve," *Industry Standard*, December 13, 1999.
[29] U.S. Patent and Trademark Office.
[30] The differences between corporation, university, and federal patent numbers reflect differences in the level of R&D budgets and in the propensity to patent relative to those budgets. In 1999, corporations received one patent for every $2.7 million in industrial R&D (total expenditures, $180 billion); universities had one patent for every $8.5–$9.5 million in academic R&D ($28–$32 billion); and the federal government had one patent for expenditures in the range of $22–$24 million in federally-performed R&D ($22–$24 billion). Corporations are more prolific in patenting because of profit incentives and because over two-thirds of academic research is basic research, which is much less amenable to patenting than applied research and development. Only eight percent of corporate research is basic. (Source of R&D expenditures: National Science Foundation.) To give perspective to the difference between corporate and academic patenting: in 2001, the top patenting organization was IBM, with 3,411 patents; MIT was the top patenting university, with 125, ranking 131st on the organizational list (including foreign inventors). In recent years, the annual number of patents granted to IBM has almost equaled the number granted to all U.S. universities combined.

endangers the confidentiality of the trade secret, trade secret licensing is far less common than patent licensing and the legal sale of trade secrets is almost nonexistent.

"Dormant" technologies, particularly from large companies, are a major source of licensed or purchased technology. Many companies develop technologies they never use or commercialize. Some firms recognize the inherent value of these innovative technologies and choose to license or sell them to benefit financially without having to commercialize them in-house. For example, IBM licensed its unused patents in 1990, and saw its royalty revenue jump from $30 million a year to more than $1 billion in 1999.[31]

Examples of Licensing and Sale of Technology

Stanford University has provided Transgenomic, a Nebraska biotechnology firm, with a non-exclusive license to DNA testing technology developed at the university through research supported by NIH.

Los Alamos National Laboratory (LANL) invented a Long-Range Alpha Detection (LRAD) technology for environmental monitoring and for nuclear decontamination and decommissioning. BNFL Instruments licensed the LRAD technology and then entered into a CRADA with LANL to further develop the technology. BNFL Instruments is converting the LRAD technology into reliable instrumentation to supply the decommissioning, land remediation, and waste management markets.

Other examples of technology licensing or sale include the following:

- ***Beth Israel Deaconess Medical Center*** in Boston developed a device to assist surgeons performing beating-heart, open-heart surgery. Licensed to Genzyme Surgical Products, over 300 surgeons have used this device in more than 8,000 operations.
- ***University of Connecticut Health Center*** licensed a dental composite to a dental materials manufacturer; the product has been used in over one million dental procedures.
- ***Red Hat Software*** granted Dell Computer Corporation a nonexclusive, worldwide license to reproduce and install on Dell computers Red Hat software.
- ***DEKA Research and Development*** licensed to Johnson & Johnson its mobility aid for the physically challenged to climb stairs and traverse uneven terrain.
- Two firms can ***cross-license*** their technologies, each giving the other rights. For instance, ***Intel*** and ***AMD***, major makers of computer microprocessors, have had a cross-licensing agreement in place since 1976 that allows each to use any patented technology developed by the other.

Academia and nonprofit research institutes license technology as well, though not, as noted, at the same scale as corporations. Even so, university patenting and

[31] Kevin G. Rivette and David Kline, *Rembrandts in the Attic: Unlocking the Hidden Value of Patents*, Harvard Business School Press, 1999.

licensing activity has grown significantly over the past several decades, fueled by two key factors. The first is the federal Bayh-Dole Act of 1980, which allows universities to retain patent rights on federally-funded R&D (rights previously held by the federal government). Essentially, the law seeks to promote greater technology commercialization and economic growth through permitting universities to create new revenue streams by patenting and licensing technologies developed with federal funds. The second factor driving patent and licensing growth is advances in biotechnology and the profitability of their commercialization, along with major increases in federal biomedical research funding.

Data trends reflect these factors:

- The annual number of patents granted to universities rose from 589 in 1985 to a peak of 3,340 in 1999 (falling to 3,087 in 2000).
- Universities' share of patents assigned to U.S. inventors climbed from 0.7 percent in 1979 to 3.6 percent in 1999 (falling slightly to 3.5 percent in 2000).
- For 73 major universities and research institutions, between FY 1991 and FY 2000,
  - the number of licenses yielding income rose from 1,990 to 5,653;
  - the annual number of new licenses executed went from 1,030 to 2,668; and
  - annual licensing income climbed from $149 million to $1.06 billion.[32]
- The share of university patents going to biomedical discoveries went from 11 percent in 1970 to 50 percent in 1999.[33]

Universities have needed time to learn how to take advantage of the Bayh-Dole Act, and even now they are learning how to be more effective.[34]

Under the Bayh-Dole Act, universities and nonprofit organizations are to license technologies to small businesses when feasible. Consequently, it is no surprise that about two-thirds of licenses from academia and research institutions have been granted to small (under 500 employees) and startup firms.

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[32] Most of the income (57%) was earned on product sales, with the remainder derived from cashed-in equity, milestone payments, and other fees. Unless otherwise noted, data and information in the next five paragraphs come from the Association of University Technology Managers, Inc., "AUTM Licensing Survey: FY 2000, Survey Summary," 2002.

[33] David C. Mowery, "The Changing Role of Universities in the 21st Century U.S. R&D System," remarks delivered at the 26th Annual AAAS Colloquium on Science and Technology Policy, May 2001 (published in *AAAS Science and Technology Yearbook 2002*).

[34] The annual ratio of licenses to patents in the AUTM survey has been falling, from 1.4 in 1993 to 1.2 in 2000. This suggests that the growth in patenting is driving the growth in university licensing activity, rather than (as is true for the federal government) a growth in the willingness to license patents. For a discussion of the academic licensing process, see the Council on Government Relations Web site, at http://www.cogr.edu/.

In fact, since 1980 at least 3,376 new companies formed using a technology license from an academic institution or research institute. As of FY 2000, 2,309 firms were still in existence. In recent years, universities are taking equity positions in about 60 percent of the startups formed. Many of these startup firms are spinoffs.

The overall economic impacts of academic licensing are substantial. In FY 1999, U.S. universities and nonprofit research institutes held 17,000 active licenses and options. Licensees reported product sales from 25% of these agreements; it is estimated that these sales resulted in $39.7 billion of economic activity in the United States, supporting 263,800 jobs and generating about $5 billion in tax revenues at all levels.[35]

However, the revenues from academic and nonprofit licensing are relatively small. They amount to just one percent of corporate annual licensing revenues.[36] And gross academic licensing revenues (before administrative and legal costs) are only four percent of academic research budgets—they are not a major source of university income. Moreover, in most research institutions, the large majority of licensing revenue is generated by a small number of very successful licenses (sometimes one). Of 20,968 active licenses in FY 2000, only 125 (0.6 percent) generated over $1 million in royalty income. In 1995, the five top-grossing licenses accounted for 66, 85, and 94 percent of gross licensing revenues at the University of California, Stanford University, and Columbia University, respectively; the great majority of revenues stemmed from biomedical inventions.[37]

So we see that most academic licenses have little or no monetary payoff, particularly those outside of biomedicine, and even lucrative licenses do not have major budgetary impacts, except in a few cases. Thus, for most research institutions, the primary reason to promote patenting and licensing is not financial, but the economic impact of getting technology into the commercial world.

The ***federal government*** has become an increasingly active licensor of technology developed in its laboratories. The number of patent licenses granted by the government has risen from 128 in FY 1987 to a peak of 596 in FY 1999 to 577 in FY 2001. In the latter year, the government had 3,142 active invention licenses.[38] Sixteen percent of large corporate laboratories indicate that licensing from a federal laboratory has been an important interaction.[39] A small proportion of federal technology licenses goes to startup firms.

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[35] Association of University Technology Managers, Inc., "AUTM Licensing Survey: FY 1999, Survey Summary," 2000.

[36] The gross license income received by academic and nonprofit research organizations in FY 1999, $862 million, was less than that earned by IBM alone.

[37] Mowery, *op. cit.*

[38] Office of the Secretary, U.S. Department of Commerce, *op. cit.* Government revenue from patent licenses has risen each year, from $5.9 million in FY 1987 to $71.1 million in FY 2001. The Office of Technology Policy indicates that not all agencies are able to provide license revenue data, so these figures undercount actual revenues to an unknown degree. Even so, it is clear that federal licensing revenue is no more than 10 percent of academic licensing revenue and no more than one-tenth of one percent of corporate licensing revenue.

[39] James D. Adams, Eric P. Chiang, Jeffery L. Jensen, *op. cit.*

Examples of License-Enabled Startup Spinoffs

Corporation as the Licensor

In 1996, ***Xerox Corporation*** formed Xerox Technology Enterprises (XTE) to oversee the development of startup spinoffs from Xerox's Palo Alto Research Center. While XTE companies are created as independent entities, they can tap into established Xerox resources, including corporate engineering, marketing, and professional services support. Ultimately, each company will be merged into the Xerox Corporation, become a publicly traded subsidiary, or be sold. The companies range from software ventures to providers of innovative document hardware.[40]

University as the Licensor

Alfalight was founded in November 1998 to commercialize diode-laser devices created at the Reed Center for Photonics, ***University of Wisconsin-Madison College of Engineering***. The company, founded by two university professors, holds three exclusive licenses from the Wisconsin Alumni Research Foundation (WARF) in exchange for WARF's holding an equity position in Alfalight.

In the last 20 years, more than 35 new companies have formed to commercialize technologies developed at the ***University of Washington*** (UW). The companies include Optiva, which manufactures an ultrasonic toothbrush that removes significantly more plaque and bacteria than conventional brushing; Neopath, with a promising new technology for automated analysis of Pap smears; and Ostex International, which markets a test kit for monitoring degenerative bone disease. Altogether, UW-related startup companies generate some 3,500 jobs and $79 million in annual expenditures.[41]

In 2000, two companies were formed to commercialize technologies developed at the ***University of Kansas***: Nacelle Therapeutics, to develop treatments for genetically based diseases as cystic fibrosis, and AgriEnergetics, based on a new livestock monitoring technology called infrared thermal imaging.

Federal Laboratory as the Licensor

In November 2000, the ***Pacific Northwest National Laboratory*** (PNNL) announced it was spinning off its 19th new company, Wave ID. The new firm, led by a PNNL engineer, brings radio-frequency tag technology, a high-tech inventory tracking system, to commercial markets. In exchange for an exclusive license, Wave ID will pay royalties to PNNL, located in Richland, Washington.

The number of federal patents has been relatively stable, unlike the pattern at universities in which patents and licenses have grown at roughly the same pace. Rather, the government has become more aggressive in seeking licensees for its patents (because

[40] *2001–2002 Fact Book*, Xerox Corporation.
[41] *Grant and Contract Guide*, University of Washington, at http://www.washington.edu/research/or/overview/strength.html.

of the incentives created by the federal technology transfer legislation of the 1980s).[42] Even so, as noted, the academic and nonprofits sectors remain far more active in licensing than is the federal government, relative to the size of R&D expenditures.[43]

Often, universities, research institutes, the federal government, and firms market available technology through ***technology intermediaries.*** Third-party technology brokers are useful for preparing marketing materials, publicizing the technology, identifying and screening potential licensees or purchasers, and negotiating a deal that provides fair compensation and properly protects the owner's IP. Licensees and purchasers often engage brokers to assist in identifying and negotiating licenses or purchases of technologies appropriate to their needs.

With the advent of the Internet, a large number of on-line IP exchanges have been created to register and match technologies being offered with organizations seeking technologies.[44] Unlike brokers, IP exchanges are neutral and do not provide advice and counsel.

For the most part, patent license brokers and IP exchanges are for-profit entities. NASA does contract with a series of universities and other nonprofit organizations to promote the transfer, including licensing, of technologies developed in federal laboratories. Descriptions of the types and activities of technology intermediaries are provided in much more detail in Chapter Four.

2.2.3 Technical Assistance

The third form of technology transfer is ***technical assistance***—obtaining help through an external source to answer or solve a specific, well-defined R&D question or problem.[45] The primary form of technical assistance is ***expertise*** provided by scientists and engineers in technology organizations. Usually, the technical assistance is provided over a relatively short period of time (from a few minutes to several weeks).

Under the congressional mandate to promote the transfer of federal technology, most large federal laboratories have programs (fee-based and free) offering firms access to research problem-solving expertise not easily available from the private sector (see box for examples).[46] Also, laboratory personnel often provide informal technical assistance at no cost. Some federal laboratories (e.g., the Idaho National Engineering and

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[42] The federal government was granted 981 patents in 1987 and 921 in 2000. The peak was 1,258 in 1994. However, the annual ratio of licenses to patents has gone from about 0.1 to 0.5 over the same period. (Exact ratios cannot be calculated due to definitional differences and lack of detailed data.)

[43] See footnote 21.

[44] See, for example, www.yet2.com, www.uventures.com, or www.ipex.net.

[45] Technical assistance can be distinguished from contract R&D in that the former is used to overcome a particular problem or unanswered question impeding a firm's ongoing internal R&D, while the latter is used when a firm wishes to shift a significant portion of its R&D to an external contractor.

[46] Intellectual property rights are held by the firm when it pays for assistance, and by the laboratory when assistance is free. Laboratories are not to provide technical assistance that competes with the private sector.

Environmental Laboratory and Sandia National Laboratories) make a particular effort to reach out to local area firms.

Examples of Expert Technical Assistance Programs through Federal Laboratories

Fee-based

DOE laboratories can sign a reimbursable Technical Assistance Agreement with a firm for up to $50,000, including all costs of labor, depreciation, and added factors.[47] Intellectual property rights are automatically granted to the sponsor.

Free

Air Force Research Laboratory (AFRL), research facilities in Arizona, California, Florida, Massachusetts, New Mexico, New York, Ohio, and Texas.
Technical Assistance allows AFRL to assist companies in an informal and timely manner. Companies are not charged for AFRL technical efforts. Transfer of Air Force expertise or technology via this mechanism is accomplished without the legal protection of a CRADA or license. Examples of technical assistance projects range from a new high-efficiency lubricant dryer that has filled over 200 million air conditioners and refrigerators and displaced over 250 million pounds of Freon from the atmosphere to a new aluminum die casting now in over a half a million consumer air compressors.[48]

Pacific Northwest National Laboratory (PNNL), DOE, Richland, Washington
PNNL offers businesses up to five days of free expert technical help during a year. Small businesses that use the free technical assistance program get a royalty-free license for four years for any inventions made in the course of technical assistance.

Few research universities have free-standing technical assistance programs for technology development.[49] However, faculty typically are free to pursue consulting arrangements. In addition, a number of university schools and departments, particularly schools of engineering, operate “corporate affiliate” programs that, for an annual membership fee, give firms access to an array of university resources that include bringing a defined problem to a research group, faculty member, or student project.

Nonprofit research institutes, such as Battelle, provide expert technical assistance on an ad hoc basis. Independent technical consultants offer expert help as well.

Technology businesses also can obtain technical assistance through informal, person-to-person mechanisms such as professional networks and even ad-hoc conversations in social settings at conferences.

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[47] Efforts greater than $50,000 are carried out under Work for Others, DOE’s contract research program.
[48] Paragraph quoted from AFRL Web site.
[49] Many universities do offer technical assistance programs in the realm of commercialization. Such programs are discussed in detail in Chapter Four.

Examples of University Corporate Affiliate Programs

Department of Chemistry, Northwestern University
Member benefits include early access to research; advance notification of scheduled seminars, colloquia, and symposia; opportunities for faculty members to present at a member's site and for company scientists to present on campus; free short courses; free consulting for up to two hours; access to department research facilities and the university library; and assistance in recruiting department students. Annual fee is $20,000.

Department of Computational and Applied Mathematics, Rice University
Members are invited to the annual affiliates meeting, with research lectures and presentations. Attendees are encouraged to share nonproprietary problems with faculty and graduate students during breakout sessions. Other benefits include early access to technical reports, faculty visits to member firms to discuss research or present seminars, and preferential access to students for recruiting and internships. Annual fee is $4,000, or $2,000 for small and new firms.

School of Engineering, University of California-Irvine
Member benefits include personal contact with faculty with relevant expertise, access to research facilities, and preferential access to students for recruiting and internships. Annual fee is between $5,000 and $20,000, depending on firm size.

A second form of technical assistance provides firms with ***access to unique research equipment***. For a fee (though in certain instances for free), firms can gain access to highly specialized "user facilities" at a federal, university, or nonprofit research laboratory.[50] Such access allows firms to undertake research that otherwise would be impossible or prohibitively expensive. Moreover, the host of the user facilities often will provide experienced staff assistance in operating the equipment.

For the most part, the federal government underwrites the cost of constructing and maintaining user facilities, whether located at a federal laboratory, university, or nonprofit research institute. Federal financing is based on the understanding that the nation benefits technologically and economically from access by researchers to the most advanced equipment and that such equipment often is too expensive for individual non-federal research organizations to purchase and maintain.

The federal government sponsors user facilities through several types of efforts. Units within agencies such as DOE (e.g., the Office of Basic Energy Sciences) and NSF (e.g., the Division of Materials Research) fund an array of "national user facilities" deemed essential to fulfil their respective missions. While many national user facilities are hosted at federal laboratories, a number are located at major research universities (e.g., Stanford University, the University of Notre Dame, and Kansas State University).

[50] For-profit corporations rarely allow access to their equipment in order to protect intellectual property and confidentiality.

Examples of Federally Sponsored User Facility Programs

A National User Facility Program

NSF's Division of Materials Research funds national user facilities, specialized instrumentation available to the materials research community and others. These facilities provide unique research capabilities that can be located at only a very few highly specialized laboratories in the country. Examples include facilities and resources for research using high magnetic fields, ultraviolet and x-ray synchrotron radiation, small-angle neutron scattering, and nanofabrication. The Division's national user facilities are located at Cornell University, Florida State University, the University of Wisconsin-Madison, and the National Institute of Standards and Technology.

Federal Laboratory User Facility

At ***Sandia National Laboratories***, the Electronic Technologies User Facility works with the U.S. microelectronics industry and universities to develop next-generation manufacturing equipment and processes. It provides a state-of-the-art fabrication environment for research in device and circuit design to meet manufacture-hardened technologies. It is the only industry-compatible microelectronics fabrication facility within DOE and has the ability to support a broad spectrum of microelectronics projects.

User Facility at an NSF-Supported UIRC

Columbia University's Materials Research Science and Engineering Center maintains a series of shared experimental facilities available to Center members, other members of the local materials community, and to outside users. The Center offers access to a shared instrument facility, electron microscopy laboratories, and a clean room.

Federal Laboratory Loaned Equipment Program

Pacific Northwest National Laboratory loans research equipment to the private sector for economic development. Annually, local private businesses receive equipment valued at over $100,000. Examples of equipment loaned include specialized lab equipment (e.g., microscopes and fume hoods), computers, and analytical and mechanical equipment. Businesses pay an annual loan fee, typically 11% of the equipment's acquisition value.

Individual federal laboratories also promote access to a wide variety of user facilities other than those in a "national" system. For instance, DOE's Sandia National Laboratories offers access to 18 separate user facilities. Some federal laboratories loan research equipment to businesses.

NSF-funded UIRCs provide member and nonmember firms with access to user facilities. The 29 Materials Research Science and Engineering Centers, for example, collectively operate 132 shared facilities for 40 types of equipment, "open for use by any interested scientist." The location of centers across the country allows most firms to be relatively close to at least one center.

The federal government also funds university-led consortia to build and operate user facilities. For example, NSF and NASA fund the University Corporation for Atmospheric Research to operate a Boulder, Colorado, facility that enables government, university and industry researchers to use Global Positioning System (GPS) technology for earth sciences research.

Other than through federally funded research centers, few universities actively market stand-alone user facility programs. However, membership in corporate affiliate programs often includes special access to certain research facilities and equipment.

2.2.4 Information Exchanges

Information exchanges, the fourth type of technology transfer, provides technology businesses access to ***existing*** technical information. Information exchanges differ from the prior forms of technology transfer in that the information obtained is currently available to many users and not customized to the needs of any one user (in contrast to cooperative R&D and technical assistance), and its transfer does not confer any IP rights to the receiver (in contrast to the license or sale of IP).

One form of information provided through exchanges is publicly available ***textual material***, such as technical books, articles, reports, working papers, theses, and presentations. This category also includes patent records, which typically describe in some detail how the invention works; however, because the technical method is patented, the reader does not have a legal right to replicate the exact technical method for commercial use.

A text might be obtained (in printed and/or electronic format) through the author, the author's employer (e.g., a university or federal laboratory), a technical journal, a funding organization (e.g., a federal agency), a trade association or professional society hosting a conference or other gathering, a publisher, a technical research service (e.g., Sopheon), a technical library, or the U.S. Patent and Trademark Office. (For the purposes of this discussion, any of these sources is considered an "exchange.")

A recent study shows that scientific publications published by publicly funded research organizations (e.g., universities, federal laboratories, FFRDCs, and nonprofit organizations) have a major impact on technology development by U.S. industry. Typically, at the front of each patent is a list of any technical information on which the patent is based. In 1996, each patent to U.S. inventors referred to 1.8 publications, on average. A full 73% of the scientific publications mentioned in patents granted to U.S. industry between 1991 and 1995 were from publicly funded research organizations.[51]

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[51] Francis Narin, "Patents and Publicly Funded Research," in *Assessing the Value of Research in the Chemical Sciences*, National Academy Press, 1998.

While most publicly available technical reports are published by universities and government laboratories, a number of corporate laboratories publish publicly available reports as well. Examples include laboratories at AT&T Corporation, General Electric, Sun Microsystems, and Microsoft Corporation.

The second type of information provided through information exchanges is ***professional expertise***, that is, information obtained directly from people rather than texts. Labor markets are one very important type of information exchange, means by which firms obtain skilled technical staff with highly useful knowledge and background that can be applied to the firms' specific research circumstances.[52] Professional networks and relationships are another important means through which firms, via their technical staff members, can keep abreast of relevant technical developments. Over their professional lives, many researchers build a significant network of colleagues outside of the workplace with whom they share technical information and opinion. Public presentations, in workshops, seminars, and the like, usually combine verbal delivery of professional expertise with text handouts (e.g., a working paper on which the presentation is based). Informal information exchange at conferences builds relationships and participants' knowledge that might later be drawn on to solve a technical problem.

Nonproprietary technical information is available through information exchanges in three ways:

- Some information is ***freely available*** (e.g., mailed on request, downloaded from university Web sites, handed out at a public lecture, or obtained in conversation with professional colleagues).
- Some information can be obtained through paying an ***access fee*** to the "exchange," for example, the registration fee at a conference (which allows one to attend panels, obtain handouts, and have conversations with attendees) or the membership fee for a corporate affiliates program (which provides members with advance copies of department technical reports).
- Some information can be obtained through ***direct purchase*** (e.g., of a working paper) or direct hire (of a new employee).

While nonproprietary technical information often is sought in order to solve a particular technical problem, much is gathered in order to stay abreast of developments in the field. In the latter case, the information may not be drawn on until a later date, if ever. It is technology transfer "in reserve," so to speak. Thus, the effective use of nonproprietary information exchanges requires both initiative (in seeking out an array of information sources) and strategy (determining which sources are most important).

[52] In labor markets, scientists and engineers carry technical information obtained through a number of transferring organizations, including the academic institutions at which he or she was trained, prior employers, and trade and professional associations. As will be discussed in the next chapter, the hiring of recent graduates from science and engineering programs can be an important aspect of technology transfer.

2.2.5 Summary of Technology Transfer

In summary, the four types of technology transfer can be distinguished from each other as follows:

- In cooperative R&D, the technology transferees are active ("hands-on") in working with one or more external organization to develop a new patentable, commercializable technology.
- In technology licensing or sale, transferees typically purchase an already patented, commercializable technology from another source.
- In technical assistance, transferees seek help on relatively narrow technical questions that, if answered, can lead to a commercializable technology.
- Through nonproprietary information exchanges, transferees aim to expand the knowledge base on which they can draw as they carry out R&D that, one hopes, will lead to a commercializable technology.

2.3 Technology Commercialization

Commercialization is the process of transforming technology into economically successful products. Several key points made in Chapter One about the technology commercialization process bear repeating:

- Commercialization is a costly, lengthy process with a highly uncertain outcome. On average, the costs of commercialization run from between 10 and 100 times the costs of research, development, and demonstration of the new technology.
- Success is rare—less than five percent of new ideas are successfully commercialized.[53]
- Even when successful, commercialization does not happen quickly. On average, the commercialization of university research takes over six years, and that of radically new technologies far longer.
- The direct economic benefits of commercialization are likely to be geographically dispersed. Manufacturing and distribution sites are often in different states, or countries, from the site of technology development. However, at the original site, successful commercialization can have a clustering effect, attracting additional technology development and commercialization activity.

[53] For pharmaceuticals, the success rate is said to be far lower. Of every 5,000 medicines tested, according to the Pharmaceutical Research and Manufacturers of America, only five on average are tested in clinical trials. Based on research by the Tufts Center for the Study of Drug Development, only one of these five is eventually approved for patient use. For outline of steps in drug development, see Tufts Center press release, November 30, 2001, http://www.tufts.edu/med/csdd/images/StepsInDrugDevelopment.pdf.

The commercialization process has three components. First is the ***technical*** effort required to transform technology into a viable and desirable product, and to produce the product in sufficient quantities and quality. Second is the ***business management and market analysis*** needed to ensure adequate and profitable product demand exists, that IP is appropriately managed, and that the parts of the firm built around the new product are well-run. Third is access to the ***factors of production*** required for successful commercialization—financial capital, physical facilities, and skilled workforce.

For the most part, firms obtain from the private sector the technical and business services and factors of production needed in the commercialization process. While the technology transfer process largely involves gaining access to unique technical information, the expertise required for commercialization, though quite specialized, is available from a number of sources. However, such access can be costly, sometimes prohibitively so for some small and medium-size firms. Because successful technology commercialization generates public benefits, technology commercialization services are commonly offered or supported by the public sector.

The subsections below review each of the three components in more detail, including the types of commercialization resources available to technology firms. Chapter Four examines in greater detail the various types of public and nonprofit organizations that support technology commercialization.

2.3.1 Technical Aspects

Two major technical aspects of the commercialization process are product development and design and manufacturing engineering. In ***product development and design***, scientists and engineers transform innovations into products with technical, value, and aesthetic characteristics attractive to prospective users and suitable for cost-effective manufacturing. Technical areas of focus include functionality, reliability, manufacturability, and maintainability.[54]

An important part of product development and design is the prototyping process, in which product concepts are conceived, fabricated, tested, and revised, usually many times. In recent years, a number of "rapid" prototyping techniques and methods have been introduced to reduce the time and costs of the product development process.

Manufacturing engineering concerns the design of the production process for the new product. The breadth of the field is suggested by the subject matter of the technical associations within the Society of Manufacturing Engineers, covering the material-specific (e.g., composites, electronics, and plastics), advanced machinery (e.g., automation and integration, machine vision, and robotics), and production stages (e.g., material forming, fabrication, and finishing processes).

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[54] The Product Development and Management Association (PDMA) defines manufacturability as "the extent to which a new product can be easily and effectively manufactured at minimum cost and with maximum reliability." See PDMA glossary at http://www.pdma.org/library/glossary.html.

Often, manufacturing engineers collaborate with product designers in a process of "concurrent engineering," so that all aspects of product development and manufacturing systems design occur in an integrated manner, rather than sequentially or by separate functions. Small-lot manufacturing runs are often carried out to test product designs and manufacturing methods simultaneously.

For firms involved in technology commercialization, a wide variety of resources are available to support the technical aspects of that process. These resources include

- private-sector firms providing technical services and assistance;
- trade and professional associations (with state and local chapters) offering access to information on experiences in the field, best practices, and peer-to-peer connections;
- technical assistance brokering services linking firms to consultants;
- cooperative benchmarking consortia in which firms in an industry collectively identify best practices in the product development process and manufacturing engineering; and
- publicly supported programs (e.g., in universities, Manufacturing Extension Partnership programs, nonprofit organizations, and government agencies) furnishing services not offered by the private sector or at a much reduced (i.e., often free) cost.

Publicly supported services may offer access to dedicated technical staff in product development and manufacturing engineering, to user facilities (e.g., a federal laboratory offers access to equipment for product testing), and to consulting experts (e.g., an intermediary links firms with experts). They may have a national, state, or regional focus. Publicly supported services are thoroughly described in Chapter Four.

2.3.2 Business Management and Market Analysis

Solving the technical issues of product design and manufacture is a necessary, but insufficient, condition for successful commercialization; a firm needs to obtain sufficient revenue from product sales to gain an adequate return on its investment. Elements of the business management and market analysis strand of the technology commercialization process include the following:

- ***Business planning*** – ensuring that the business built around the product is viable (including, for example, adequate capital, skilled workforce, financial controls, and management talent) and able to fully support and take advantage of successful product commercialization.

Examples of Technical Resources for Commercialization

For-profit Firms

Fine Pitch http://www.solectron.com/gscf/finepitch.html

Trade and Professional Associations

Product Development and Management Association http://www.pdma.org/
Industrial Designers Society of America http://www.idsa.org/
Society of Manufacturing Engineers http://www.sme.org/
Offers a Technical Referral Database, providing access to over 1,300 manufacturing professionals who will confer on technical questions, free of charge.

Technical Assistance Brokering Services

Sopheon http://www.sopheon.com

Cooperative Benchmarking Organizations

Product Development Benchmarking Association http://www.pdba.org/
Agile Manufacturing Benchmarking Consortium http://www.ambcbenchmarking.org/
Pharmaceutical Industry Benchmarking Group http://www.pibg.org/

Publicly Supported Services

The ***Center for Industrial Research and Service*** at ***Iowa State University*** offers Iowa manufacturers services in product development, 3-D computer-aided design, rapid prototyping, and product testing.

The ***Solar Thermal Design Assistance Center*** at ***Sandia National Laboratories*** (Albuquerque, New Mexico) works with manufacturers of solar thermal products on technical issues such as product concept, design prototyping, testing, manufacturing processes, production, field evaluation, and disposal. The ***National Solar Thermal Test Facility*** is available to test solar thermal components.

The ***Best Manufacturing Practices Center of Excellence*** is sponsored by the ***Office of Naval Research, U.S. Department of the Navy*** and operated by the ***Engineering Research Center, University of Maryland***. The Center identifies, researches, and promotes exceptional manufacturing practices, methods, and procedures in design, test, production, facilities, logistics, and management. Staff assist with systems engineering best practices throughout a product's life cycle to reduce risk and eliminate surprises.

The ***Mid-America Manufacturing Technology Center*** (the Manufacturing Extension Partnership organization for Colorado, Kansas, Missouri, and Wyoming) provides assistance in product design, prototype development, testing, design for manufacturability, and materials selection.

- ***Market characterization*** – determining market size, segments, and trends; ascertaining patterns in market growth and structure; identifying competitive products and firms; and understanding distribution channels and purchasing patterns.
- ***Marketing strategy*** – establishing a price structure and developing an effective approach to increasing buyer awareness of and appreciation for the product.
- ***Manufacturing, supply chain, distribution, and service systems development*** – overseeing the creation of the systems necessary for making, moving, and maintaining the product.
- ***Management of intellectual property rights*** – ensuring that IP rights remain in force and are not violated by other parties.

Increasingly, as noted, firms are siting product manufacturing, distribution, and service facilities in locations other than the site of the technology development and product creation. Competitiveness considerations motivate firms to locate material-handling operations in places that offer the best combination of overall costs, workforce skills, and access to markets. The commercialization process can result in significant geographic fragmentation of functions.[55]

As an important part of this trend, technology developers are increasingly ***outsourcing*** the actual tasks of manufacturing, distribution, and even product design to contractors. The belief is that, rather than directly owning and overseeing all aspects of business operations, firms will do better by focusing on their "core competencies," which for high-technology firms means technology development, and contracting with external specialized organizations for components of the commercialization process such as product design, engineering, manufacturing, human resources, information technology, distribution, and sales.

At the extreme, the outsourcing model leads to a "virtual firm," the owner of the IP with few physical assets, the manager of a web of electronically-linked arrangements with other organizations that do the actual work of technology commercialization.

In high-technology electronics, firms such as Cisco, IBM, Nortel, Compaq, Sony, and Palm are hiring contractors such as Selectron, Flextronics, and Celestica. Services of these firms include manufacturing, distribution, repairs, and product design. Solectron notes that it seeks to "provide its clients with new ways of operating—such as outsourcing all operations except research, product conceptualization, marketing, and sales—allowing clients to outsource those activities that were not part of their core competencies."

In the biomedical industry, numerous firms, such as Nova Biomedical, are available to handle multiple aspects of the commercialization process. For instance,

[55] Paul Sommers and Daniel Carlson, "What the IT Revolution Means for Regional Economic Development," The Brookings Institution, February 2003.

Nova, which works with 23 technology developing firms, indicates: "From product development to manufacturing, distribution and field service, Nova can provide either the entire package or individual functions to supplement a client's internal capabilities."

Outsourcing at Biogen

In 1996, Biogen received permission from the Food and Drug Administration to manufacture Avonex, a drug for treating multiple sclerosis. The firm examined four core tasks of drug production—bulk manufacturing, formulation (freeze-drying and storing the drug), packaging, and warehousing/distribution. Biogen decided it could handle bulk manufacturing at its facility in Cambridge, Massachusetts, but decided to contract out all other services:

- Formulation was handled by a biomedical contract manufacturer in Bedford, Ohio.
- Packaging was given to a small firm in Philadelphia, Pennsylvania.
- Warehousing and distribution was turned over to Amgen, with a distribution facility in Louisville, Kentucky.

Source: David Bovet and Joseph Martha, "Biogen Unchained," *Harvard Business Review*, Reprint F00305, 2000.

In the parlance of the outsourcing industry, firms offering multiple services, such as Solectron and Nova, are aiming to be "supply-chain" facilitators. The supply chain is "a network of facilities that procure raw materials, transform them into intermediate goods and then final products, and deliver the products to customers through a distribution system."[56]

Services Offered by a Supply Chain Facilitator

Design – building-block technology modules, certification processing, circuit test development, component engineering, component qualification, electrical design, engineering revision control, environmental stress testing, functional design, functional test development, manufacturability design, mechanical design, prototype build, qualification testing, reliability engineering, systems test development, testability design

Manufacture – component and subsystem assembly, direct fulfillment, distribution, electromechanical assembly, engineering change, finished goods warehousing, local supply-chain design, new product introduction, printed circuit board assembly, power, packaging and cooling, quality assurance, retail packaging, supplier qualification, systems manufacturing, systems testing, vendor managed inventory control

Service – asset recovery, customer call centers, customer relationship management, end-of-life service support, failure analysis, last-time-buy component management, recycling, refurbishment, remanufacturing, returns processing, reverse logistics, troubleshooting support, upgrades, warranty repair

[56] Hau L. Lee, and Corey Billington, "Managing Supply Chain Inventory: Pitfalls and Opportunities," *Sloan Management Review*, Vol. 33, No. 3 (Spring 1992), pp. 65–73.

In the electronics industry, supply chain service firm operations are global. Solectron notes it has 54 sites worldwide, and the capacity to design a product in California, build it in Malaysia, assemble it in Mexico, and service it in Tennessee. In 2001, 51 percent of Solectron's sales came from sites outside the United States.

Another emerging trend in the commercialization process, acquisition of the technology-developing firm, also can lead to increased geographic dispersion. With the level of resources required for successful commercialization one to two orders of magnitude greater that needed for technology development, new and small technology-developing firms have great difficulty obtaining the required funds. Currently, investors are quite averse to initial public offerings (IPOs). As a result, many new firms with promising technologies are selling themselves (and their patents) to large buyers.

> For now, the best hope for many entrepreneurs is to position themselves as research and development labs for the giants. They can cook up their technology in pre-IPO obscurity, prove that it works, and then sell out to an acquirer who has the wherewithal to turn their dreams into businesses.[57]
>
> (B)iotech research firms tend to sell or license their technologies to larger pharmaceutical firms, or to form joint ventures with them, or to sell them their entire companies. The different business skills required and the high cost of scaling up to global-scale manufacturing and distribution usually discourage small research firms from growing internally.[58]

The sale of a startup often is followed by the relocation (or retirement) of assets and personnel. Thus, technology developers themselves, as well as commercialization functions, may be moved from the site of the original innovation.

To assist firms in business management and market analysis, resources are available from a wide variety of public-sector and nonprofit organizations:

- trade and professional associations, including industry-specific (e.g., the Software and Information Industry Association), topic-specific (e.g., the American Marketing Association), and technology business councils (e.g., the Santa Cruz Technology Alliance);
- Small business development centers located throughout the country (commonly at institutions of higher education) and funded by the U.S. Small Business Administration;
- state Manufacturing Extension Partnership programs;

[57] Steve Hamm, "Startups May Die, But Not Their Bright Ideas," *Business Week*, March 10, 2003, pp. 70–71.

[58] Joseph Cortright and Heike Meyer, "Signs of Life: The Growth of Biotechnology Centers in the U.S.," The Brookings Institution, June 2002.

- technology entrepreneurship centers (e.g., the University of California at San Diego CONNECT and Pittsburgh's Innovation Works);
- peer support organizations (e.g., local chapters of the MIT Enterprise Forum, the Council of Growing Companies, and the Institute of Electrical and Electronic Engineers Entrepreneurs' Networks); and
- technology business assistance organizations sponsored by state and local governments (e.g., Florida funds six Innovation and Commercialization Centers across the state).

The various public-sector and nonprofit organizational options for providing business management and market analysis services in particular, and commercialization services in general, are explored in greater detail in Chapter Four.

2.3.3 Factors of Production

Technology commercialization cannot take place without key factors of production, including financial capital, physical facilities, and a skilled workforce. An important part of general economic development practice is providing access to these factors, so most readers will be familiar with the process for doing so. Thus, this subsection's discussion will be relatively brief.

Capital is the equity and/or debt needed to finance the product commercialization process and technology business development. Equity, investment in shares of a company, is "patient capital" that gives managers the financial base on which they can plan long-term, without worrying about delivering immediate returns. Equity can be provided through

- the business owners,
- wealthy individuals ("angel investors"), sometimes organized in regional venture capital clubs or networks,
- corporations,
- venture capital partnerships (which raise funds from corporations, university foundations, government pension funds, and wealthy individuals),
- small business investment companies (SBICs, licensed by and eligible for long-term loans from the U.S. Small Business Administration, in exchange for pledging to invest in small firms), and
- public and quasipublic venture capital funds (typically sponsored by state governments).

The following box provides links through which one can obtain lists of equity-providing organizations and individuals, typically organized by geography.

Debt capital, loans of varying length to a firm, is usually important in the process of product commercialization and technology business development. Debt is often used to finance the purchase of tangible assets, such as land, buildings, and equipment. Debt also may be used for working capital. Generally, lenders require that firms demonstrate that revenues will be sufficient to make regular debt payments, and that sufficient collateral is present. Important sources of debt capital include banks, bond and other credit markets, mortgage firms, and public and quasipublic development finance organizations.

Sources of Venture Capital Organization Listings

- Regional Venture Organizations, National Venture Capital Association http://www.nvca.org/resources/regintvo.html
- Regional and Community Venture Fund Profiles, Community Development Venture Capital Alliance http://www.cdvca.org/fund_profiles.html
- National Association of Seed and Venture Funds http://www.nasvf.org/
- Directory of State-Assisted Venture Capital Programs, Rural Policy Research Institute http://www.rupri.org/pubs/archive/wpapers/WP2000-1/index.html
- Small Business Investment Companies, Small Business Administration http://www.sba.gov/INV/opersbic.html
- Small Business Investment Companies, National Association of Small Business Investment Companies http://www.nasbic.org/index.cfm
- Venture Capital Clubs http://kwilliams.bizhosting.com/vclubs.html and http://www.venturea.com/clubs2.htm
- Angel Capital Electronic Network (ACE-Net) https://ace-net.sr.unh.edu/pub/
- Netpreneur Exchange http://www.netpreneur.org/funding/Resources/Angel _Funding.html
- The Capital Connection http://capital-connection.com/

Most technology firms use private, for-profit sector firms (e.g., commercial and industrial real estate firms, and developers) to obtain any ***physical facilities*** needed within the firm for technology commercialization and business development, including sites for administration, manufacturing, distribution, and continued R&D. To provide options not available through the private sector, many regional public purpose organizations develop and operate industrial parks, research parks, and business incubators. Also, development organizations also may have programs to expedite permitting processes and to provide tax incentives.

The Association of University Research Parks (AURP) defines a university-related research park or technology incubator as a property-based venture with the following characteristics:

- Existing or planned land and buildings designed primarily for private and public research and development facilities, high-technology and science-based companies, and support services.

- A contractual and/or formal ownership or operational relationship with one or more universities or other institutions of higher education, and science research.
- A role in promoting research and development by the university in partnership with industry, assisting in the growth of new ventures, and promoting economic development.
- A role in aiding the transfer of technology and business skills between the university and industry tenants.

The park or incubator may be a nonprofit or for-profit entity owned wholly or partially by a university or a university-related entity. Alternatively, the park or incubator may be owned by a nonuniversity entity but have a contractual or other formal relationship with a university, including joint or cooperative ventures between a privately developed research park and a university.[59]

According to the National Business Incubation Association (NBIA):

> Business incubation is a dynamic process of business enterprise development. Incubators nurture young firms, helping them survive and grow during the start-up period when they are most vulnerable. Incubators provide hands-on management assistance, access to financing, and orchestrated exposure to critical business or technical support services. They also offer entrepreneurial firms shared office services, access to equipment, flexible leases, and expandable space — all under one roof. An incubation program's main goal is to produce successful graduates — businesses that are financially viable and freestanding when they leave the incubator, usually in two to three years. [60]

Successful technology commercialization depends on access to a ***skilled workforce*** in management, production, sales, distribution, and support. As noted earlier, many technology firms choose to outsource certain functions, giving contractors the responsibility of managing a workforce. For some retained functions, technology firms can upgrade and enhance workers' skills through standardized and customized training programs offered by community colleges, state land grant universities, and private vocational schools.[61] Regional workforce investment boards (WIBs), funded by the Employment and Training Administration, U.S. Department of Labor, are responsible for coordinating the delivery of training services to local employers. WIBs are charged with linking their activities with economic development agencies. However, this charge is relatively new, and some WIBs are better at the task than others.

[59] AURP Web site (www.aurp.net). The AURP site provides access to a directory of research parks, expert consultants, and best practice material.
[60] NBIA Web site (www.nbia.org). The NBIA site provides access to a directory of incubators, expert consultants, and best practice material.
[61] The standardized and customized training curricula of over 1,000 colleges can be found at http://www.customized-training.org/, a Web site sponsored by the Employment and Training Administration.

2.4 Concluding Remarks

The transfer of technology from external sources can be highly important to a firm's product development process. Effectively carrying out the three components of technology commercialization is critical to a new product's success. For economic development practitioners to know how best to facilitate technology transfer and commercialization, they need to understand the extent to which geographic proximity to technology research is important, and the roles that the public and nonprofit sectors can play in promoting technology transfer and commercialization. These topics are explored in the following chapters.

Chapter Three
The Geographic Patterns and Impacts of Innovation

This chapter provides context, exploring the trends and the economic effects of innovation (scientific research and technology development) across the United States in the recent past. The chapter sets the stage for examining, in later chapters, technology transfer and commercialization programs.

The chapter's primary units of analysis are research and development (R&D) expenditures and patents. For the most part, the development of new technology results in new intellectual property—patents and trade secrets. Patents are the best available proxy for technology development, as the number and location of trade secrets are unknown (by definition).

Section 3.1 provides an overview of U.S. R&D and patenting activity over time, in terms of total numbers, distribution by performer, and distribution by metro and nonmetro areas. Section 3.2 examines the geography of innovation in detail, in particular looking at patterns of patenting and R&D across states and metro areas. The section also analyzes the role that innovation plays in economic performance, particularly increases in value added per worker and regional economic expansion. Section 3.3 explains the geography of innovation in light of recent literature. It also provides brief comments on the geography of commercialization, of which little study has been made as of the present.

3.1 General Trends in U.S. R&D and Patenting Activity

A summary of findings in this section is as follows:

- The pace of U.S. technology development activity has more than doubled in the past two decades.
- Industry performs the large majority of U.S. applied research and development, and so, not surprisingly, obtains the bulk of the patents.
- Universities, nonprofit research institutes, and the federal government are responsible for a significant majority of this country's basic research.
- Industrial R&D is carried out, for the most part, by very large companies.
- The majority of patents are not in advanced technology industries.

The pace of U.S. technology development activity has increased significantly in the past two decades. Between 1980 and 2002, the inflation-adjusted level of U.S. R&D expenditures increased from $122.8 billion to $291.7 billion (2002$), a rise of 138 percent.

U.S. patenting activity has climbed at the same rate; this might be expected, as patents are the outcome of the R&D process. Between 1980 and 2001, the number of patents granted to U.S. inventors rose from 37,400 to 87,600. The year 1998 showed a particularly significant increase in patents, and that increase has been sustained ever since (Figure 3.1).[62]

Industry performs the large majority of U.S. research and development, and so, not surprisingly, obtains the bulk of the patents. Universities, nonprofit research institutes, and the federal government carry out most of this country's basic research.

In 2002, industry performed 72 percent of all R&D expenditures; universities, 13 percent; the federal government, 11 percent; and nonprofit research institutes, 4 percent.[63,64] In 2001, for-profit corporations received 77 percent of all patents assigned to U.S. inventors, independent inventors received 17 percent, universities four percent, the federal government one percent, and nonprofit R&D institutes less than one percent.[65] Hence, industry has a far higher propensity to patent than do other R&D performers.

Of the three phases of R&D activity (basic research, applied research, development), industry dominates the latter two, the ones that most directly lead to patents.[66] (See Table 3.1.) Industry provides over two-thirds of this country's applied R&D expenditures and 89 percent of development expenditures, and spends 92 percent of its R&D funds on applied research and development. For the most part, basic research is left to academia, the federal government, and nonprofits. In a metaphorical sense, the

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[62] The number of patents granted by U.S. Patent and Trademark Office (USPTO) to foreign inventors has climbed at a rapid pace as well. In 2001, foreign inventors received 78,400 patents. Over the last decade, foreign inventors annually receive 44–48 percent of USPTO utility patent grants.

[63] National Science Foundation, "Slowing R&D Growth Expected in 2002," *Infobrief*, NSF 03-307, December 2002. For the purposes of comparison in terms of scale: In 2002, R&D expenditures for over 700 U.S. universities totaled $37.5 billion. In fiscal 2002, seven U.S. corporations had worldwide R&D budgets of at least $4.0 billion (Ford, General Motors, IBM, Microsoft, Bristol-Myers Squibb, Pfizer, and Cisco Systems); the aggregate R&D budget for this group was $37.9 billion. ("The Corporate R&D Scorecard 2002," *Technology Review*, December 2002/January 2003, pp. 67–70.)

[64] R&D performed by the federal government is known as "federal intramural R&D," carried out by federal laboratories and Federally Funded Research and Development Centers. Total R&D expenditures funded by the federal government includes federal intramural R&D plus R&D grants and contracts with universities, nonprofit research institutes, corporations, and individuals.

[65] U.S. Patent and Trademark Office and Association of University Technology Managers. In 2001, U.S. corporations received about 70,000 patents; independent inventors, 13,300; and the federal government, 960. In 2000 (the latest year available), universities received about 3,100 patents and nonprofit research institutes, about 500. In 2001, IBM had the most patents of any corporation, with 3,411. By comparison, the University of California system had 401 patents; the single academic establishment with the most patents was the Massachusetts Institute of Technology, with 125.

[66] According to the National Science Foundation, ***basic research*** is directed toward increases in knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific application toward processes or products in mind; ***applied research*** is directed toward gaining knowledge or understanding deemed useful in meeting a recognized and specific need; and ***development*** is the systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems or methods, including design and development of prototypes and processes. More detailed definitions are available at http://www.nsf.gov/sbe/srs/nsf99335/appa.htm#define.

seeds of technology development are planted by public purpose organizations; the fruits are nurtured and harvested by industry.

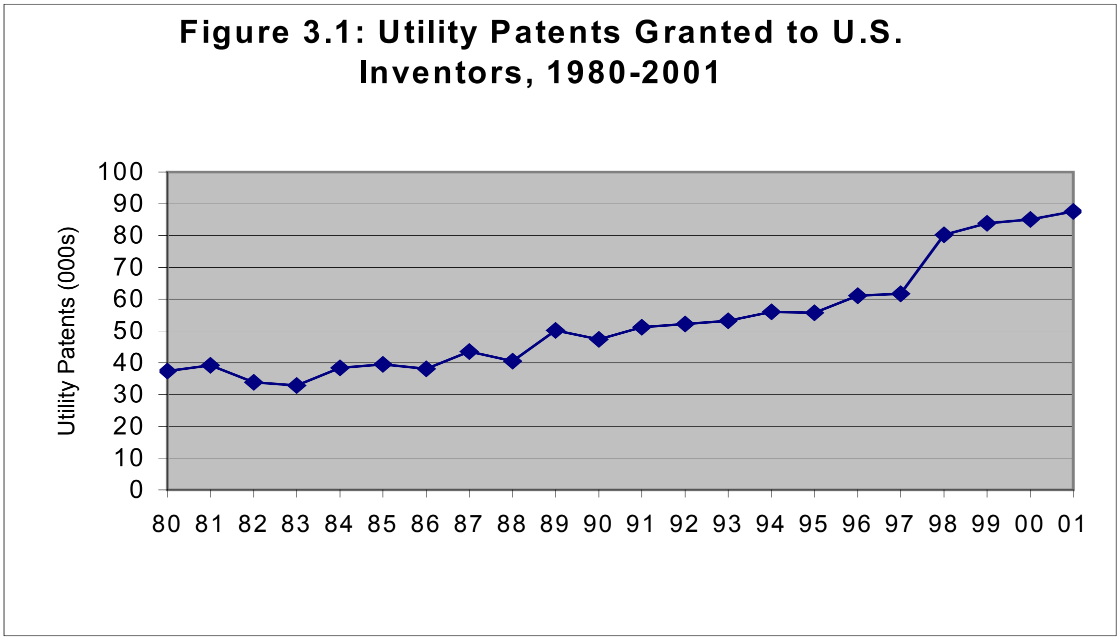

Table 3.1: R&D Expenditures by Performing Sector and Character of Work, 2000

	Total	Industry	Universities	Federal	Other Nonprofits
Character of Work (millions of dollars)					
R&D Total	264,622	197,280	30,154	28,437	8,750
Basic Research	47,903	15,378	20,656	7,377	4,492
Applied Research	55,041	37,648	7,260	7,629	2,504
Development	161,679	144,254	2,238	13,433	1,754
Percent Distribution by Character of Work					
R&D Total	100.0%	100.0%	100.0%	100.0%	100.0%
Basic Research	18.1%	7.8%	68.5%	25.9%	51.3%
Applied Research	20.8%	19.1%	24.1%	26.8%	28.6%
Development	61.1%	73.1%	7.4%	47.2%	20.0%
Percent Distribution by Performing Sector					
R&D Total	100.0%	74.6%	11.4%	10.7%	3.3%
Basic Research	100.0%	32.1%	43.1%	15.4%	9.4%
Applied Research	100.0%	68.4%	13.2%	13.9%	4.5%
Development	100.0%	89.2%	1.4%	8.3%	1.1%
Source: National Science Foundation					

Industrial R&D is carried out, for the most part, by very large companies. In 1999, 55 percent of industrial R&D was carried out by firms with 10,000 or more employees; 41 percent was performed by firms with 25,000 or more employees. At the same time, small firms do have a significant R&D role—19 percent of industrial R&D was carried out by firms with less than 500 workers. (See Figure 3.2.)

The majority of patents are <u>not</u> in advanced technology industries. With the visible emergence of centers of advanced technology industries during the 1990s, it has been popular to assume that technology development takes place largely within such industries. In fact, this has not been the case. While the percent of patents going to firms in advanced technology industries has increased over time, even in 2000 such patents comprised less than half of all patents (Figure 3.3). Patents are distributed across a broad array of advanced technology and more mature industries (Figure 3.4).[67] While three of the top four industry groups represent advanced technology industries, the drugs and medicine group (perhaps the most popular target industry in economic development at present) has fewer patents than five mature industry groups.

At the same time, Figure 3.3 makes clear, the share of patents going to advanced technology industries has been rising rapidly. Between 1980 and 1999, the number of patents in information technology and biomedical technology rose 400 percent, compared to 63 percent for all other technologies.[68]

Consistent with the patent data, only a little over half of industrial R&D expenditures take place within advanced technology industries (Table 3.2). Motor vehicles, chemicals other than pharmaceuticals, wholesale and retail trade, and machinery each have significant R&D budgets.[69]

As the patent and R&D data indicate, increasing value added and competitiveness through technology development takes place across all industries. Thus, technology transfer and commercialization programs and policies have an important role to play throughout the U.S. economy, not only in advanced technology industries. This insight is particularly valuable to those many regions of the country that are not strong in advanced technology industry assets. Technology development can be facilitated in regions reliant on more mature industries, such as textiles and machinery.

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[67] The U.S. Patent and Trademark Office assigns each patent to an SIC industry group based on a patent technology class—SIC industry crosswalk it developed. Six industry groupings are considered advanced technology—Drugs And Medicines (SIC 283), Office Computing & Accounting Machines (SIC 357), Electronic Components & Accessories & Communications Equipment (SIC 366-367), Guided Missiles & Space Vehicles & Parts (SIC 376), Aircraft & Parts (SIC 372), and Professional & Scientific Instruments (SIC 38, except 3825). In Figure 3.4, the aerospace industries are part of Transportation Equipment.

[68] Diana Hicks, Tony Breitzman, Dominic Olivastro, Kimberly Hamilton, "The changing composition of innovative activity in the US – a portrait based on patent analysis," *Research Policy*, Vol. 30, 2001, pp. 681–703.

[69] The specific numbers for these industries are not available to protect confidentiality, but can be deduced from the original data table. See National Science Foundation, *Science and Engineering Indicators: 2002*, Appendix Table 4-31. http://www.nsf.gov/sbe/srs/seind02/append/c4/at04-31.xls

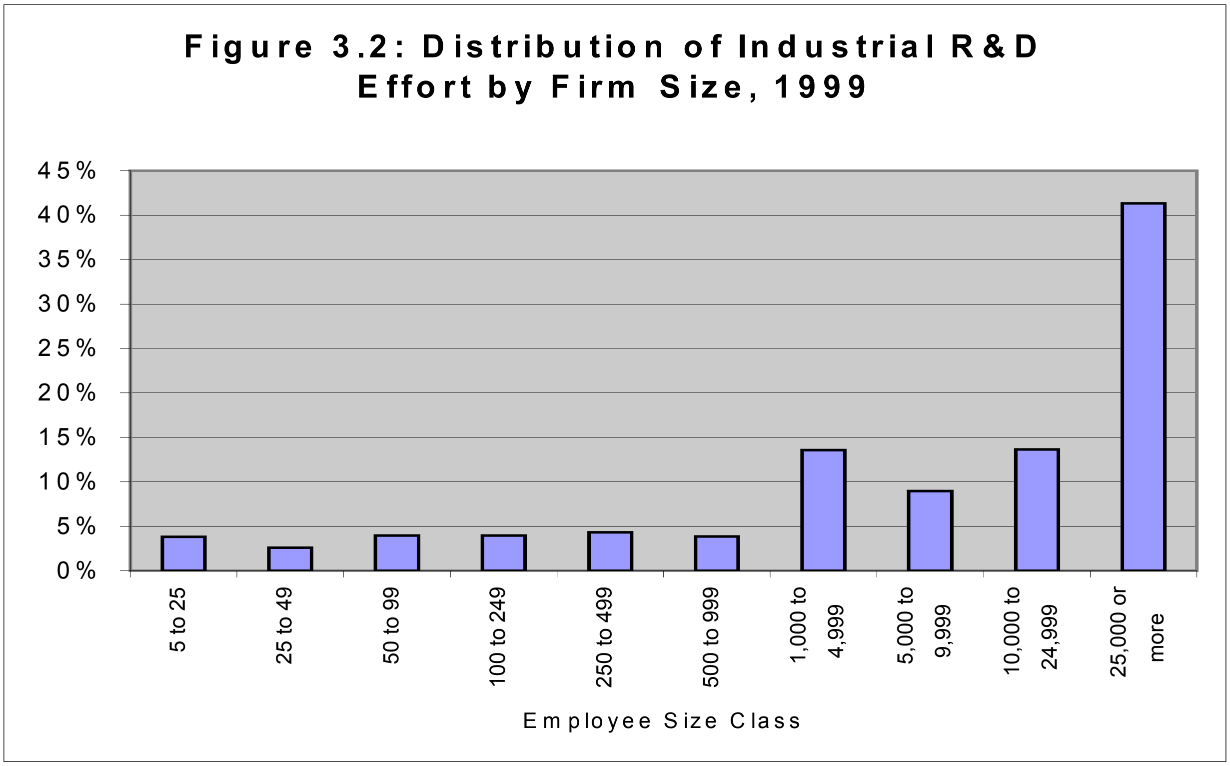
Figure 3.2: Distribution of Industrial R&D Effort by Firm Size, 1999
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
5 to 25
25 to 49
50 to 99
100 to 249
250 to 499
500 to 999
1,000 to 4,999
5,000 to 9,999
10,000 to 24,999
25,000 or more
Employee Size Class

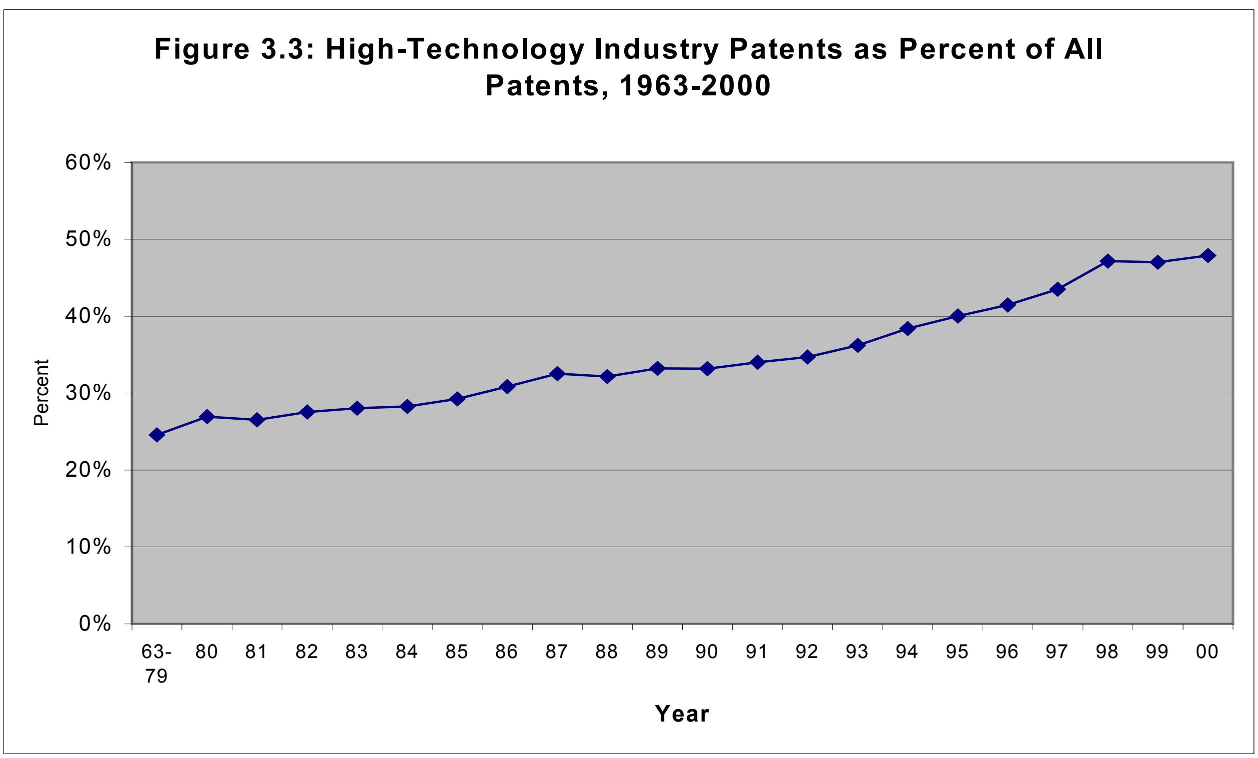
Figure 3.3: High-Technology Industry Patents as Percent of All Patents, 1963-2000
Percent
60%
50%
40%
30%
20%
10%
0%
63-79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
00
Year

Figure 3.4: U.S. Patents by Industry, 2000

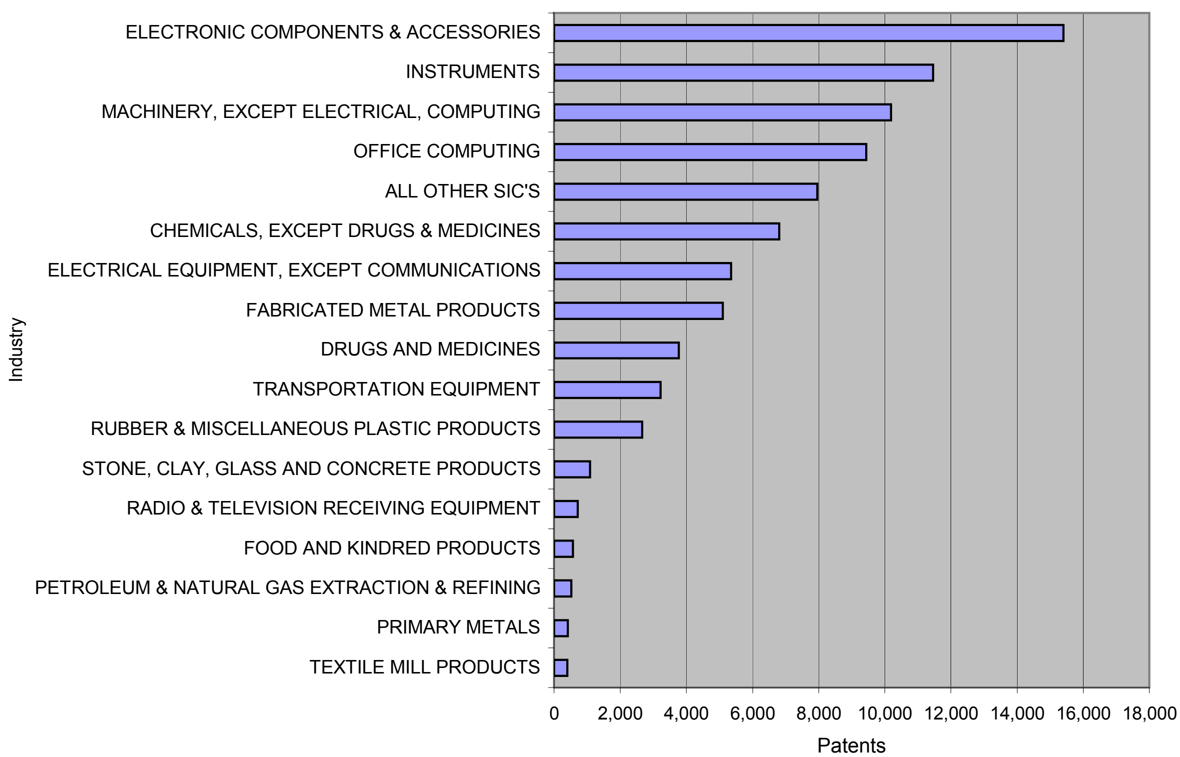

Table 3.2: Percent Distribution of Industrial R&D Expenditures by Industry, 1999

Computer and electronic products, including:	19.7	Electronic equipment, appliances	1.4
Instruments	7.8	Plastics and rubber products	1.0
Semiconductors, electronic components	5.9	Fabricated metal products	0.9
Communications equipment	3.3	Food	0.6
Transportation equipment, including:	18.6	Construction	0.4
Aerospace products and parts	7.9	Health care services	0.4
Chemicals (including pharmaceuticals)	11.1	Petroleum and coal products	0.3
Trade	10.7	Nonmetallic minerals	0.3
Prof., scientific, and tech. services, including:	10.4	Miscellaneous manufacturing	0.3
Scientific R&D services	5.7	Primary metals	0.3
Computer systems design	2.7	Transportation and warehousing	0.3
Software	6.0	Management of companies and enterprises	0.2
Machinery	3.3	Newspaper, periodical, book, and database	0.2
Small nonmanufacturing companies	2.8	Textiles, apparel, and leather	0.2
Broadcasting and telecommunications	2.2	Furniture and related products	0.1
Medical equipment and supplies	1.8	Utilities	0.1
Small manufacturing companies	1.7		

Source: National Science Foundation

3.2 The Geography of Innovation

3.2.1 Overview – States and Metro Areas

A summary of findings in this section is as follows:

- At the state level, the level of patent activity is closely associated with the level of industrial R&D. To a lesser extent, the level of patent activity also is influenced by the presence of advanced technology industries. The level of patenting activity is not consistently related to the level of public R&D.
- Technology development activity takes place largely within metropolitan areas.

At the state level, the level of patent activity is closely associated with the level of industrial R&D. To a lesser extent, the level of patent activity also is influenced by the presence of advanced technology industries. The level of patenting activity is not consistently related to the level of public R&D.

In light of the discussion in section 3.1, it is not surprising to find a strong relationship between industrial R&D and overall patenting activity at the regional level. Among the states, 70 percent of the difference in patenting rate (patents per 100,000 jobs) can be explained by differences in industrial R&D intensity (industrial R&D expenditures per job).[70] When the percent of state jobs in advanced technology industries is incorporated into the analysis, 75 percent of the difference in patenting rates is explained.

However, the level of public R&D (which includes R&D performed by academic institutions, the federal government, and nonprofit research institutes) by itself cannot explain a region's patenting rate. Some states with high patenting rates have low public R&D intensity, some with low patenting rates have high public R&D intensity.[71] In general, public patenting activity is too small to have a major impact; for some regions, the primary benefit of a public R&D base is that, through technology transfer, it provides a foundation for a vibrant industrial R&D base. However, not all areas have been able to leverage their public R&D activity in such a way.

Moreover, areas with high patenting rates do not need to have a relatively strong public R&D base. To a large extent, the findings of universities, nonprofits research institutes, and the federal government are publicly available; proximity to such organizations can be helpful, but is not necessary.

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[70] The regression analysis examined the relationship between state patenting rate for 1990–2000 and the average industrial R&D per job between 1987 and 1998.

[71] The regression analysis looked at the relationship between patenting rate and public R&D in total, as well as between patenting rate and each component of public R&D (academic, federal intramural, nonprofit research institute).

These various conclusions are evident is Table 3.3, which looks at numbers for the states with the highest and lowest patenting rates. Among the states with the highest patenting rate, most are in the top ten in terms of industrial R&D intensity and advanced technology; the reverse is true for the states with the lowest patenting rates. There is no obvious pattern regarding public R&D. The table makes clear that the level of industrial R&D activity is many times greater than public R&D.

The influence of advanced technology industries on a higher patenting rate is logical, as the pace of technological change in advanced technology industries is faster than in other industries. At the same time, the table makes clear, an advanced technology orientation is not required for a high patenting rate. Delaware and Michigan, in particular, have a relatively low percentage of advanced technology jobs (with their emphases on chemicals and autos, respectively), but a high patenting rate.

Table 3.3: Patenting Rate, Industrial R&D Intensity, Percent High Technology Jobs, Selected States

States with Highest Patenting Rate	Average Annual Patents per 100,000 Jobs, (1990–2000)	Average Annual Industrial R&D per 100,000 Jobs ($ millions, 1987–98)	Rank	% High-tech Jobs	Rank	Average Annual Public R&D per 100,000 Jobs ($ millions, 1987–98)	Rank
Delaware	112.1	$355.1	1	3.4	32	$18.6	35
Idaho	101.4	152.6	9	5.9	14	15.7	42
Connecticut	92.9	157.1	8	6.6	8	22.9	26
New Jersey	84.4	220.7	4	7.1	6	24.0	20
Massachusetts	80.2	227.9	3	10.4	1	77.7	3
New Hampshire	77.6	90.7	16	9.6	3	24.4	18
California	76.1	194.1	5	8.9	4	52.4	7
Minnesota	73.5	105.1	12	6.9	7	17.5	38
Vermont	72.2	81.1	19	6.3	12	20.0	31
Michigan	69.0	238.0	2	3.2	36	18.4	36
States with Lowest Patenting Rate							
Maine	18.9	$17.0	40	3.3	34	$9.6	49
North Dakota	18.6	9.6	45	2.6	40	23.5	23
Kentucky	18.5	18.2	39	2.5	42	8.9	50
Wyoming	18.1	5.5	48	1.4	50	22.0	28
Alabama	16.1	42.3	31	3.3	35	53.5	6
Alaska	14.9	6.2	47	2.1	45	40.8	8
South Dakota	12.3	3.5	50	4.7	22	9.7	48
Arkansas	12.3	12.0	41	2.4	43	10.6	47
Hawaii	12.0	10.8	43	2.0	46	23.9	21
Mississippi	11.8	5.2	49	1.9	47	23.1	25

Sources: Patents, U.S. Patent and Trademark Office; R&D expenditures, National Science Foundation; jobs, U.S. Bureau of Economic Analysis; high-tech jobs, Progressive Policy Institute.

Three less populous states with high patenting rates are quite dependent on the patent productivity of a single firm. In 1999 in Idaho, Micron Corporation received 73 percent of the patents; in Vermont, IBM received 62 percent of the patents, and in Delaware, DuPont received 49 percent.

Technology development activity takes place largely within metropolitan areas. While 84 percent of U.S. jobs are located in metropolitan areas, metropolitan areas receive 93 percent of U.S. utility patents and public R&D expenditures.[72] (See Table 3.4.) The patenting rate (patents per 100,000 jobs) in metropolitan areas is over two-and-a-half times that for rural areas; public R&D per job in metro areas is almost three times that for rural areas. Metro areas also have 94 percent of U.S. high-tech jobs.

The metro share of patent and R&D activity has been increasing slightly over time. (From 1991 to the latest year available, metro share of patents rose from 92 to 93 percent and share of academic R&D from 91 to 92 percent.)

Table 3.4: U.S. Technology Development Activity by Metro and Rural Area

	Percent		Rate per 100,000 Jobs	
	Metro	Rural	Metro	Rural
Jobs (2000)	84.1	15.9		
			R&D $ (millions)	
Public R&D	92.6	7.4	$42.4	$17.7
Academic (1998)	92.5	7.5	21.1	10.1
Federal (1998)	93.0	7.0	17.6	6.9
Nonprofit (1997-98)	96.4	3.4	3.7	0.7
			Patents	
Patents (1999)	93.1	6.9	68.1	26.4
High-tech Jobs (1999)	93.6	6.4		

Sources: Jobs, U.S. Bureau of Economic Analysis; high-tech jobs, U.S. Conference of Mayors; patents, U.S. Patent and Trademark Office; academic R&D, National Science Foundation; federal R&D, RAND; nonprofit R&D from National Science Foundation, RAND, Association of University Technology Managers.

As will be discussed in further detail below and in Chapter IV, technology development activity is concentrated in metro areas because R&D institutions seek close access to an array of external resources, such as specialized labor and business services and other R&D institutions. In other words, R&D institutions seek opportunities for technology transfer.

[72] Industrial R&D expenditure data are not available by metro/nonmetro areas. However, there is no reason to think that the geographic distribution of industrial R&D is significantly more dispersed than public R&D. Rather, as discussed in Chapter Four, there is reason to think it is more concentrated in metro areas.

3.2.2 Patenting Activity in Metro Areas

While technology development is almost entirely a metropolitan area phenomenon, it by no means takes place in equal measure across all metro areas. To the contrary, the variation in patenting and R&D among metro areas is substantial.

To set the stage for the metro area analysis, it is necessary to first review the metro area definitional framework. According to the U.S. Office of Management and Budget (OMB), the general concept of a metropolitan area "is that of a core area containing a large population nucleus, together with adjacent communities having a high degree of economic and social integration with that core." OMB largely determines the extent of economic integration through examining commuting patterns. Of the 276 metropolitan areas identified by OMB, 258 are "Metropolitan Statistical Areas" (MSAs) and 18 are Consolidated Metropolitan Statistical Areas (CMSAs). Essentially, CMSAs are "super-MSAs", composed of two or more contiguous Primary Metropolitan Statistical Areas (PMSAs), each of which independently meets the OMB standards for economic and social integration. So the 18 CMSAs are in turn made up of 73 PMSAs.[73] Thus, there are 331 "unit" metropolitan areas in the U.S. (MSAs and PMSAs). For the purposes of this analysis, "metro areas" includes MSAs and CMSAs and "unit areas" includes MSAs and PMSAs.[74] (A list of metro and unit areas, with data, is provided in Appendix B.)

It is helpful to examine patenting trends both for metro areas and unit areas. Within CMSAs, PMSAs function as distinct economic regions in their own right; moreover, PMSA boundaries tend to correspond more closely than CMSA boundaries as the focus of action for individual economic development agencies. At the same time, patterns of regional economic activity and technology development do not respect local boundaries. For instance, patenting activity that takes place largely in an industry cluster within one PMSA may draw on R&D available throughout a CMSA. Hence, in certain instances it will be useful to look at CMSA-wide activity.

[73] While the ten largest metropolitan areas, as measured by jobs, are CMSAs (e.g., New York-Northern New Jersey-Long Island, Chicago-Gary-Kenosha), a CMSA designation is not a function of size, but of having more than one primary geographic focus of economic activity. So the smallest CMSAs (Portland-Salem, Cincinnati-Hamilton, Milwaukee-Racine, Sacramento-Yolo) are less than half the size of the largest MSAs (Atlanta, Minneapolis-St. Paul, Phoenix, St. Louis, and San Diego). Some of the CMSAs are dominated by a large central PMSA (e.g., New York, Chicago, Los Angeles); other CMSAs (e.g., San Francisco-Oakland-San Jose) do not have a dominant PMSA, but rather have two or more PMSAs of somewhat equal size.

[74] The unit analysis will cover 318 areas, rather than 331. In New England, OMB metro area definitions are by towns, rather than by county as in the rest of the country. However, certain useful data are provided only by county. To use such data, OMB provides a definition of New England County Metropolitan Areas (NECMAs) as county-level approximations of MSAs in New England. For this analysis, NECMAs are used in place of MSAs. The Boston NECMA approximates the Boston CMSA, which has ten PMSAs. The New Haven NECMA combines five Connecticut PMSAs which are part of the New York CMSA, so is a "super PMSA." The replacement of 15 PMSAs with the two NECMAs moves the total unit area count from 331 to 318.

A summary of findings in this section is as follows:

- Less than a fifth of U.S. metropolitan areas specialize in patenting (that is, have a patenting location quotient greater than 1.0). The same pattern is true for unit areas.
- Patenting activity varies greatly by location. Only 24 unit areas produced over 1,000 patents in 1999. The range of unit area patenting rate extended from zero to 545 patents per 100,000 jobs, with a median of 34 patents per 100,000 jobs.
- Unit area patenting rates correlate with the percent of the local economy devoted to advanced technology, the level of educational attainment, and the size of the metro area (MSA or CMSA) in terms of number of jobs.
- Metro size matters. Metro areas with more than 1 million jobs are far more likely to specialize in patenting (and have unit areas that specialize in patenting) than are metro areas with fewer jobs.
- Of the metro areas with less than 1 million jobs that specialize in patenting, almost two-thirds are dependent on just two R&D organizations for at least half of their patents. In comparison, few metro areas with more than 1 million jobs have such dependency.
- Corporate size matters. In almost every metro and unit area that specializes in patenting, the top patenting organizations are Fortune 1000 firms.
- High patenting rates for unit areas often are not sustained over time, particularly in areas dependent on older industries and one or two firms.

Less than a fifth of U.S. metro areas specialize in patenting. In 1999, only 52 of the 276 metropolitan areas in the U.S. (19 percent) "specialized" in patenting, that is, had a share of U.S. metro patents greater than or equal to its share of U.S. metro jobs.[75] Only a slightly higher proportion of unit areas specializes in patenting (72 of 318, or 23 percent).

Table 3.5 provides basic data on metro and unit areas that specialize in patenting.[76] Several observations can be made:

- First, the relative number of metro areas and unit areas that specialize in patenting is small.

[75] This indicator also can be defined as a patents location quotient greater than or equal to 1.0.
[76] Patent, job, and R&D measures for each of 318 metro areas are in Appendix B.

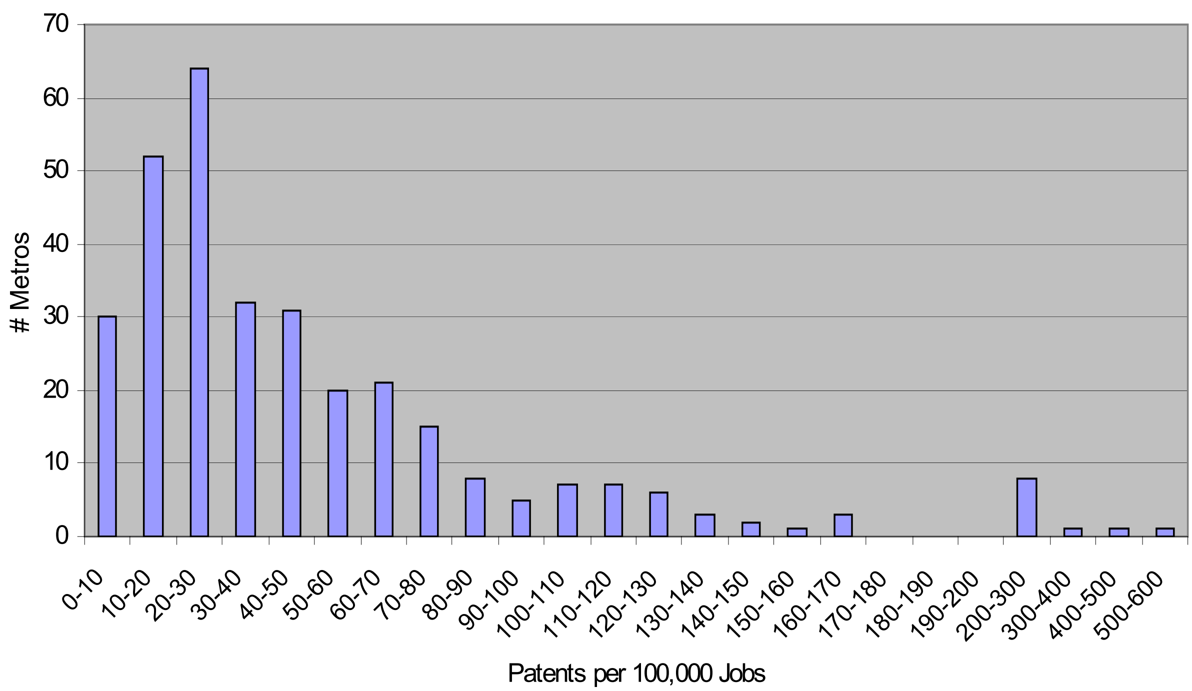
Table 3.5: Metro Areas Specializing in Patenting, 1999

	Median # Jobs	Median Patents/ 100K Jobs	Areas with Patenting LQ > 1[a] #	% Areas in Category	% Metro Patents	% Metro Jobs
Metro Areas (276)	139,000	30.5	52	18.8	66.4	42.8
CMSAs (18)	2.5 million	74.1	12	66.7		
MSAs (258)	120,000	28.0	40	15.5		
Unit Areas (318)	150,000	33.8	72	22.6	63.0	35.4
PMSAs (59)	393,000	73.5	31[b]	52.5		
MSAs (258)	120,000	28.0	40	15.5		
Boston NECMA (1)	3.3 million	114.6	1	100.0		

[a] Share of metro area patents divided by share of metro area jobs. Metro areas with a patenting rate greater than the U.S. metro rate of 68.1 per 100,000 jobs have a location quotient greater than 1.
[b] Of the 18 CMSAs, 16 have at least one PMSA that specializes in patenting.

Source: Patents from U.S. Patent and Trademark Office; jobs from U.S. Bureau of Economic Analysis.

Figure 3.5: Distribution of Metro Areas by Patenting Rate, 1999



- Second, patenting is quite geographically concentrated—the fraction of metro and unit areas that specialize in patenting provide about two-thirds of all metro patents.
- Third, larger areas and components of larger areas (CMSAs and PMSAs) have median patenting rates far higher than, and are far more likely to specialize in patenting than, smaller areas (MSAs).

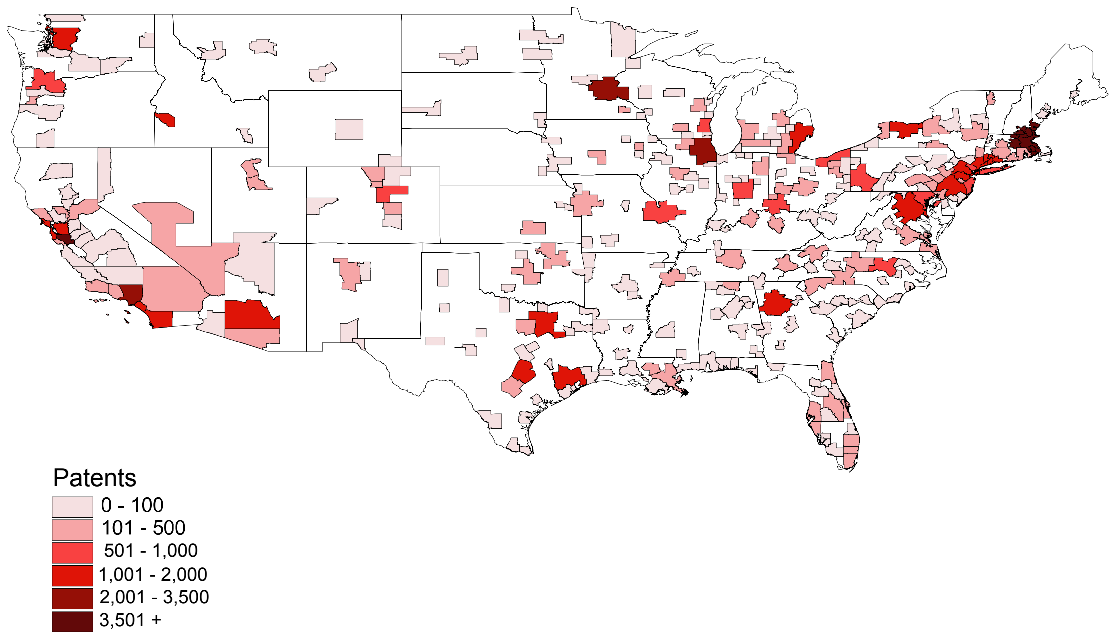
Relatively few unit areas produce large numbers of patents. Only 24 unit areas produced over 1,000 patents in 1999. For the most part, these were in metropolitan areas with large numbers of jobs—along the Washington-Boston corridor, in California and Texas, and in the metro areas of Chicago, Detroit, Minneapolis-St. Paul, Atlanta, Phoenix, and Seattle. (Map 3.1)

Patenting rates vary considerably among unit areas. While the median patenting rate among unit areas is 34 patents per 100,000 jobs, in 1999 the range extended from zero in Laredo, Texas, to 545 patents per 100,000 jobs in San Jose, California (Figure 3.5). Areas specializing in patenting were located primarily in the Northeast, Midwest, California, Texas, and Colorado (Map 3.2).

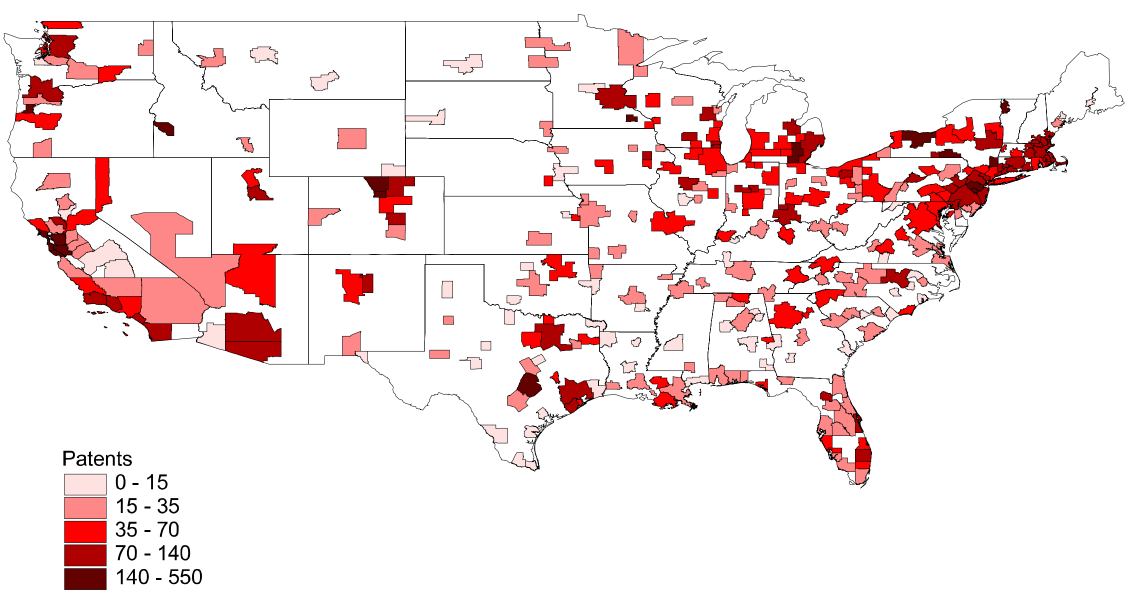
Unit area patenting rates are correlated with the percent of the local economy devoted to advanced technology, level of educational attainment, and job total for the whole metro area (MSA or CMSA). Regression analysis indicates that over half of the difference in patenting rates among unit areas can be explained by these three factors.[77] The importance of each is logical, given prior observations. Advanced technology industries have higher patenting rates than other industries. (Map 3.3 visually shows the percent of Gross Metropolitan Product attributable to advanced technology.) Higher educational attainment (percent of population with at least a bachelor's degree) provides a knowledgeable workforce base for carrying out innovative activities (whether in advanced technology industries or not). (See Map 3.4.) As we saw in Table 3.5, metro areas with more jobs tend to have higher patenting rates. Compared to smaller metro areas, larger areas typically have greater innovation resources and so offer greater opportunities for technology transfer. In particular, this analysis indicates that the patenting rates of PMSAs, regardless of jobs number, can be partially explained by the jobs number of the CMSA of which they are a unit (Map 3.5). In other words, patenting activity in PMSAs appears to take advantage of the resources available throughout the CMSA. The relationship between metro area size and patenting rate will be explored more fully below.

[77] Individually, the percentage of economic output from advanced technology industries explains about half the difference in patenting rates; the level of educational attainment, about a quarter of the difference; and the number of jobs in the metro area, about 9 percent of the difference. The overall ability of these three factors to explain patenting rate differences is not cumulative, as they each are correlated with the other two to some extent, as will be discussed.

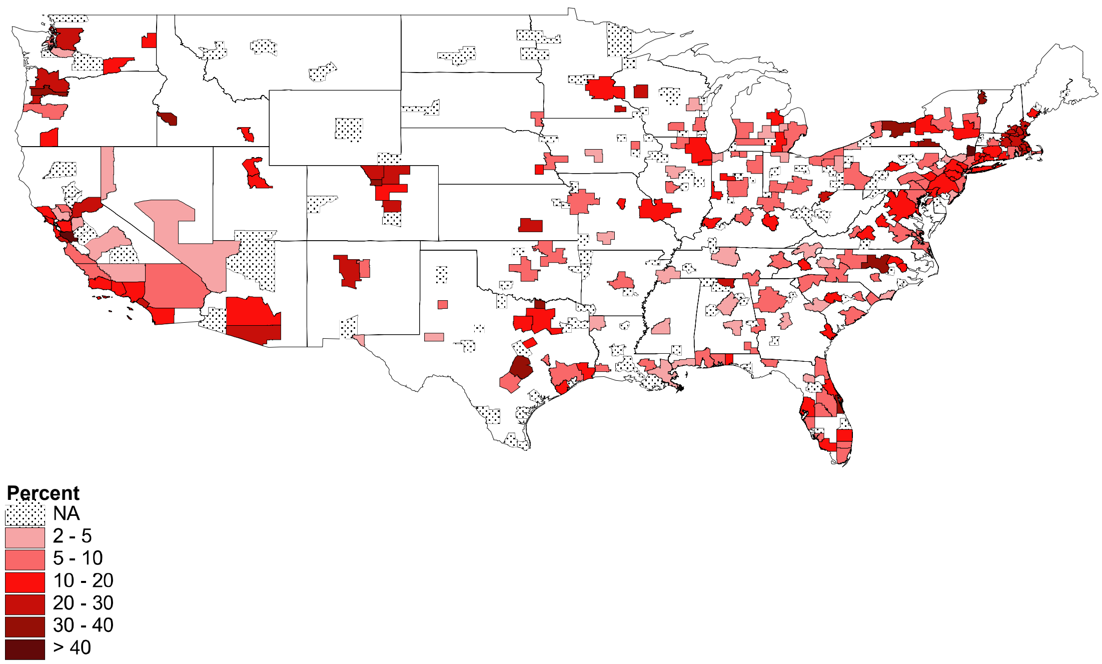
Map 3.1: Total Patents, 1999



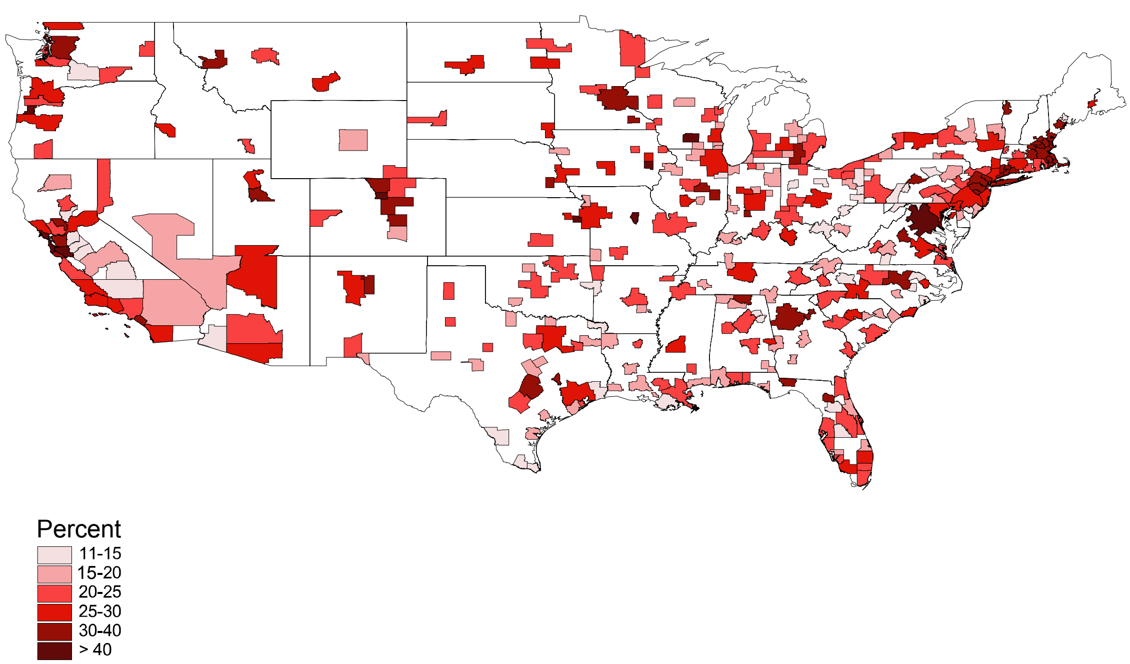
Map 3.2: Patents per 100,000 Jobs, 1999



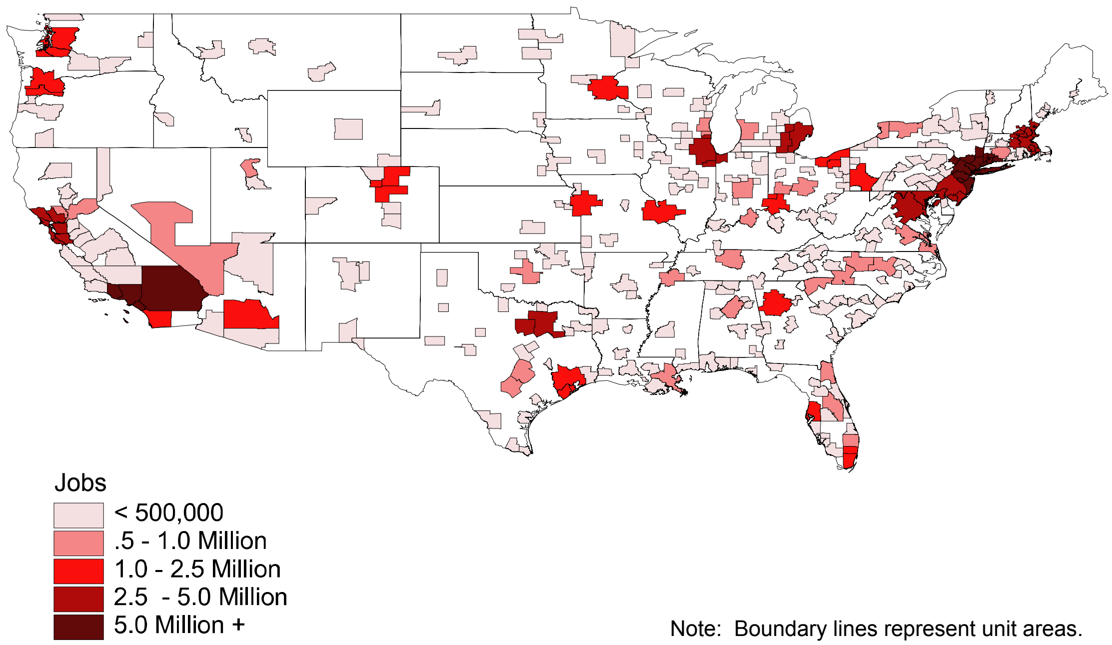
Map 3.3: High-Tech Industry Output as Percent of Gross Metro Product, 1999



Map 3.4: Percent Adults with Bachelor's Degree, 2000



Map 3.5: Metropolitan Area Jobs, 1999



As for the states, regression analysis for unit areas shows that differences in public R&D intensity (academic, nonprofit, and government R&D dollars per job) have negligible explanatory power regarding differences in patenting rates. As mentioned earlier, public R&D can, but does not necessarily, play an important foundation role in stimulating technology transfer to local industry. The dynamics of public R&D is discussed further a few pages hence.

The 15 unit areas with the highest patenting rates are listed in Table 3.6. Compatible with the regression analysis, the table shows that high patenting rates are consistent with a relatively high percent of economic output from advanced technology industries and high educational attainment. Twelve of the 15 areas are above median and metro-wide average for both variables; 14 are above the median on both variables.

Data on industrial R&D, the variable with the strongest influence on patenting rates at the state level, are not available at the metro level. Table 3.6 does indicate the percent of patents in each metro area granted to corporations. Clearly, the influence of industrial R&D on metro patenting is quite high. The percent of patents from academic, government, and nonprofit organizations is typically well under 10 percent. It can be inferred that the relationship between level of industrial R&D and patenting rate is as strong (if not stronger) at the metro level as it is at the state level.

Table 3.6: Unit Areas with Highest Patenting Rates, 1999

Unit Area	Patents per 100,000 Jobs	Patenting LQ	High-tech as % of Gross Metro Product	% Adults with Bachelor's Degree[a]	Distribution of Patents	
					% Corporate	% Academic, Government, Nonprofit
San Jose, CA PMSA	544.9	8.00	57.8	40.5	71.8	1.0
Boise City, ID MSA	480.8	7.06	36.0	26.5	95.6	0.0
Dutchess County, NY PMSA	319.0	4.68	50.7	27.6	96.7	0.0
Rochester, NY MSA	280.0	4.11	31.9	27.1	96.4	0.5
Rochester, MN MSA	270.3	3.97	30.2	34.7	86.9	9.2
Boulder-Longmont, CO PMSA	264.5	3.88	39.6	52.4	85.7	3.6
Corvallis, OR MSA	262.2	3.85	28.3	47.4	87.1	3.0
Austin-San Marcos, TX MSA	234.4	3.44	36.2	36.7	92.9	1.1
Fort Collins-Loveland, CO MSA	224.9	3.30	23.8	39.5	92.1	1.8
Santa Cruz-Watsonville, CA PMSA	222.4	3.26	20.7	34.2	85.3	1.6
Burlington, VT NECMA	216.0	3.17	38.6	37.2	94.0	0.8
Middlesex-Somerset-Hunterdon, NJ PMSA	167.9	2.46	16.1	37.4	86.7	2.8
Trenton, NJ PMSA	167.0	2.45	16.5	34.0	82.6	7.5
Ann Arbor, MI PMSA	161.9	2.38	11.9	36.9	77.5	10.0
Binghamton, NY MSA	159.2	2.34	35.9	22.0	94.2	0.0
All Metros	68.1	1.00	12.0	26.6		
Unit Metro Median	33.8	0.50	6.2-7.0[b]	22.7		
U.S.					78.7	5.8

[a] Percent of population 25 years old and higher with at least a bachelor's degree.
[b] The metro median for high-tech output as a percent of Gross Metro Product is given as a range, as the U.S. Conference of Mayors published data only for 205 of 318 metro areas (the largest and all with high-tech output of 10 percent or more). For the remaining 113 metro areas, aggregate high-tech output equals 3.3 percent of aggregate Gross Metro Product.

Sources: Patents, U.S. Patent and Trademark Office; jobs, U.S. Bureau of Economic Analysis; high-tech as percent of Gross Metro Product, U.S. Conference of Mayors; education, U.S. Census Bureau.

Metro areas with more than 1 million jobs are far more likely to specialize in patenting (and have unit areas that specialize in patenting) than are metro areas with fewer jobs. The patenting rate declines with metro jobs size class. As Table 3.7 indicates, two-thirds of the metro areas with over 1 million jobs specialize in patenting, compared to only 14 percent of the smaller metro areas. The median patents per 100,000 jobs for metro areas with over 1 million jobs is 73, compared to 28 for metro areas with less than 1 million jobs. The median patent rate and the percent specializing in patenting are the lowest for metro areas of less than 250,000 jobs.

Table 3.7: Metro Area Patenting Rates and Specialization by Jobs Size Class, 1999			
MSA/CMSA Jobs Size Class (# in class)	Median Patents/100K Jobs	Patenting LQ>1[a]	
		#	%
2.5 million + (9)	75.6	6	66.7
1.5-2.5 million (7)	71.9	5	71.4
1.0-1.5 million (8)	74.1	5	62.5
500,000-1.0 million (28)	35.6	5[b]	17.9
250,000-500,000 (29)	48.1	5	17.2
<250,000 (195)	24.0	26	13.3
1.0-2.5 million + (24)	72.9	16	66.7
<1.0 million (252)	27.6	36	14.3
All (276)	30.5	52	18.8

[a] Share of metro area patents divided by share of metro area jobs. Metro areas with a patenting rate greater than the U.S. metro rate of 68.1 per 100,000 jobs have a location quotient greater than 1.
[b] The shift from specialization to nonspecialization at the 1 million job threshold is somewhat dramatic. There are 12 metro areas with between 713,000 and 1.01 million jobs; all have a patenting LQ < 1.

Sources: Patents, U.S. Patent and Trademark Office; jobs, U.S. Bureau of Economic Analysis

Figure 3.6 illustrates the distribution of metro jobs and patents by jobs size class. The figure shows that patenting location quotients increase with jobs size class.[78] Both the table and the figure support the notion that a certain critical mass of economic activity is more conducive to technology development, and that size is necessary to support the array of external resources certain R&D organizations seek.

Analysis at the unit level also indicates that the patenting rate falls with metro area size, and confirms the influence of a high technology presence. Table 3.8 shows that median unit area patenting rate by metro jobs size class follows the trend for metro areas in Table 3.6. In the regression analysis described earlier, it was found that patenting rate is a function of high-technology industry presence, educational attainment, and metro area size. Table 3.8 indicates the strong relationship between patenting rate, presence of high technology, and the number of metro jobs—the decline in unit area median patenting rate by metro jobs size class is consistent in magnitude with a decline in median high-technology presence. The table also suggests that the median educational

[78] It should be noted that the outsized performance of the 2.5 million+ jobs class is largely due to the extraordinarily high patenting activity in the San Francisco-Oakland-San Jose CMSA, with 251 patents per 100,000 jobs in 1999. Absent that CMSA, the group location quotient for the eight remaining large metro areas is 1.07. To put the role of the San Francisco-Oakland-San Jose CMSA in perspective, that CMSA, with 3.3 percent of metro jobs, provides 12.0 percent of metro patents; all 195 metro areas with less than 250,000 jobs combined provide 18.1 percent of metro jobs, but only 12.2 percent of patents.

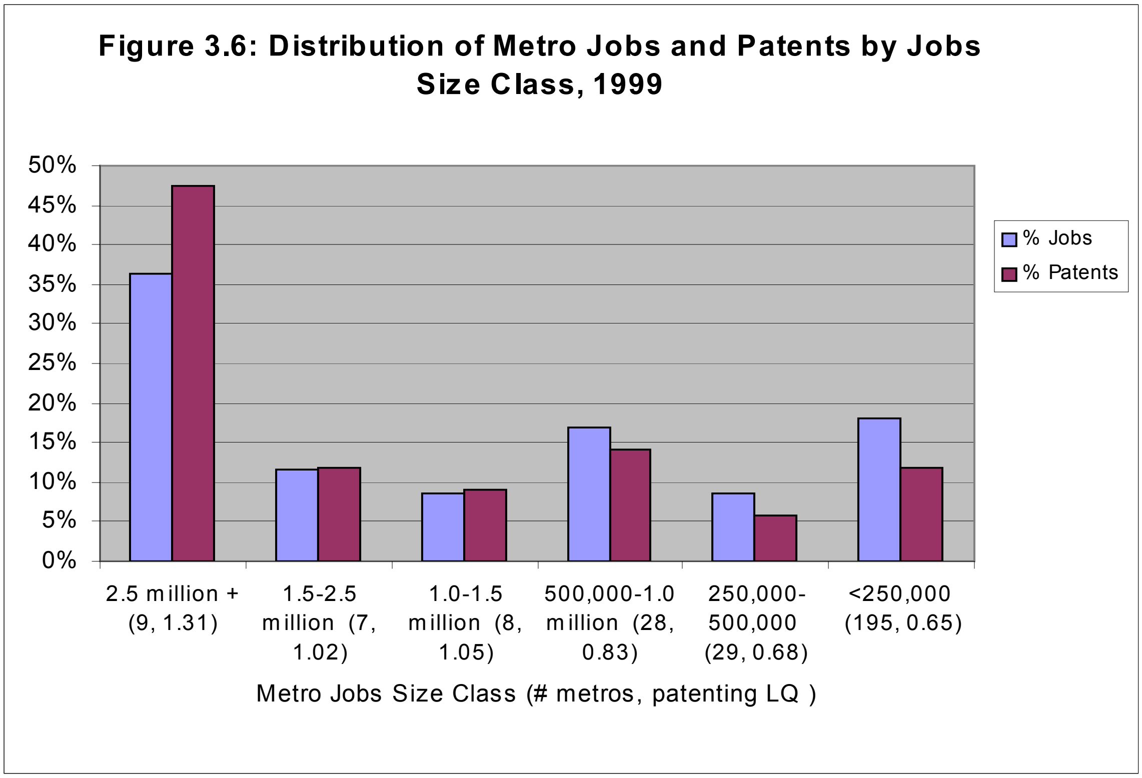


Table 3.8: Unit Area Patent Rate, Educational Attainment, and High Technology Presence, by Metro Size

MSA/CMSA size (# unit areas)	Median Patents/100K Jobs (1999)	Patenting LQ>1		Median High Tech as % of Gross Metro Product	Median % Adults with Bachelor's Degree (2000)
		#	%		
2.5 million + (38)	74.3	21	55.3	13.0	28.1
1.5-2.5 million (14)	62.7	6	42.9	9.5	24.8
1.0-1.5 million (12)	77.4	7	58.3	12.2	25.3
500,000-1.0 million (30)	38.5	7	23.3	7.7	24.8
250,000-500,000 (29)	48.1	5	17.2	8.5	24.6
<250,000 (195)	24.0	26	13.3	3.3[a]	20.0
1.0-2.5 million+ (64)	71.2	34	53.1	12.0	27.4
< 1.0 million (254)	28.0	38	15.0	4.6-5.4[a]	22.0
All (318)	33.8	72	18.8	6.2-7.0[a]	22.7

[a] The metro median for high tech output as a percent of Gross Metro Product is given as a range, as the U.S. Conference of Mayors published data only for 205 of 318 metro areas (the largest and all with high tech output of 10 percent or more). For the remaining 113 metro areas, aggregate high tech output equals 3.3 percent of aggregate Gross Metro Product.

Sources: Patents, U.S. Patent and Trademark Office; jobs, U.S. Bureau of Economic Analysis; high tech as percent of Gross Metro Product, U.S. Conference of Mayors; education, U.S. Census Bureau.

Table 3.9: For Patent-Specializing Unit Areas, Percent of Patents Provided by the Two Leading Patent Organizations, 1999

	Unit Area Jobs (000s)	Metro Area Jobs (000s)	Patents per 100,000 Jobs	# Patents	Leading Patent Organization	% Patents[a]	2nd Patent Organization	% Patents, Two Firms[a]
Unit Areas with Highest Reliance on Two Organizations:								
Kokomo, IN MSA	56	56	102.5	57	Delco	82.5	Pioneer Hi-Bred	87.7
Peoria-Pekin, IL MSA	182	182	102.0	186	Caterpillar	79.6	U.S. Dept. of Agr.	84.4
Rochester, MN MSA	85	85	270.3	229	IBM	74.2	Mayo Foundation	83.4
Boise City, ID MSA	227	227	480.8	1,093	Micron Tech.	76.4	Hewlett-Packard	82.5
Binghamton, NY MSA	119	119	159.2	190	IBM	74.2	Lockheed-Martin	81.6
Rochester, NY MSA	560	560	280.0	1,568	Kodak	53.8	Xerox	80.6
Dutchess County, NY PMSA	115	9,926	319.0	368	IBM	69.0	Siemens	81.3
Burlington, VT MSA	115	115	216.0	249	IBM	73.1	Micron Tech.	77.5
Corvallis, OR MSA	39	39	262.2	101	Hewlett-Packard	60.4	Micron Tech.	74.3
Elmira, NY MSA	45	45	102.4	46	Corning	69.6	NA	69.6
Unit Areas with Lowest Reliance on Two Organizations								
Boston-Worcester-Lawrence-Lowell-Brockton, MA-NH NECMA	3,322	3,322	114.6	3,806	MIT	3.2	General Hospital Corp.	5.3
Orange County, CA PMSA	1,454	7,150	101.3	1,473	McDonnell Douglas	3.2	Raytheon	5.6
Bergen-Passaic, NJ PMSA	675	9,926	74.4	502	Conopco	4.8	Becton,Dickinson	8.0
Boulder-Longmont, CO PMSA	180	1,458	264.5	476	Storage Technology	4.8	Cirrus Logic	8.8
San Francisco, CA PMSA	1,139	3,754	149.2	1,700	Sun Microsystems	5.8	Univ. of CA	9.6
San Diego, CA MSA	1,351	1,351	129.4	1,748	Hewlett-Packard	5.3	Qualcomm	10.4
Ventura, CA PMSA	303	7,150	108.1	328	Amgen	6.4	Rockwell	10.7
San Jose, CA PMSA	1,039	3,754	544.9	5,664	IBM	6.2	Sun Microsystems	11.6
Santa Barbara-Santa Maria-Lompoc, CA MSA	191	191	110.8	212	Univ. of CA	8.0	Raytheon	11.8
Oakland, CA PMSA	1,075	3,754	147.9	1,589	Univ. of CA	9.3	Sun Microsystems	12.4

[a] Percentages derived from examining USPTO tables. Effort made to combine figures for related corporations. Data provided only for organizations with at least five patents over previous five years.

Sources: Patents, U.S. Patent and Trademark Office; jobs, U.S. Bureau of Economic Analysis.

attainment falls with jobs size class as well, though in this form of analysis the differences are apparent only at either end of the size class spectrum.

In metro areas with less than 1 million jobs, almost two-thirds of the patent-specializing unit areas depend on just two R&D organizations for at least half of their patents. Such dependency is rarely found in metro areas with more than 1 million jobs.

Most smaller metro areas that specialize in patenting are "company towns." Of the 38 unit areas in metro areas with less than 1 million jobs that specialize in patenting, 24 (63 percent) rely on two organizations to provide at least half the patents; 13 (34 percent) are rely on one organization. In contrast, of the 34 patent-specializing unit areas in metro areas with more than a million jobs, just four (12 percent) depend on two organizations for over half the patents. All four are relatively small outer PMSAs.[79]

Table 3.9 illustrates this pattern, showing those unit areas with less than 1 million jobs and specializing in patenting with the highest and lowest reliance on two patenting organizations.

In almost every metro and unit area that specializes in patenting, the top patenting organizations are Fortune 1000 firms. This finding is consistent with the section 3.1 finding that large firms carry out the majority of industrial R&D. It is extremely rare to find a corporation not in the Fortune 1000.[80] An academic, federal government, or nonprofit institution is the first or second top patenting organization only in 18 of the 72 high patenting unit areas. (A list of the top two patenting organizations for unit areas that specialize in patenting is provided in Appendix B.)

The experience of the last decade suggests that high patenting rates for unit areas often are not sustained, particularly in areas dependent on older industries and one or two firms.

Table 3.10 shows the ten unit areas in 1990 and 1999 with the highest patenting rates. A review of the table indicates the following:

- Only four of the ten unit areas with the highest patent rate in 1990 remained on the list in 1999.
- Those areas leaving the list relied on established industries (advanced materials, telecommunications, oil) for innovation; those coming to the list in 1999 all had significant involvement in new forms of information technology.

[79] Dutchess County, NY (115,000 jobs), outside of New York City; Hamilton-Middletown, OH (133,000 jobs), outside of Cincinnati; Brazoria, TX (79,000 jobs), outside of Houston; and Wilmington-Newark, DE-MD (334,000 jobs), outside of Philadelphia.

[80] In 2002, members of the Fortune 1000 had at least $1.18 billion in revenues.

Table 3.10: Trends in Patenting Rate, Top Ten Unit Areas in 1990 and 1999						
Unit Areas with Highest Patents per 100,000 Jobs (1990)	Unit Area Jobs (000s)	Metro Area Jobs (000s)	% Patents from Top 2 Orgs.[a]	Patents Per 100,000 Jobs		
				1990	1999	% Change
Brazoria, TX PMSA	71	1,828	69.1	204.3	113.2	-44.6
Trenton, NJ PMSA	196	9,575	19.7	192.9	167.0	-13.4
Saginaw-Bay City-Midland, MI MSA	169	169	71.6	188.6	123.2	-34.7
Rochester, NY MSA	530	530	80.1	172.9	280.0	62.0
San Jose, CA PMSA	899	3,332	10.3	144.0	544.9	278.4
Wilmington-Newark, DE-MD PMSA	290	2,884	62.7	139.0	125.3	-9.9
Middlesex-Somerset-Hunterdon, NJ PMSA	555	9,575	16.8	126.6	167.9	32.6
Boulder-Longmont, CO PMSA	129	1,079	13.8	124.4	264.5	112.6
Elmira, NY MSA	43	43	69.2	114.8	102.4	-10.8
Corvallis, OR MSA	32	32	49.1	114.8	262.2	128.5
Unit Areas with Highest Patents per 100,000 Jobs (1999)						
San Jose, CA PMSA	1,039	3,754	11.6	144.0	544.9	278.4
Boise City, ID MSA	227	227	82.5	56.0	480.8	758.5
Dutchess County, NY PMSA	115	9,926	81.3	89.1	319.0	258.0
Rochester, NY MSA	560	560	80.6	172.9	280.0	62.0
Rochester, MN MSA	85	85	83.4	73.4	270.3	268.4
Boulder-Longmont, CO PMSA	180	1,458	8.8	124.4	264.5	112.6
Corvallis, OR MSA	39	39	74.3	114.8	262.2	128.5
Austin-San Marcos, TX MSA	670	670	54.1	84.7	234.4	176.8
Fort Collins-Loveland, CO MSA	124	124	63.9	74.5	224.9	202.0
Santa Cruz-Watsonville, CA PMSA	110	3,754	18.8	75.6	222.4	194.3
U.S. unit area median				26.1	33.8	29.5
U.S.				40.3	61.4	52.4
U.S. metro				44.2	68.1	54.0
U.S. rural				19.6	26.4	34.3

[a] For 1990 leading organizations, patent data for 1995, earliest year available.

Sources: Patents, U.S. Patent and Trademark Office; jobs, U.S. Bureau of Economic Analysis.

- Of the leading areas in 1990, four were diversified (top two patenting organizations provide less than 20 percent of patents) and five were dependent on one or two organizations to provide the majority of patents. All five dependent areas were not on the 1999 list; four of the five (all reliant on advanced materials firms) actually saw a decline in patenting rate over the decade, in contrast to the experience of the nation as a whole. Only one diversified area, focused on older industries, experienced a patent rate decline.

- Every unit area in a metro area with fewer than 1 million was dependent on two firms for a majority of patents (with the bare exception of Corvallis, Oregon in 1990).
- Every area on the 1999 list experienced triple-digit percent growth in patenting rate over the decade, with one exception. However, seven of the ten areas show very high dependency on two firms for patent activity. This dependency could result in vulnerability to decline in patenting activity in the future if new firms or new industries emerge as innovation leaders.

3.2.3 Public R&D in Metro Areas

In this section, we explore the geography of R&D at academic, nonprofit research, and federal laboratories. These institutions can be valuable resources of technology transfer. For context, in 1998 academic institutions provided half of metro public R&D expenditures, federal laboratories provided 41 percent, and nonprofit research institutes provided nine percent.[81] For the most part, the analysis below is carried out at the metro level, reflecting the understanding that R&D resources are accessible throughout a CMSA. Section 3.2.4 examines the nature of the relationship between the geography of public R&D and the geography of patenting.

A summary of findings in this section is as follows:

- Public R&D is even more geographically concentrated than patenting. Only a fifth of metro areas specialize in public R&D. Moreover, over a quarter of metro areas have no such R&D.
- Federal intramural R&D expenditures are particularly concentrated geographically; academic/nonprofit R&D is concentrated, but much less so.
- Unlike for patenting, share of academic/nonprofit R&D relative to share of jobs does not fall dramatically with metro size class. Even so, certain trends are visible at either end of the size class spectrum:
  - First, as a group, metro areas with over 2.5 million jobs have the highest academic/nonprofit R&D intensity.
  - Second, as metro size declines, the range of R&D intensity widens considerably, particularly for metro areas below 250,000 jobs. Few of these areas specialize in academic/nonprofit R&D; nearly half have no measurable academic/nonprofit R&D. At the same time, almost a tenth of the smallest metro areas are “university towns”, with R&D location quotients of over 3.0.

[81] This analysis relies on a U.S. database of 1,820 R&D institutions, including 718 academic institutions, 847 federal R&D establishments, and 255 nonprofit research institutes. For 1998, metro public R&D expenditures totaled $47.5 billion; performer shares were $23.7 billion for academia, $19.7 billion for federal laboratories, and $4.2 billion for nonprofit research institutes. The nonprofit research institute data, gathered from three sources (see Table 3.4), cover only 60% of total R&D expenditures, as estimated by NSF, in that sector.

Only a fifth of metro areas specialize in public R&D. Over a quarter have no such R&D. As shown in Table 3.11, in 1998 only 54 metro areas (20 percent) specialized in public R&D, that is, had a share of metro public R&D greater than the share of metro jobs.[82] These metro areas had 71 percent of metro R&D expenditures and only 29 percent of metro jobs. Over a quarter of metro areas have no discernable public R&D.[83] In comparison, only two metro areas had no patents, again indicating that patenting activity does not necessarily require public R&D close by.

Federal intramural R&D expenditures are particularly concentrated geographically; academic/nonprofit R&D is concentrated, but much less so. As Table 3.11 indicates, in 1998 only 28 metro areas (10 percent) specialized in federal intramural R&D. In contrast, 63 metro areas (23 percent) specialized in academic/nonprofit R&D.[84]

The concentration of federal intramural R&D is striking. The 28 specializing metro areas accounted for 84 percent of metro federal intramural R&D expenditures (but only 22 percent of metro jobs). The Washington-Baltimore-Hagerstown CMSA alone had 26 percent of all in-house federal R&D expenditures. In fact, the seven metro areas with the largest shares of federal R&D activity together accounted for 66 percent of metro federal R&D (but only 16 percent of metro jobs).[85] On the other hand, almost half of metro areas had no federal R&D.[86] (See Maps 3.6 and 3.7)

The geographic concentration of federal intramural R&D is due largely to the facts that the Department of Defense, the Department of Energy, the National Aeronautics and Space Administration, and the National Institutes of Health together account for 82 percent of the federal intramural R&D budget, and that their research is largely carried out at a handful of sites.

Academic/nonprofit R&D is concentrated geographically and institutionally, though less so than federal intramural R&D. Over a third of metro areas do not have academic/nonprofit R&D.[87] As an indication of the relatively greater dispersal of

[82] This indicator also can be defined as a public R&D location quotient greater than or equal to 1.0.
[83] The analysis looks similar at the unit level. Only 64 unit areas (20 percent) specialize in public R&D; 85 (27 percent) do not have public R&D.
[84] For the purposes of analysis, we are combining academic and nonprofit research institute R&D expenditures. In terms of technology transfer dynamics, the two performing sectors are not too dissimilar. As the nonprofit research sector is relatively small, it simplifies the analysis to combine it with academia. For the record, however, nonprofit activity, which is devoted primarily to biomedical research, is about as geographically concentrated as federal R&D. In particular, the Boston NECMA has 21 percent of the sector's R&D expenditures.
[85] In addition to the Washington-Baltimore-Hagerstown CMSA, these are (in order of federal R&D share) Los Angeles-Riverside-Orange County (California) CMSA; San Francisco-Oakland-San Jose (California) CMSA, Houston-Galveston-Brazoria (Texas) CMSA, Santa Fe (New Mexico) MSA, Albuquerque (New Mexico) MSA, and Huntsville (Alabama) MSA.
[86] Again, the analysis for unit areas is similar. Only 34 (11 percent) specialized in federal R&D; 149 (47 percent) have no federal R&D.
[87] The analysis for unit areas is similar. Only 74 (23 percent) specialized in academic/nonprofit R&D; 84 (26 percent) have no academic/nonprofit R&D.

academic/nonprofit R&D compared to federal, in 1998 the top seven metro areas provided “only” 39 percent of metro academic R&D, compared to 28 percent of metro jobs. The greater Boston has the largest share of metro academic/nonprofit R&D, at 7.7 percent, followed closely by the Washington-Baltimore and New York metro areas, with 7.5 percent each.[88] (See Maps 3.8 and 3.9.)

The variation in academic/nonprofit R&D intensity (R&D expenditures per 100,000 jobs) across metro areas is quite wide, ranging from zero to $517 million for Bryan-College Station, Texas (Figure 3.7). Among all metro areas, the median R&D intensity is only $1.7 million.

A small number of institutions provide the bulk of the metro academic/nonprofit R&D. Of 817 metro institutions with R&D capability, just 80 universities and 10 nonprofit research institutes (those with at least $100 million in R&D annually) collectively account for 70 percent of the R&D.

Table 3.11: Public R&D Intensity of Metro Areas, by Performer, 1998

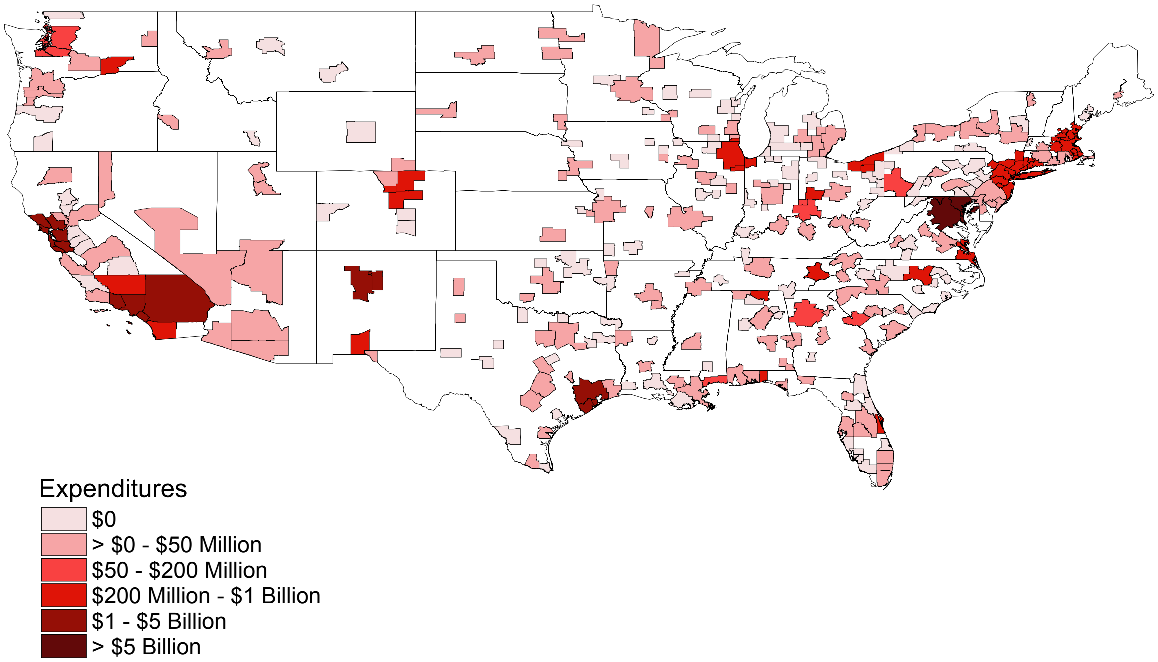
	# Metro Areas (N=276)	% Metro Areas	Median # Jobs (000s)	Median R&D $/100K Jobs (millions)	% Metro R&D by Performer	% Metro Jobs
Public R&D[a]						
LQ > 1	54	19.6	151	$111.9	70.8	29.2
0 < LQ > 1	146	52.9	181	6.5	29.2	64.5
LQ = 0	76	27.5	69	0.0	0.0	6.3
Academic/Nonprofit[b]						
LQ > 1	63	22.8	234	$47.6	71.0	35.3
0 < LQ > 1	115	41.7	194	3.7	29.0	56.5
LQ = 0	98	35.5	72	0.0	0.0	8.2
Federal[c]						
LQ > 1	28	10.1	189	$44.8	83.7	21.8
0 < LQ > 1	121	43.8	218	2.1	16.3	64.7
LQ = 0	127	46.0	81	0.0	0.0	13.6

[a] Metro areas with public R&D intensity greater than the U.S. metro rate of $42.4 million per 100,000 jobs have a location quotient greater than 1.
[b] Metro areas with academic/nonprofit R&D intensity greater than the U.S. metro rate of $24.8 million per 100,000 jobs have a location quotient greater than 1.
[c] Metro areas with federal R&D intensity greater than the U.S. metro rate of $17.6 million per 100,000 jobs have a location quotient greater than 1.

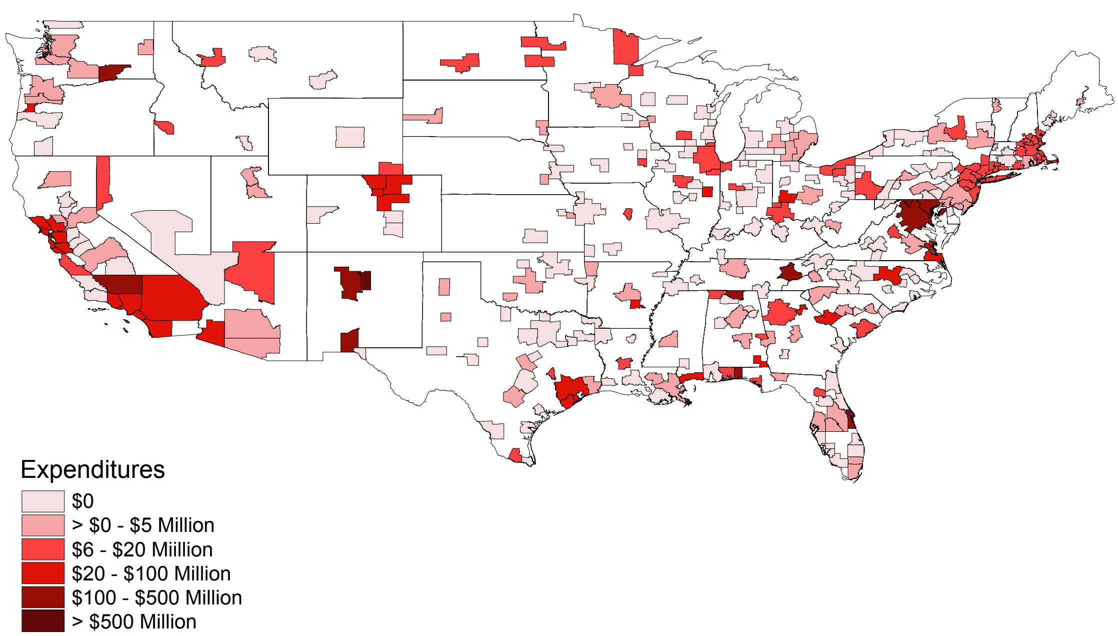
Sources: R&D from National Science Foundation, Association of University Technology Managers, and RAND Corporation; jobs, U.S. Bureau of Economic Analysis.

[88] The other four leaders (in order of share) are San Francisco-Oakland-San Jose (California) CMSA, Los Angeles-Riverside-Orange County (California) CMSA, Raleigh-Durham-Chapel Hill (North Carolina) MSA, and Philadelphia-Wilmington-Atlantic City (Pennsylvania-New Jersey-Delaware-Maryland) CMSA.

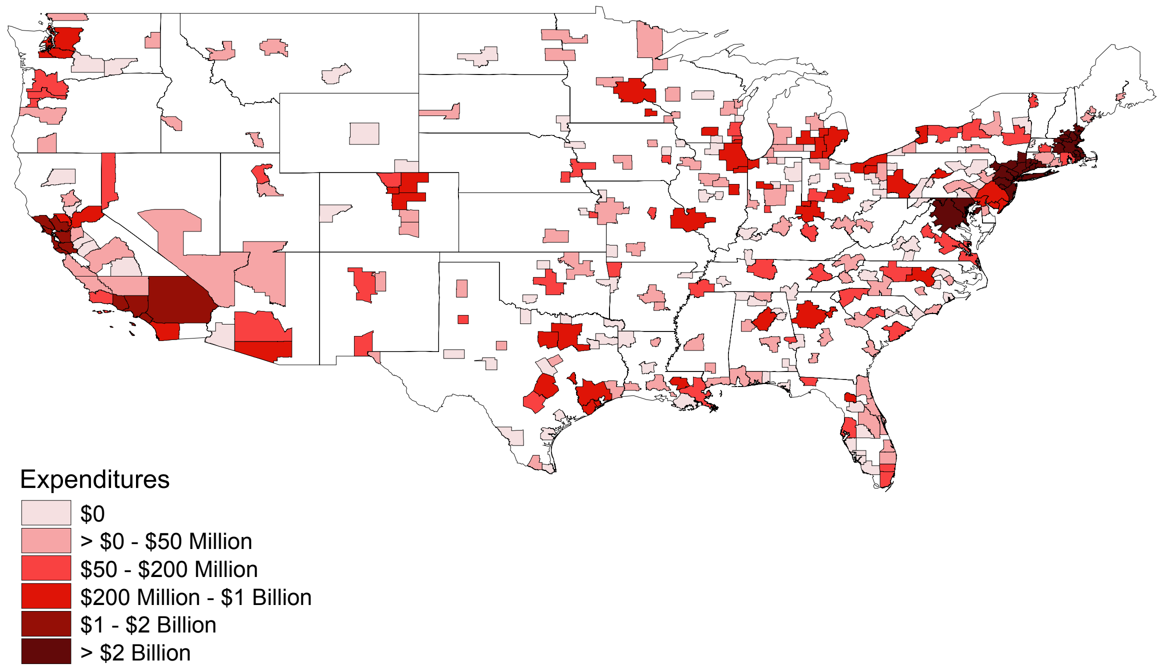
Map 3.6: Federal Intramural R&D, 1998



Map 3.7: Federal Intramural R&D per 100,000 Jobs, 1998



Map 3.8: Academic/Nonprofit R&D, 1998



Map 3.9: Academic/Nonprofit R&D per 100,000 Jobs,1998

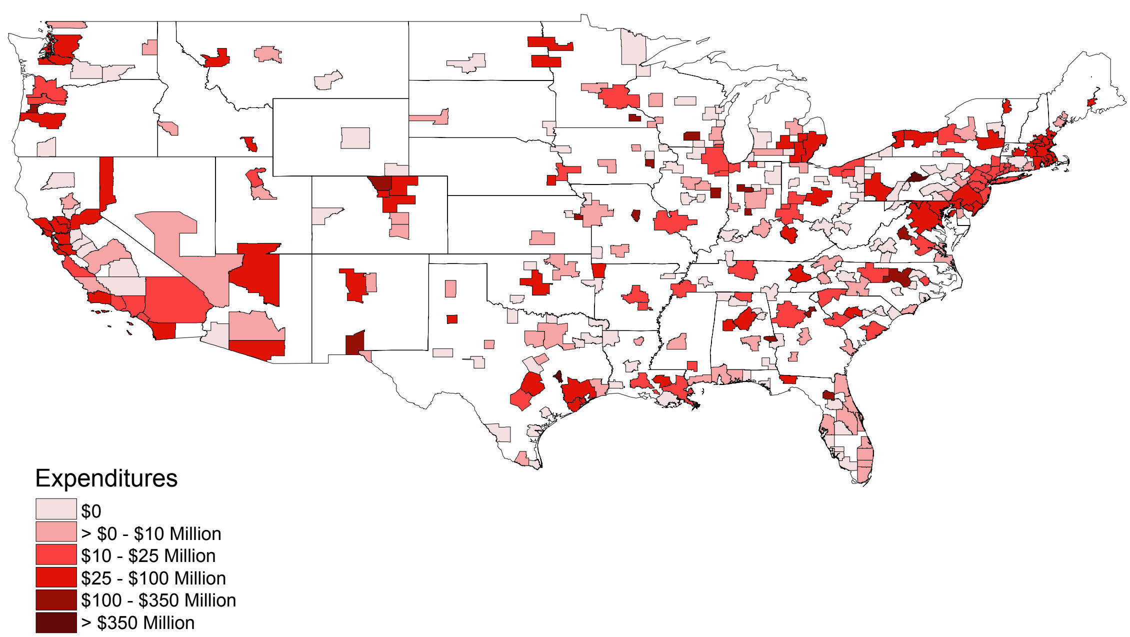
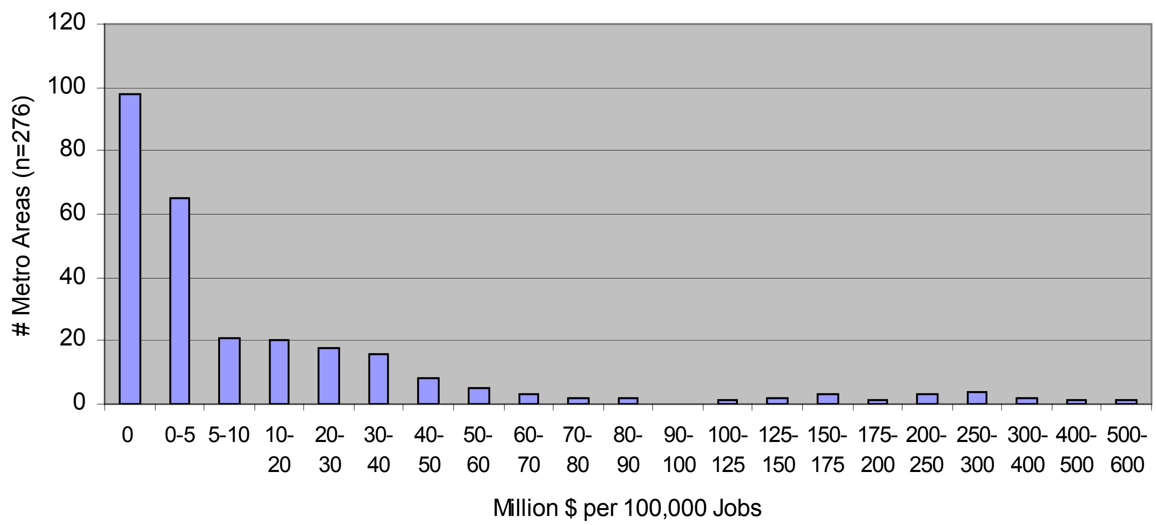


Figure 3.7: Distribution of Metro Areas by Academic/Nonprofit R&D Intensity, 1998



In light of the relatively greater dispersal of academic/nonprofit R&D in comparison to federal R&D, the far higher patent productivity of that sector (see Section 3.1), and difficulties inherent in technology transfer from much of national security-related R&D (which dominates the federal R&D budget) the following analysis focuses largely on the academic/nonprofit sector.

Unlike for patenting, share of academic/nonprofit R&D relative to share of jobs does not fall dramatically with metro size class. Even so, certain trends are visible at either end of the size class spectrum.

Figure 3.8 provides the share of metro jobs and academic/nonprofit R&D by jobs size class. Unlike Figure 3.6, there is no straightforward linear decline in class location quotient as metro job size falls.[89] In general, the distribution of academic/nonprofit R&D among the various job size classes is not too dissimilar to the distribution of jobs. The R&D share of metro areas with 2.5 million or more jobs does visibly exceed the share of jobs, due primarily to the high R&D intensity in the Boston, Washington-Baltimore, and San Francisco-Oakland-San Jose metro areas. At the same time, the 250,000–500,000 job size class has a slightly greater share of R&D than it does of jobs, and the 1–1.5 million job size class has an equal share of each.

[89] The correlation between academic/nonprofit R&D intensity and metro size is almost zero.

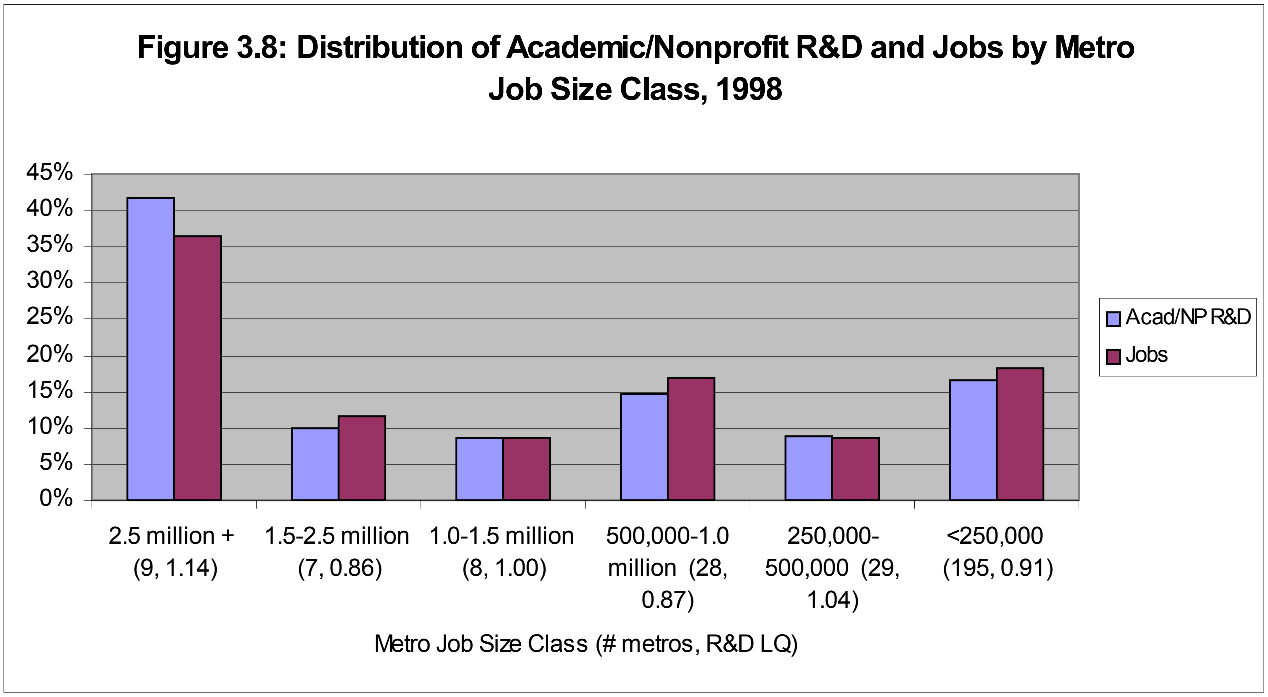


Table 3.12: Metro Area Academic/Nonprofit R&D Intensity and Specialization by Jobs Size Class, 1998

MSA/CMSA Jobs Size Class (# in class)	R&D/100K Jobs (million $) Median	Mean	Standard Deviation[b]	R&D Location Quotient[a] LQ=0 #	LQ=0 %	LQ>1 #	LQ>1 %	LQ>3 #	LQ>3 %
2.5 million + (9)	$26.2	$30.5	$17.4	0	0.0	5	55.5	0	0.0
1.5-2.5 million (7)	21.3	20.5	8.7	0	0.0	3	42.9	0	0.0
1.0-1.5 million (8)	21.8	23.7	15.4	0	0.0	3	37.5	0	0.0
500,000-1.0 million (28)	14.7	21.9	27.7	0	0.0	8	28.6	1	3.6
250,000-500,000 (29)	13.2	25.5	33.6	3	10.3	12	41.4	2	6.9
<250,000 (195)	0.1	26.8	77.6	95	48.7	32	16.4	18	9.2
250,000-2.5 million + (81)	17.9	24.2	27.2	3	3.7	31	38.3	3	3.7
<250,000 (195)	0.1	26.8	77.6	95	48.7	32	16.4	18	9.2
All (276)	1.7	26.0	66.9	98	35.5	63	22.8	21	7.6

[a] Share of metro area academic/nonprofit R&D divided by share of metro area jobs. Metro areas with non-industrial R&D expenditures greater than the U.S. metro rate of $24.8 million per 100,000 jobs have a location quotient greater than 1.
[b] Standard deviation is a measure of dispersion around the mean. For any set of normally distributed observations, about two-thirds fall within the range of the mean plus and minus the standard deviation.

Sources: R&D, National Science Foundation and Association of University Technology Managers; jobs, U.S. Bureau of Economic Analysis.

However, Table 3.12 shows that the graph masks a number of trends in the geography of R&D. Essentially, as job size classes fall below 1 million, the dispersion of R&D intensity widens; for the job size class of less than 250,000 jobs, the rate of specialization falls and the dispersion widens dramatically. Nearly half of the small metro areas have no measurable academic/nonprofit R&D. Only 16 percent of metro areas in this class specialize in R&D, compared to 38 percent for metro areas with more than 250,000 jobs. Yet over half of the small areas that specialize in R&D have location quotients of over 3.0. In general, "university towns" with high R&D expenditures but few jobs not connected to the university have the highest academic/nonprofit R&D intensity for metro areas, by far (Table 3.13).[90] In fact, despite the large number of small metro areas without academic/nonprofit R&D, the large R&D budgets of state universities located in small metro areas results in that size class having the second highest mean R&D intensity.

Table 3.13: Metro Areas with Highest Academic/Nonprofit R&D Intensity, by Jobs Size Class, 1998

MSA/CMSA Jobs Size Class	Leading Metro Area	R&D/100K jobs (million $)	LQ	Total R&D (million $)	Primary R&D Institutions
2.5 million +	Boston-Worcester-Lawrence-Lowell-Brockton, MA-NH NECMA	$64.6	2.59	$2,105,157	MIT, Harvard, Mass. General Hospital
1.5-2.5 million	Houston-Galveston-Brazoria, TX CMSA	34.8	1.40	789,856	Baylor Univ., Univ. of Texas
1.0-1.5 million	San Diego, CA MSA	56.3	2.26	733,648	UC-San Diego
500,000-1.0 million	Raleigh-Durham-Chapel Hill, NC MSA	141.7	5.69	963,967	Duke, NC State, Univ. of North Carolina
250,000-500,000	Madison, WI MSA	154.2	6.19	443,695	Univ. of Wisconsin
<250,000	Bryan-College Station, TX MSA	516.6	20.73	393,720	Texas A&M
	State College, PA MSA	467.2	18.75	362,643	Penn State Univ.
	Corvallis, OR MSA	340.5	13.67	138,240	Oregon State Univ.
	Champaign-Urbana, IL MSA	327.8	13.16	329,266	Univ. of Illinois
	Athens, GA MSA	284.7	11.43	217,945	Univ. of Georgia
	Iowa City, IA MSA	278.3	11.17	199,063	Univ. of Iowa
	Bloomington, IN MSA	255.8	10.27	171,754	Indiana University
	Rochester, MN MSA	230.3	9.24	189,200	Mayo Foundation
	Gainesville, FL MSA	228.6	9.17	274,862	Univ. of Florida
	Lawrence, KS MSA	225.8	9.06	117,115	Univ. of Kansas
	Lafayette, IN MSA	221.6	8.89	216,479	Purdue Univ.

Sources: for R&D, National Science Foundation, Association of University Technology Managers, and RAND Corporation; for jobs, U.S. Bureau of Economic Analysis

[90] Note in the table that the dominant university in every metro area below 500,000 jobs is a public university.

3.2.4 The Relationship between Metro Area Patenting and Public R&D

In the archetypal image of regional advanced technology development, university R&D facilities feed innovations to corporations which turn these new technologies into commercially viable products, creating new jobs in the process. However, from previous analysis, we saw that the presence of public R&D is not strongly correlated statistically with patenting activity; while it may be helpful, it often does not have a strong impact. In this section, we explore further the relationship between the geography of public R&D to the geography of patenting.

First, we examine the connection between academic/nonprofit R&D and patenting, then that for federal R&D and patenting. For this analysis, we look at patenting specialization at the unit level, the level at which economic development agencies operate. However, as noted earlier, we recognize that patenting organizations in one PMSA have the opportunity to draw on public R&D throughout the CMSA. Consequently, for this analysis, a PMSA is said to specialize in academic/nonprofit or federal R&D if either its location quotient or the CMSA location quotient are greater than one.

A summary of findings for this section is as follows:

- Very few unit areas specialize in both patenting and academic/nonprofit R&D.
- Specialization in patenting clearly does not require specialization in academic/nonprofit R&D.
- Conversely, specialization in academic/nonprofit R&D is no guarantee that a unit area will specialize in patenting. Even so, specialization in academic/nonprofit R&D does greatly increase the likelihood that a metro area also specializes in patenting.
- The above findings hold by metro jobs class. However, again, size matters:
  - While specialization in academic/nonprofit R&D improves the likelihood of specialization in patenting, particularly for smaller metro areas, metro size has a significantly greater impact.
  - Size greatly improves the likelihood of specialization in patenting, academic/nonprofit R&D, or both.
- Findings regarding the relationship between federal R&D activity and patenting are similar to those for academic/nonprofit R&D.

The number of unit areas that specialize in patenting and in academic/nonprofit R&D is very small. Seventy-two unit areas specialize in patenting, and 89 specialize in academic/nonprofit R&D, but only 37 (12 percent of 318) specialize in both (Table 3.14).

Specialization in patenting does not require specialization in academic/nonprofit R&D. As Table 3.14 indicates, nearly half of the unit areas specializing in patenting do not specialize in academic/nonprofit R&D.

Table 3.14: Distribution of Unit Areas by Specialization in Patenting and Academic/Nonprofit R&D

		Academic/Nonprofit R&D LQ[a]					
		>1		<1		Total	
		#	%	#	%	#	%
Patenting LQ	>1	37	11.6	35	11.0	72	22.6
	<1	52	16.4	194	61.0	246	77.4
	Total	89	28.0	229	72.0	318	100.0
Patenting LQ	>1		51.4		48.6		100.0
	<1		21.1		78.9		100.0
	Total		28.0		72.0		100.0
Patenting LQ	>1		41.6		15.2		22.6
	<1		58.4		84.7		77.4
	Total		100.0		100.0		100.0

[a] For PMSAs in this analysis, the academic/nonprofit R&D LQ is considered greater than 1 if either the PMSA LQ >1 or its CMSA LQ > 1.

Conversely, specialization in academic/nonprofit R&D is no guarantee that a unit area will specialize in patenting. Even so, specialization in academic/nonprofit R&D greatly increases the likelihood that a metro area also specializes in patenting. According to Table 3.14, only 42 percent of unit areas specializing in the former specialize in the latter. However, the likelihood that an area that does not specialize in academic/nonprofit R&D specializes in patenting is barely one-third as high (15 percent).

Size greatly improves the likelihood of specialization in patenting, academic/nonprofit R&D, or both. As Figure 3.9 indicates, 75 percent of units in metro areas of over 1 million jobs specialize, compared to less than 30 percent of those in smaller metro areas.

Metro size has a significantly greater impact on specialization in patenting than does specialization in academic/nonprofit R&D. For metro areas with less than 1 million jobs, specialization in academic/nonprofit R&D greatly improves the likelihood of specialization in patenting, but for the most part cannot overcome the advantages of size.

Figure 3.9 shows that for metro areas with over 1 million jobs, unit areas are more likely to specialize in patenting, whether or not the metro area specializes in academic/nonprofit R&D, compared to their counterparts in smaller metro areas.

Figure 3.9: Percent Unit Metro Areas Specializing in Patents and Academic/Nonprofit R&D, by Metro Jobs Size Class

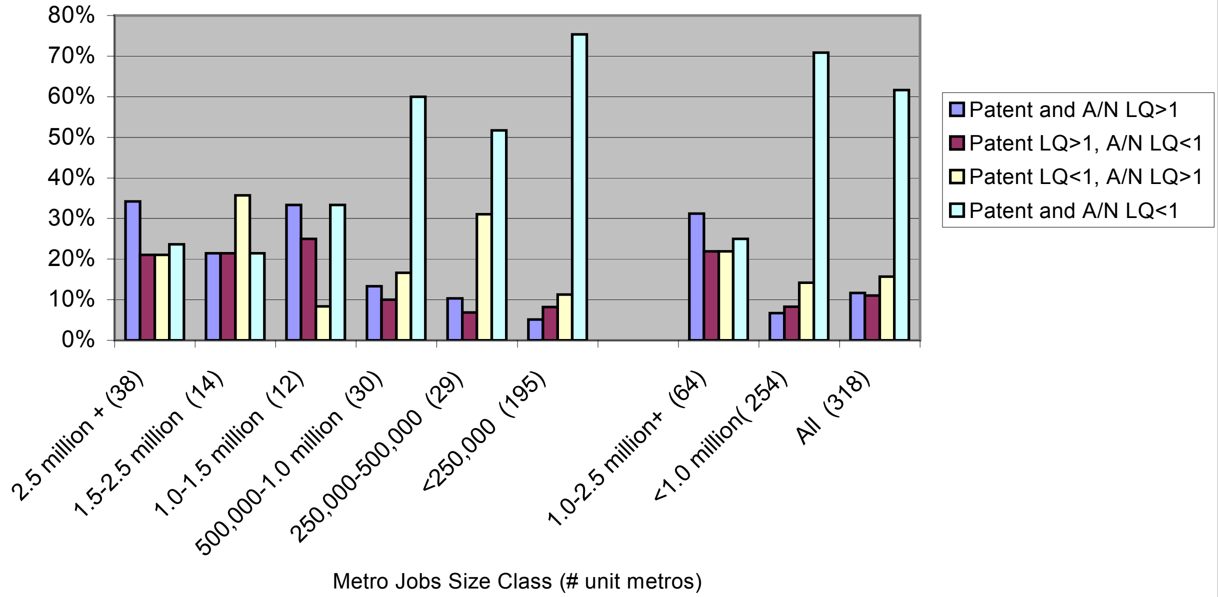
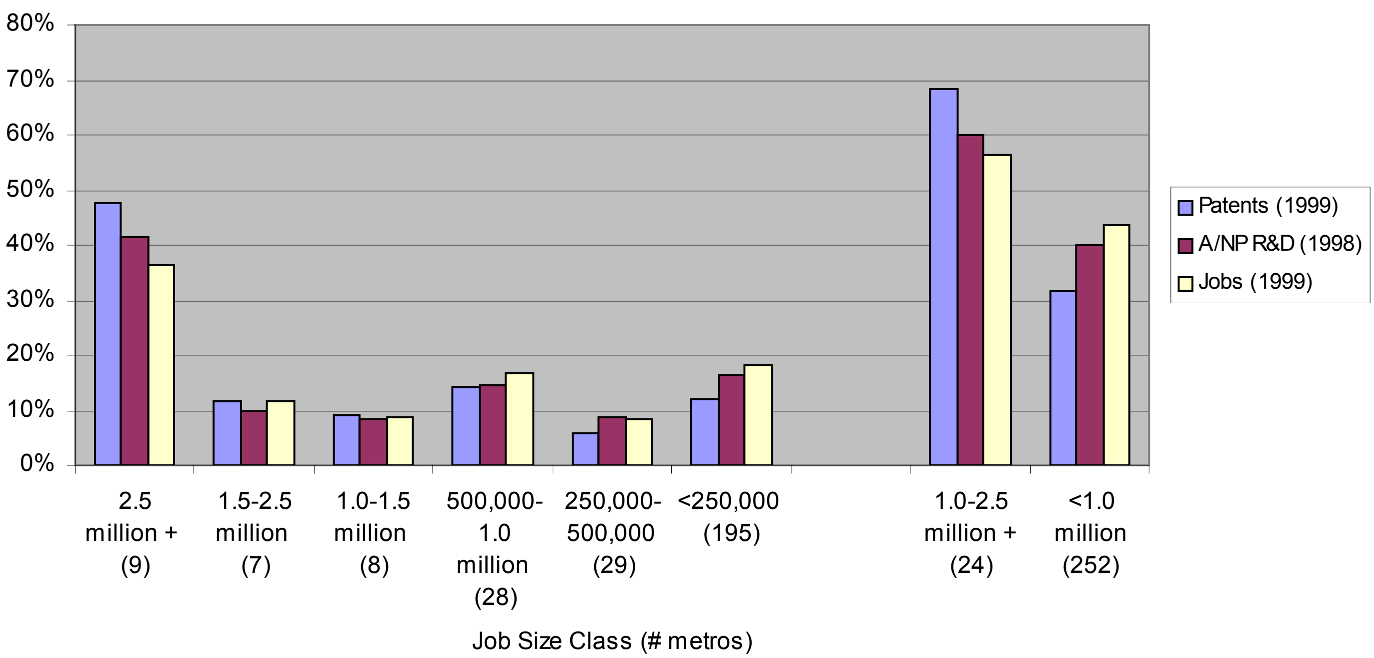


Figure 3.10: Distribution of Patenting and Academic/Nonprofit R&D by Metro Job Size Class



In metro areas of over 1 million jobs specializing in academic/nonprofit R&D, 59 percent of unit areas specialize in patenting; for smaller metro areas that specialize in academic/nonprofit R&D, only 32 percent of unit areas specialize in patenting. In larger metro areas that do not specialize in academic/nonprofit R&D, 47 percent of unit areas specialize in patenting; for smaller metro areas, the comparable figure is only 10 percent.

For smaller metro areas, specialization in academic/nonprofit R&D increases the likelihood of specialization in patenting from 10 to 32 percent. For larger metro areas, the impact is positive, but not as great (47 percent vs. 59 percent).

Still, units in larger metro areas are more likely to specialize in patenting, regardless of their specialization in academic/nonprofit R&D, than are units in smaller metro areas. For smaller areas, specialization in patenting and specialization in R&D tend to be independent phenomena. Some areas are dependent on one or two large corporations for patents and have little local academic/nonprofit R&D. Other areas are "university towns" without high patenting rates.

The relative dominance of larger metro areas regarding share of patents and share of academic/nonprofit R&D compared to share of jobs can be seen in Figure 3.10. While share of academic/nonprofit R&D is relatively high, share of patents is higher still, particularly for the largest size class.

These results prompt the following observations:

- In general, as suggested earlier, metro areas with over 1 million jobs are more likely to have the critical mass of technology-focused industry, services, researchers, and amenities that stimulates and enables technology development.
- In the larger cities, the critical mass of academic/nonprofit R&D activity useful in supporting industrial technology development may be below the level of specialization.
- Because of their breadth of resources, larger metro areas can better enable the transfer of technology from academic/nonprofit institutions to local industry. A study of the relationship between metro size, academic R&D, and innovation indicates a given level of academic R&D has dramatically less impact on local innovations as metro area population declines.[91]
- Some smaller metro areas host patent activity for one or two large corporations with little need for access to local academic/nonprofit R&D.

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[91] Attila Varga, "Local Academic Knowledge Transfer and the Concentration of Economic Activity," *Journal of Regional Science*, Vol. 40, No. 2, 2000, pp. 289-309. Varga analyzed innovative activity in 1982, and determined that, at that time, $300 million in university research yielded 112 innovations for tier one cities (average population 3 million), only 16 innovations for tier two cities (average population 1 million), 5 for tier three (average population 400,000), and 2 for tier four (average population 200,000).

Findings regarding the relationship between federal R&D activity and patenting are consistent with, and stronger in degree than, those for academic/nonprofit R&D.

- The number of unit areas that specialize in patenting and in federal R&D is very small. As Table 3.15 shows, only 20 (6 percent) unit areas specialize in both.
- Specialization in patenting does not require specialization in federal R&D. As Table 3.15 indicates, almost three-quarters of areas specializing in patenting do not specialize in federal R&D.
- Conversely, specialization in federal R&D is no guarantee that a unit area will specialize in patenting. According to Table 3.15, only 43 percent of unit areas specializing in the former specialize in the latter. In fact, of the 15 unit areas with the highest federal R&D intensity, only four specialize in patenting (Table 3.16).
- Even so, specialization in federal R&D greatly increases the likelihood that a metro area also specializes in patenting. The likelihood that an area that does not specialize in academic/nonprofit R&D specializes in patenting is less than half as high (19 percent).
- Size greatly improves the likelihood of specialization in patenting, federal R&D, or both. Sixty-nine percent of units in metro areas of over 1 million jobs specialize, compared to only 21 percent of those in smaller metro areas.
- For metro areas with less than 1 million jobs, specialization in federal R&D greatly improves the likelihood of specialization in patenting, but cannot overcome the advantages of size. For smaller metro areas that specialize in federal R&D, 27 percent of unit areas specialize in patenting; among those not specializing in federal R&D, only 9 percent specialize in patenting. For larger metro areas, the impact of specialization in federal R&D is positive, but not nearly as great (58 percent vs. 51 percent). Even so, units in larger metro areas are far more likely to specialize in patenting, regardless of their specialization in federal R&D, than are units in smaller metro areas.

Table 3.15: Distribution of Unit Areas by Specialization in Patenting and Federal R&D

		Federal R&D LQ[a]					
		>1		<1		Total	
		#	%	#	%	#	%
Patenting LQ	>1	20	6.3	52	16.4	72	22.6
	<1	26	8.2	220	69.2	246	77.4
	Total	46	14.5	272	85.5	318	100.0
Patenting LQ	>1		27.8		72.2		100.0
	<1		10.6		89.4		100.0
	Total		14.5		85.5		100.0
Patenting LQ	>1		43.5		19.1		22.6
	<1		56.5		80.9		77.4
	Total		100.0		100.0		100.0

[a] For PMSAs in this analysis, the federal R&D LQ is considered greater than 1 if either the PMSA LQ >1 or its CMSA LQ > 1.

Sources: federal R&D, RAND; patents, U.S. Patent and Trademark Office.

Table 3.16: Patenting Rates for Unit Areas with Highest Federal R&D Location Quotients

	MSA/CMSA jobs	Federal R&D LQ[a]	Patenting LQ	Academic/Non profit LQ[a]
Santa Fe, NM MSA	78,838	88.20	1.27	0.15
Huntsville, AL MSA	190,320	24.73	0.83	0.81
Las Cruces, NM MSA	60,566	20.34	0.34	5.35
Richland-Kennewick-Pasco, WA MSA	86,437	19.79	0.93	0.00
Fort Walton Beach, FL MSA	92,905	17.10	0.41	0.00
Albuquerque, NM MSA	367,690	16.14	0.91	1.45
Washington, DC-MD-VA-WV PMSA	4,262,884	9.50	0.66	2.15
Bakersfield, CA MSA	256,938	8.15	0.32	0.00
Melbourne-Titusville-Palm Bay, FL MSA	195,421	7.18	1.34	0.12
Baltimore, MD PMSA	4,262,884	**7.15**	0.74	**2.04**
Hagerstown, MD PMSA	4,262,884	**7.15**	0.13	**2.04**
Knoxville, TN MSA	352,601	6.44	0.82	1.78
Corvallis, OR MSA	38,526	5.14	3.85	13.72
Oakland, CA PMSA	3,754,251	5.02	2.17	**1.63**
Pine Bluff, AR MSA	39,123	4.77	0.04	0.43

[a] For PMSAs, federal and academic/nonprofit location quotients are for PMSA or CMSA, whichever is higher. CMSA location quotients are in bold.

Sources: Jobs, U.S. Bureau of Economic Analysis; federal R&D, RAND; patents, U.S. Patent and Trademark Office; academic and nonprofit R&D, NSF and Association of University Technology Manager.

3.2.5 The Role of Science and Engineering Graduate Students

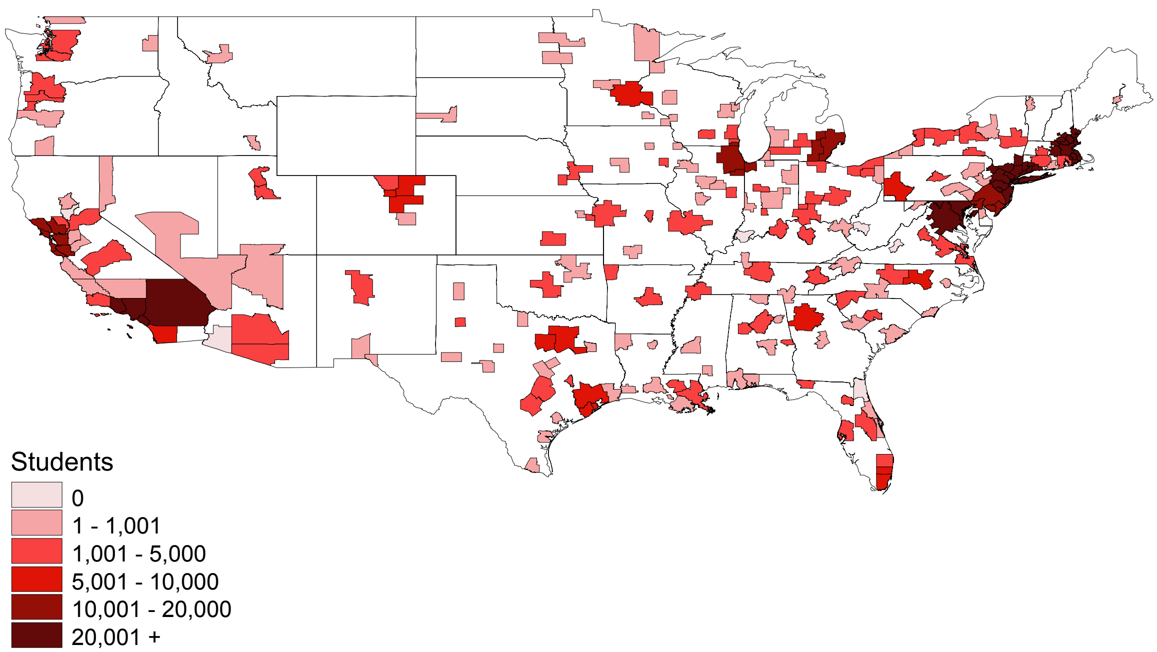
Several observers have posited the value to technology development of the co-location of industrial R&D with graduate science and engineering (S&E) programs. The thought is that a steady local stream of S&E graduates yields a knowledgeable, motivated technical workforce available to carry out R&D in established firms and startups.

As might be expected, S&E graduate student intensity (S&E graduate students per 100,000 jobs) is highly correlated with academic/nonprofit R&D intensity.[92] (See Maps 3.10 and 3.11.) Consequently, the pattern of impact of S&E graduate programs on patenting is quite similar to that of academic/nonprofit R&D. A summary is as follows:

- In general, differences in metro and unit area S&E graduate program intensity explain relatively little of the difference in patenting rates.[93]
- Compared to the other measures, a relatively high percent of metro areas specialize in S&E graduate student education (27 percent). The rate of unit area specialization is even higher (31 percent).
- However, just 12 percent of unit areas specialize in both S&E graduate education and patenting (see Table 3.17).
- Specialization in patenting does not require specialization in S&E graduate education. As Table 3.17 indicates, almost half of areas specializing in patenting do not specialize in S&E graduate education.
- Conversely, specialization in S&E graduate education is no guarantee that a unit area will specialize in patenting. According to Table 3.17, only 39 percent of unit areas specializing in the former specialize in the latter.
- Even so, specialization in S&E graduate education greatly increases the likelihood that a metro area also specializes in patenting. The likelihood that an area that does not specialize in academic/nonprofit R&D specializes in patenting is less than half as high (15 percent).
- Size greatly improves the likelihood of specialization in patenting, S&E graduate education, or both. Seventy percent of units in metro areas of over 1 million jobs specialize, compared to only 35 percent of those in smaller metro areas.
- For metro areas with less than 1 million jobs, specialization in S&E graduate education greatly improves the likelihood of specialization in patenting, but cannot overcome the advantages of size. For smaller metro areas that specialize in S&E graduate education, 26 percent of unit areas specialize in patenting; among those not specializing in S&E graduate education, only 11 percent specialize in patenting. For larger

[92] The correlation coefficient is 0.87 (with 1.0 being perfect correlation). The correlation coefficient between academic R&D intensity only (without nonprofit R&D) and S&E graduate student intensity is just slightly higher, 0.89.
[93] Differences among the former explain four percent of differences among the latter.

Map 3.10: S & E Graduate Students, 1999



Map 3.11: S & E Graduate Students per 100,000 Jobs, 1999

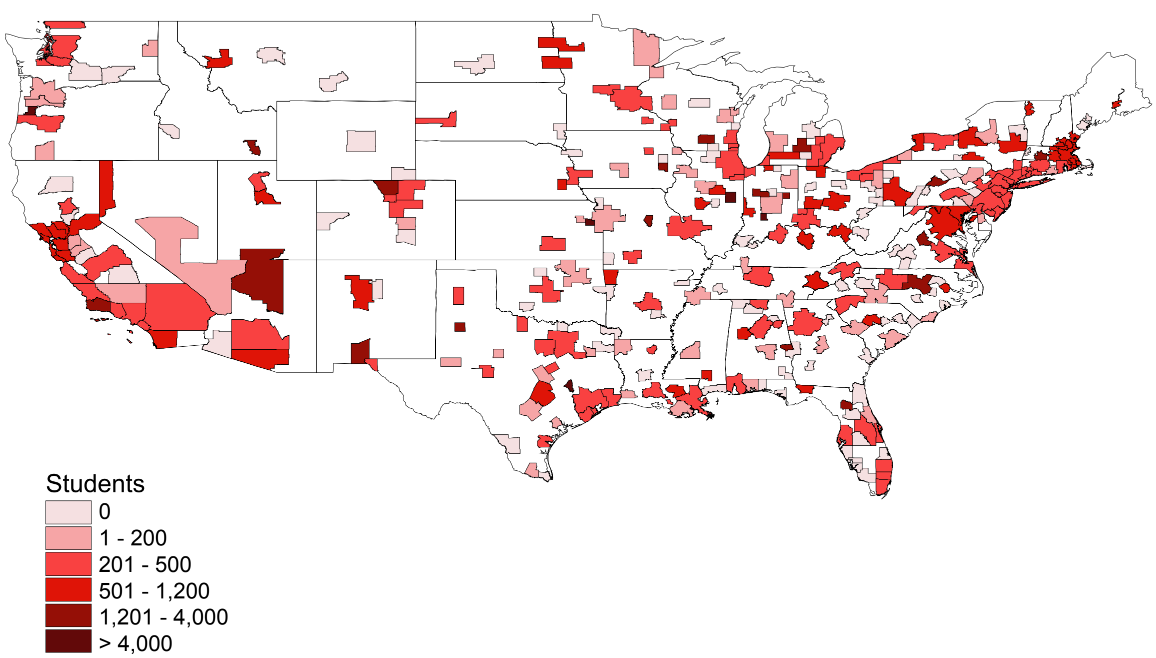


Table 3.17: Distribution of Unit Areas by Specialization in Patenting and S&E Graduate Education

		S&E Graduate Education LQ[a]					
		>1		<1		Total	
		#	%	#	%	#	%
Patenting LQ	>1	39	12.3	33	10.4	72	22.6
	<1	61	19.2	185	58.2	246	77.4
	Total	100	31.4	218	68.6	318	100.0
Patenting LQ	>1		54.2		45.8		100.0
	<1		24.8		75.2		100.0
	Total						100.0
Patenting LQ	>1		39.0		15.1		22.6
	<1		61.0		84.9		77.4
	Total		100.0		100.0		100.0

[a] For PMSAs in this analysis, the S&E graduate education LQ is considered greater than 1 if either the PMSA LQ >1 or its CMSA LQ > 1.

Sources: Patents, U.S. Patent and Trademark Office; S&E graduate students, National Science Foundation.

metro areas, the impact of specialization in S&E graduate education is even greater (66 percent vs. 41 percent). Moreover, units in larger metro areas are far more likely to specialize in patenting, regardless of their specialization in S&E graduate education, than are units in smaller metro areas.

3.2.6 The Impact of Technology Development Activity on Metro Area Economic Performance

From a public policy perspective, the fundamental purpose of the promotion of technology development activity is to encourage improvement in regional economic performance. In this section, we examine technology-related and other factors that influence four measures of economic performance—average annual wage, increase in average annual wage, growth in jobs, and growth in wage and salary disbursements. Average annual wage and increase in average annual wage reflect trends in value added. As discussed in Chapter One, the intent of technology-based development is to raise value added per worker and so improve the standard of living; a positive statistical correlation between technology development and wages would support this notion. It also is appropriate to explore the extent to which technology development influences the size of the local economy—growth in jobs and wage and salary disbursements are proxies for regional economic expansion.

A summary of findings in this section is as follows:

- Average annual wage (Map 3.12) and increase in average annual wage are found to be strongly influenced by patenting, industrial R&D, number of jobs, and educational attainment. Public R&D has a slight negative impact on the two wage measures. The presence of advanced technology has a somewhat positive affect on wage measures; the presence of advanced technology industries tends to reflect greater patenting activity and industrial R&D intensity.
- No aspect of technology development activity is found to have a positive impact on growth of regional earnings (Map 3.13) or jobs. The presence of advanced technology industries does not have an impact on regional growth as well.

Over three-quarters of the differences among unit areas in annual average earnings per job can be explained by differences in the number of patents, number of jobs, patenting rate, and educational attainment (in order of importance).[94] ***Academic/nonprofit R&D intensity and S&E graduate student intensity have slightly negative impacts.***

The raw number of patents explains over half the difference in average annual wages among unit areas. Number of patents in turn is influenced by metro size (number of jobs) and patenting rate (in turn, as we saw, influenced by presence of advanced technology, educational attainment, and metro size). Together, patents, number of jobs, and patenting rate explain almost 70 percent of the differences in annual average wage.

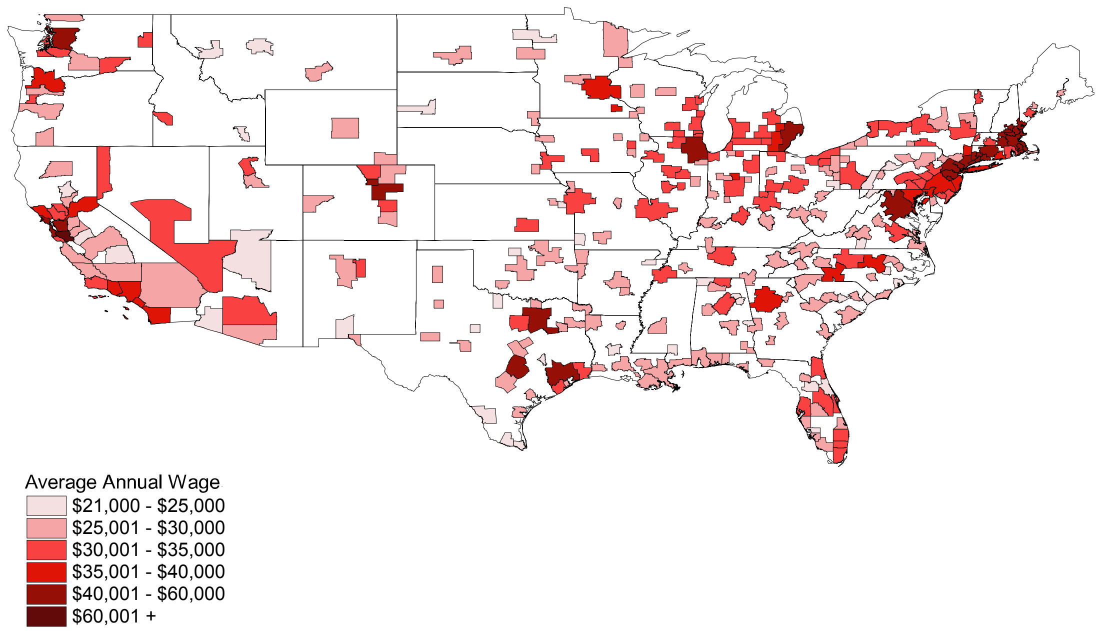
In statistical analysis at the state level, the substitution of industrial R&D intensity for patenting rate slightly increases the portion of average annual earnings explained.[95] That industrial R&D intensity has a slightly stronger impact than patenting rate is logical. Patenting is the largest and most perceptible outcome of industrial R&D, but there are other, difficult-to-measure, outcomes as well, such as new trade secrets. It should be remembered that patenting is largely an industrial phenomenon—academia and the federal government in combination only account for five percent of all patents.

At the unit level, academic/nonprofit R&D intensity and S&E graduate education intensity have slight negative impacts on average annual earnings. In large part, this is because average wages are quite low in many small university towns.

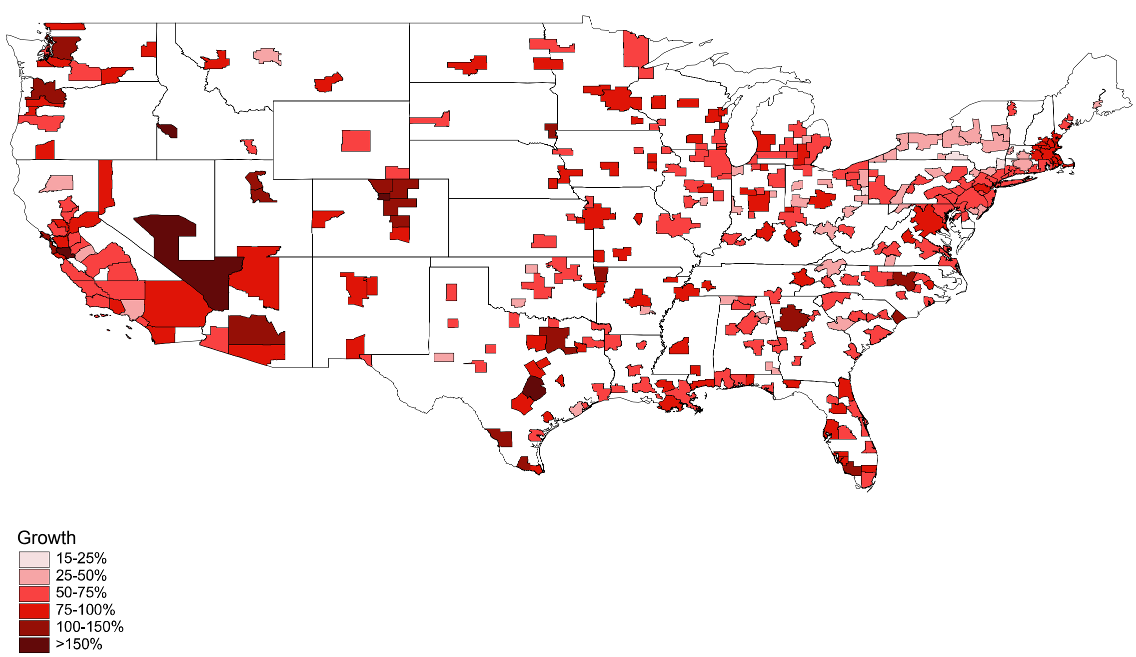
Table 3.18 provides evidence of the relationships suggested by the statistical analysis. The areas with the highest average earnings are in very large metro areas, with

[94] In the analysis, the dependent, or outcome, variable is 2000 average annual earnings per job.
[95] For states, average annual R&D intensity is measured over the period 1987-98. This period provides a far better fit than other periods tested.

Map 3.12: Average Annual Wage, 2000



Map 3.13: Growth in Wage and Salary Disbursements, 1990-2000



many patents; the reverse is true for the areas with the lowest earnings. In the first group, every area but one had a patenting rate above the median; only two did in the second group. Educational levels are above the median for every member of the first group, and below the median for every member but one in the second group (including two university towns). Consistent with prior findings, academic/nonprofit R&D intensity is well above the median for every member of the first group, and dispersed at either end of the spectrum in the second group. The three unit areas in the table with the highest academic/nonprofit R&D intensity are in the low earnings group. (All have a major research university.)

Increase in average annual earnings per job. For the increase in average annual earnings per job over the last decade, the statistical analysis yields approximately the same results.[96] Two-thirds of the difference among unit areas in terms of increase in annual average earnings is explained by differences in average annual number of patents, average annual number of jobs, average annual patenting rate, and educational attainment. Again, at the state level, the substitution of industrial R&D for patenting rate slightly boosts the proportion of differences in earnings increase that can be explained. S&E graduate education intensity and academic/nonprofit R&D intensity again have slight negative impacts on wage levels.

In general, the statistical analysis suggests, high industrial R&D intensity and patenting rate lead to greater increases in average annual earnings per job. Gaps between low average earning and high average earning areas have increased over the last decade largely due to these factors.

Table 3.19 illustrates the nature of these relationships for the unit areas with the highest and lowest increases in average annual earnings between 1990 and 2000. As in Table 3.18, the areas with the largest earnings increases are in large metro areas and tend to have high levels of patents and patenting rate, with the reverse being true for areas with low earnings increases. The relationship between academic/nonprofit R&D intensity and increase in earnings also has similar aspects to the previous table. All areas in the first group are above the median, while the second group is quite dispersed. The second group has the two areas with the highest academic/nonprofit R&D intensity and seven areas with zero academic/nonprofit R&D intensity.

Growth in Total Jobs and Earnings. Technology development activity—whether in the form of patenting, industrial R&D, and public R&D—appears to have negligible impact on two measures of regional economic growth—change in total jobs and total earnings (wage and salary disbursements). Educational attainment explains about a fifth the growth of wage and salary disbursements (by far the strongest impact of any of the variables); it has little explanatory power regarding the growth of jobs. The impact of metro size, academic/nonprofit R&D, and S&E graduate education are slightly negative.

[96] The dependent variable is the dollar increase in average annual earnings per job between 1990 and 2000. Independent variables for patenting cover the same period.

Table 3.18: Unit Areas with Highest and Lowest Average Annual Earnings Per Job, 2000, by Selected Characteristics

	Average Annual Earnings, 2000	MSA/ CMSA jobs, 1999	Patenting Rate, 1999	Total Patents, 1999	% Adults with Bachelor's Degree, 2000	Academic/ Nonprofit R&D per 100,000 jobs, 1998[a]
Unit Areas with Highest Earnings per Job						
San Jose, CA PMSA	$74,374	3,754,251	544.9	5,664	40.5	43.9
San Francisco, CA PMSA	59,077	3,754,251	149.2	1,700	43.6	50.0
New York, NY PMSA	56,434	9,926,248	38.9	1,704	29.2	26.1
New Haven-Bridgeport-Stamford-Danbury-Waterbury, CT NECMA	49,723	9,926,248	120.7	1,033	33.9	31.9
Middlesex-Somerset-Hunterdon, NJ PMSA	48,308	9,926,248	167.9	1,091	37.4	31.0
Newark, NJ PMSA	47,651	9,926,248	112.2	1,136	31.5	**21.5**
Jersey City, NJ PMSA	47,097	9,926,248	28.4	72	25.3	**21.5**
Seattle-Bellevue-Everett, WA PMSA	45,265	1,919,299	88.2	1,296	35.9	40.8
Washington, DC-MD-VA-WV PMSA	45,129	4,262,884	45.1	1,299	41.8	53.4
Boston-Worcester-Lawrence-Lowell-Brockton, MA-NH NECMA	44,395	3,321,855	114.6	3,806	34.4	65.7
Unit Areas with Lowest Earnings per Job						
Auburn-Opelika, AL MSA	$23,506	45,520	41.7	19	27.9	196.7
Hattiesburg, MS MSA	23,366	54,605	18.3	10	24.3	20.9
Visalia-Tulare-Porterville, CA MSA	23,317	138,941	9.4	13	11.5	0.0
Laredo, TX MSA	23,234	71,177	0.0	0	13.9	0.0
Las Cruces, NM MSA	23,151	60,566	23.1	14	22.3	132.7
Myrtle Beach, SC MSA	22,999	109,147	12.8	14	18.7	0.0
Lawrence, KS MSA	22,876	53,515	48.6	26	42.7	225.8
Yuma, AZ MSA	22,495	59,649	5.0	3	11.8	0.0
McAllen-Edinburg-Mission, TX MSA	21,536	162,967	3.1	5	12.9	1.1
Brownsville-Harlingen-San Benito, TX MSA	21,203	112,488	8.0	9	13.4	0.0
Unit area median	$28,968	168,171	33.8	54.5	22.7	4.2

[a] For PMSAs, academic/nonprofit R&D intensity is whichever is higher of PMSA and CMSA figure. CMSA figures are in bold.

Sources: Earnings and jobs, U.S. Bureau of Economic Analysis; patents, U.S. Patent and Trademark Office; educational attainment, U.S. Census Bureau; academic/nonprofit R&D from National Science Foundation, RAND, and Association of University Technology Managers.

Table 3.19: Unit Areas with Highest and Lowest Increase in Average Annual Earnings Per Job, 1990–2000, with Selected Characteristics						
	Increase Avg. Annual Earnings, 1990–2000	MSA/ CMSA jobs, 1999	Avg. Annual Patenting Rate, 1990–99	Avg. Annual Total Patents, 1990–99	% Adults with Bachelor's Degree, 2000	Academic/ Nonprofit R&D per 100,000 jobs, 1998[a]
Unit Areas with Highest Increase in Earnings per Job						
San Jose, CA PMSA	$42,080	3,754,251	290.9	2761.7	40.5	43.9
San Francisco, CA PMSA	28,771	3,754,251	89.8	949.2	43.6	50.0
New York, NY PMSA	22,726	9,926,248	30.6	1274.8	29.2	26.1
Boulder-Longmont, CO PMSA	21,931	1,458,162	179.0	279.8	52.4	194.4
Jersey City, NJ PMSA	19,768	9,926,248	19.2	47.9	25.3	**21.5**
New Haven-Bridgeport-Stamford-Danbury-Waterbury, CT NECMA	19,751	9,926,248	109.4	884.4	33.9	31.9
Seattle-Bellevue-Everett, WA PMSA	19,537	1,919,299	61.1	801.0	35.9	40.8
Austin-San Marcos, TX MSA	18,669	670,341	138.4	776.1	36.7	54.5
Middlesex-Somerset-Hunterdon, NJ PMSA	17,956	9,926,248	140.4	829.1	37.4	31.0
Boston-Worcester-Lawrence-Lowell-Brockton, MA-NH NECMA	17,714	3,321,855	86.0	2641.9	34.4	65.7
Unit Areas with Lowest Increase Earnings per Job						
Yuma, AZ MSA	$5,493	59,649	5.0	3.9	11.8	0.0
Enid, OK MSA	5,467	26,907	7.4	1.7	19.6	0.0
State College, PA MSA	5,443	79,935	78.8	35.9	36.3	467.2
Wheeling, WV-OH MSA	5,438	68,177	19.1	9.5	14.6	0.0
Pocatello, ID MSA	5,387	33,722	29.7	3.6	24.9	30.8
Gadsden, AL MSA	5,223	41,276	0.0	3.1	13.4	0.0
Huntington-Ashland, WV-KY-OH MSA	5,138	127,407	19.6	21.5	14.4	0.0
Cumberland, MD-WV MSA	5,110	39,703	2.5	3.4	13.4	0.0
Auburn-Opelika, AL MSA	4,922	45,520	41.7	12.5	27.9	196.7
Steubenville-Weirton, OH-WV MSA	4,418	53,319	28.1	14.1	12.1	0.0
Unit area median	$8,288	168,171	28.5	41.1	22.7	4.2

[a] For PMSAs, academic/nonprofit R&D intensity is whichever is higher of PMSA and CMSA figure. CMSA figures are in bold.

Sources: Earnings and jobs, U.S. Bureau of Economic Analysis; patents, U.S. Patent and Trademark Office; educational attainment, U.S. Census Bureau; academic/nonprofit R&D from National Science Foundation, RAND, and Association of University Technology Managers.

Table 3.20: Unit Areas with Highest and Lowest Increase in Wage and Salary Disbursements, 1990–2000, with Selected Characteristics

Unit Areas with Highest Increase in Wage and Salary Disbursements						
	% Growth in W&S Disbursements, 1990–2000	CMSA jobs, 1999	Average Annual Patents Per 100,000 jobs, 1990–99	Average Annual Patents, 1990–99	% Adults with Bachelor's Degree, 2000	Academic/ Nonprofit R&D per 100,000 jobs, 1998[a]
Austin-San Marcos, TX MSA	214.6	670,341	138.4	776.1	36.7	54.5
Boulder-Longmont, CO PMSA	199.1	1,458,162	179.0	279.8	52.4	194.4
San Jose, CA PMSA	181.7	3,754,251	290.9	2,761.7	40.5	43.9
Boise City, ID MSA	161.8	227,346	181.1	365.1	26.5	1.6
Las Vegas, NV-AZ MSA	156.3	759,197	16.1	95.2	16.4	2.4
Fort Collins-Loveland, CO MSA	143.0	124,485	137.7	146.7	39.5	116.4
Provo-Orem, UT MSA	142.2	154,930	49.2	63.7	31.5	8.0
Fayetteville-Springdale-Rogers, AR MSA	138.9	157,232	19.3	25.7	22.4	47.6
Laredo, TX MSA	138.9	71,177	2.4	1.4	13.9	0.0
Naples, FL MSA	136.7	106,797	33.8	29.8	27.9	0.0
Unit Areas with Lowest Increase in Wage and Salary Disbursements						
Los Angeles-Long Beach, CA PMSA	36.2	7,150,946	44.1	1,853.8	24.9	25.7
Jamestown, NY MSA	34.0	59,703	17.4	10.3	16.9	0.2
Syracuse, NY MSA	33.8	355,729	45.0	156.2	24.1	25.3
Cumberland, MD-WV MSA	32.7	39,703	9.0	3.4	13.4	0.0
Utica-Rome, NY MSA	31.9	136,728	31.4	41.7	17.7	1.7
Honolulu, HI MSA	28.4	466,882	10.3	49.7	27.9	33.4
Anniston, AL MSA	28.0	54,834	6.8	3.7	15.2	0.0
Binghamton, NY MSA	24.6	119,371	111.5	130.4	22.0	17.9
Dutchess County, NY PMSA	23.9	9,926,248	209.9	233.4	27.6	**21.5**
Steubenville-Weirton, OH-WV MSA	15.8	53,319	26.8	14.1	12.1	0.0
Unit area median	68.9	168,171	28.5	41.1	22.7	4.2

[a] For PMSAs, academic/nonprofit R&D intensity is whichever is higher of PMSA and CMSA figure. CMSA figures are in bold.

Sources: Earnings and jobs, U.S. Bureau of Economic Analysis; patents, U.S. Patent and Trademark Office; educational attainment, U.S. Census Bureau; academic/nonprofit R&D from National Science Foundation, RAND, and Association of University Technology Managers.

Table 3.20 clearly shows the lack of relationship between growth in jobs and wage and salary disbursements and each independent variable listed but educational attainment. Both the fastest growing areas and the slowest growing areas include ones with very high patent activity and ones with very low patent activity. Clearly, technology development is neither a prerequisite for nor a guarantee of regional growth.

In sum, in and of itself, technology development is not guaranteed to be a driver of regional economic growth. Rather, the industrial portion of technology development activity—as measured by industrial R&D intensity and patenting rate (largely determined by industry)—affects regional standards of living through a positive impact on wage levels.

3.3 Explaining the Geography of Innovation and Its Connection to Regional Development

From the perspective of practitioners of innovation-based economic development, the previous analysis provided key findings regarding the geography of innovation:

- Innovation is correlated with greater average wages.
- Innovative activity, as measured by patenting and by R&D, is primarily an industrial phenomenon, and takes place primarily in metropolitan areas.
- Innovative activity varies greatly among metro areas.
- Innovation, as measured by patents, is concentrated in larger metropolitan areas, particularly ones with over 1 million jobs. The geographic pull of technology innovation is centripetal—activity gravitates towards a relative handful of large centers.
- While innovative activity certainly occurs in smaller metro areas, such activity tends to be highly dependent on a handful of firms, not a highly populated cluster.
- While public R&D activity can stimulate nearby industrial R&D and patenting, such effect is not apparent in many smaller metro areas with a sizable public R&D base.

The purpose of this section is to explain this geography of innovation through an examination of the literature in technology development and technology-based economic development. In this analysis, the literature is divided into three related realms: how innovative firms learn, where innovative firms locate in light of how they learn, and the nature of relations between public R&D organizations and firms.[97]

[97] For this analysis, a thorough search of relevant literature was undertaken. Sixty articles were examined. To demonstrate the recent upsurge in scholarly interest on the topic, three-quarters of the articles were published in 1999 or later.

3.3.1 Innovation and Firm Learning

Innovation takes place along a life cycle. As discussed in Chapter Two, the development of technologies occurs along a trajectory that moves from radical to incremental over time. This trajectory is "path dependent," that is, innovations build on, and do not radically diverge from, previous innovations—the former are (at least in retrospect) a logical extension of the latter. However, as technologies mature along this trajectory, radically new technologies arise to supplant them, and a new life cycle, a new trajectory, begins.[98]

In many industries, companies are driven by the need to develop new technologies and technology-based products in order to maintain, or even expand, their competitiveness. However, while the technology development process may have a certain logic retrospectively, prospectively the innovation process is an uncertain and idiosyncratic one. To a large extent, firms are working in the dark, regarding both the technical feasibility of new products and the commercial viability. This is particularly so when firms are working on radically new technologies. As the discussion in Chapter Two shows, the process of technology development and commercialization is highly uncertain.

In carrying out technology development, few firms can work alone. Many actively seek information from external sources, of the types and in the ways described in Chapter Two. Typically, this process of learning from external sources (technology transfer) is not a dramatic, high profile, highly logical effort, but rather an ongoing, incremental, often small-scale one that seldom leads to dramatic change.

The learning process is not one of simply obtaining information. Rather it involves both obtaining and transforming information, which is factual, into useable ***knowledge***, which establishes generalizations and correlations between variables. Technology is a cumulatively aggregated pool of knowledge.[99]

As Polanyi posits, knowledge is of two types, ***tacit*** and ***explicit***. Explicit (or codified) knowledge involves know-how that is transmittable in formal, systematic language and does not require direct experience of the knowledge that is being acquired. Explicit knowledge can be transferred through manuals and blueprints, for instance. On the other hand, tacit knowledge cannot be communicated in any direct or codified way, as it concerns direct experience. Tacit knowledge is intangible know-how acquired through learned behavior and procedures.[100] The distinction between tacit and documented knowledge is closely related to the distinction between "procedural" and "declarative"

[98] For discussion of life cycle dynamics, see James Utterback, *Mastering the Dynamics of Innovation*, Harvard Business School Press, 1994, and Vijay Jolly, *Commercializing New Technologies: Getting from Mind to Market*, Harvard Business School Press, 1997, Chapter 1.
[99] Manfred Fischer, "The Innovation Process and Network Activities of Manufacturing Firms", in Manfred Fischer, Luis Suarez-Villa, and Michael Steiner, eds., *Innovation, Networks and Localities*, Springer, 1999.
[100] Jeremy Howells, "Knowledge, Innovation and Location", in John R. Bryson, et al., eds., *Knowledge, Space, Economy*, Routledge, 2000.

knowledge. Procedural knowledge constitutes an ability or skill to perform some activity. Declarative knowledge constitutes explicit knowledge of facts, causal relations, etc.[101]

The transformation of information and knowledge held by others into knowledge useable to the receiver has two dimensions. First, the receiving organization must have the ability to "transcode" the external information or knowledge into a form that is internally useable, that can fit into the organization's research and learning systems. The ability to "transcode" itself depends on tacit knowledge of a particular sort; one learns how to transcode through experience. Second, for technology transfer that requires personal interactions with knowledge-holders (e.g., cooperative R&D, technical assistance, licensing), the effectiveness of transfer depends on the receiver's ability to manage the relationship. This ability also is a function of tacit knowledge, coming primarily through experience.[102] Thus, tacit knowledge is a prerequisite for all knowledge activities.[103]

Explicit knowledge is easier to transmit than tacit knowledge. In general, the more tacit a specific piece of knowledge, the greater the time and effort required to learn the code and to transform the knowledge into a form that is firm-specific and commercially relevant. Given these complexities and the learning-by-doing nature of gaining tacit knowledge, the transfer of tacit knowledge is most effective through personal interaction with the holder of that knowledge.[104]

Von Hippel defines the "stickiness" of a unit of information as "the incremental expenditure required to transfer that unit of information to a specified locus in a form useable by a given information seeker." Stickiness is a function of the nature of the knowledge (tacit or explicit), the amount of information, and the characteristics and capacity of the information providers and seekers. Von Hippel goes on to say that when information is sticky, the tendency is to carry out the transfer at the locus of the information.[105] Therefore, tacit knowledge is most effectively transferred when the provider and seeker are in geographic proximity.

At the beginning of the life cycle for a particular technology, tacit knowledge is dominant. As a technology matures, more knowledge becomes codified. So the relative importance of tacit and explicit knowledge will shift over time as a technology moves along a trajectory.[106] Thus, personal interaction and geographic proximity tend to be more important in the early stages of a technology life cycle.

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[101] Bart Nooteboom, "Innovation, learning and industrial organization," *Cambridge Journal of Economics*, Vol. 23, 1999, pp. 127–150.
[102] Clive Lawson and Edward Lorenz, "Collective Learning, Tacit Knowledge and Regional Innovative Capacity," *Regional Studies*, Vol. 33.4, 1999, pp. 305–317.
[103] Howells, *op.cit.*
[104] Fischer, *op. cit.*
[105] Eric Von Hippel, "Sticky Information and the Locus of Problem Solving: Implications for Innovation," *Management Science* 40, 1994, pp. 429–439.
[106] Howells, *op.cit.*

Individual firms vary greatly in their respective abilities to learn. The literature suggests a number of components of the ability to learn, including

- motivation and willingness to learn from external sources;[107]
- level of effort devoted to learning;[108]
- willingness to "unlearn," that is, to no longer take established procedures and knowledge for granted; [109]
- absorption capacity—the ability (tacit knowledge) to learn, assimilate, and use (recognize, absorb and utilize) knowledge developed elsewhere;
- internal technical expertise and R&D effort;[110]
- presence of organizational routines, incentives, and culture that promote learning; and
- access to and utilization of networks.[111]

These components, in turn, appear to be a function of a number of factors. One is that of experience, in terms of internal R&D effort, learning, and external relationships (e.g., networks and alliances). Essentially, the more experienced a firm is in R&D, in obtaining and using external knowledge, and in managing external relationships for technology transfer, the greater its ability to learn.

A second factor is geographic proximity to potential sources of external knowledge. As we saw above, proximity tends to facilitate obtaining tacit knowledge, and in the early phases of technology development, access to tacit knowledge is paramount. For example, several studies show that firms are much more likely to work with university researchers located within a 75-100 mile range (with a wider range for larger firms).[112] Proximity allows firms to more easily participate in networks and to gain

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[107] In general, externally linked firms are far more likely to be innovators than non-linked firms. Alan D. MacPherson, "A Comparison of Within-Firm and External Sources of Product Innovation," *Growth and Change*, Vol. 28 (Summer 1997), pp. 289–308.

[108] James D. Adams, "Endogenous R&D Spillovers and Industrial Research Productivity," National Bureau of Economic Affairs, Working Paper 7484, January 2000.

[109] Peter Maskell and Anders Malmberg, "Localised learning and industrial competitiveness," *Cambridge Journal of Economics*, Vol. 23, 1999, pp. 167–185; Nooteboom, *op. cit.*

[110] Some evidence suggests that firms that combine internal R&D with external assistance have a greater rate of innovation than firms that rely primarily on one or the other. MacPherson, *op. cit.*

[111] Fischer, *op. cit.*, provides a thoughtful overview of networks. He says that a network is an evolving mutual dependency system based on resource relationships in which their systemic character is the outcome of interactions, processes, procedures, and institutionalization. Network activities involve the creation, combination, exchange, transformation, absorption and exploitation of resources within a wide range of formal and informal relationships. Networks vary in content (narrow and specific, wide and open) and in nature of relationships (from the highly formalized to the highly informal). Networks are always a response to specific circumstances, and are shaped accordingly. Networks are of five types: customer networks, manufacturing supplier networks (of raw and intermediate goods), producer service supplier networks (of services), producer networks (competitors pooling capacities), and cooperation with public research institutions.

[112] See Edwin Mansfield, "Academic Research Underlying Industrial Innovations: Sources, Characteristics, and Financing," *The Review of Economics and Statistics*, Vol. 77, No. 1 (February 1995), pp. 55–65; Luc Anselin, Attila Varga, and Zoltan Acs, "Geographic Spillovers and University Research: A Spatial Econometric Perspective," *Growth and Change*, Vol. 31 (Fall 2000), pp. 501–515; James D. Adams,

valuable experience in managing external relationships. Proximity also allows firms to have ready access to robust labor markets and to knowledgeable workers.

A third factor is firm size. With regard to ability to learn, small firms and large firms each have advantages and disadvantages by virtue of their size. Small firms, compared to large firms, tend to have greater motivation to learn, greater openness to new ideas and willingness to let go of old ones, greater ability to make use of informal networks of firms, and greater flexibility and ability to manage change. Large firms tend to have greater R&D resources and specialization, more interfaces with the external environment, more resources to devote to external knowledge recognition, absorption and utilization, and greater ability to develop a system of boundary spanners and gatekeepers to transfer knowledge within the firm.[113]

Evidence suggests that small, independent firms are more likely to seek external resources, formal and informal, than large firms (or units of large firms), due to relatively fewer internal resources. Thus, proximity is particularly attractive for small firms.

Fischer identifies three types of manufacturing firm approaches toward external learning:[114]

- High outward orientation—The firm frequently utilizes the whole range of possibilities in obtaining external knowledge. Involved in widespread network activities in both pre-competitive and competitive stages of the innovation process. Firms most likely to be active in seeking out external information are those with in-house R&D activity.
- Medium outward orientation—The firm relies primarily on in-house problem-solving and regular contacts with customers and suppliers.
- Low outward orientation—The firm relies almost entirely on in-house problem-solving, written media, and routine inputs. It participates little in networks.

Oinas and Malecki note that a firm's high outward orientation towards learning, particularly its ability to participate in widespread networks, can overcome the constraints of a peripheral location. Compared to other firms, the networks of active, extroverted firms tend to be wider and encompass more connections both within their own region and outside it. Telecommunications can substitute to some degree for remoteness, but active engagement in personal interaction locally or nonlocally are key to success. The network of successful firms in peripheral areas must be nonlocal to a

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"Comparative Localization of Academic and Industrial Spillovers," National Bureau of Economic Affairs, Working Paper 8292, May 2001; Varga, *op. cit*.

[113] Paul Almeida, Gina Dokko, and Lori Rosenkopf, "Startup Size and the Mechanisms of External Learning: Increasing Opportunity but Declining Usefulness?," working paper, Mack Center for Technological Innovation, Wharton School, University of Pennsylvania, February 27, 2001. It is interesting to note that the authors determine firm age is not a factor in a firm's ability to learn.

[114] Fischer, *op. cit.*

considerable extent. These non-local networks frequently center on contacts made by owner-managers in previous employment.[115]

To Alderman, the critical issue from a networking perspective, regardless of location, is the firm's ability to tap into both national and international networks of customers, suppliers, and other third parties.[116] Echeverri-Carroll and Brennan found that Texas firms developing new products at a faster pace than their industry average depend not only on local knowledge networks but also on nonlocal sources of knowledge. Of particular importance to these firms were good airline connections to Silicon Valley, which facilitated intermittent geographic proximity and the development of personal relationships.[117]

De la Mothe and Pacquet say that while proximity is highly important for transferring knowledge, proximity is not solely a spatial concept. They suggest that actors may build knowledge-sharing relationships by being proximate in other ways, such as organizationally, institutionally, and ideologically.[118] In this regard, Crevoisier notes, innovative firms not located in cities need to have good connections with "interaction and learning sites", e.g., research centers, trade and occupational associations, trade fairs, technology transfer centers, and higher education and training facilities.[119]

3.3.2 Innovation, Learning, and Location

The earlier analysis indicates that innovative activity takes place in a relatively small number of metropolitan areas, primarily ones with over a million jobs. The question is: why? The literature clearly indicates that location in large metropolitan areas provides a number of important advantages to firms competing on innovation and knowledge development. In summary, these advantages are found in a depth of specialization, a breadth of diversity, and an access to important general economic resources that most smaller metro areas cannot match.

The advantages of specialization are revealed in the workings of industry ***clusters***. A regional cluster can be defined as a geographically concentrated group of business enterprises and nonbusiness organizations (e.g., training centers, professional associations) with a bond around common products and markets, common distribution channels, common technologies, common labor pools, and/or buyer-supplier

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[115] Paivi Oinas and Edward J. Malecki, "Spatial Innovation Systems," in Malecki and Oinas, eds., *Making Connections: Technological Learning and Regional Economic Change*, Ashgate, 1999.
[116] Neil Alderman, "Local Product Development Trajectories: Engineering Establishments in Three Contrasting Regions," in Malecki and Oinas, eds., *op. cit*.
[117] Elise L. Echeverri-Carroll and William Brennan, "Are Innovation Networks Bounded by Proximity?," in Manfred Fischer, Luis Suarez-Villa, and Michael Steiner, eds., *Innovation, Networks and Localities*, Springer, 1999
[118] John de la Mothe and Gilles Paquet, "Local and Regional Systems of Innovation as Learning Socio-economies," in John de la Mothe and Gilles Paquet, eds., *Local and Regional Systems of Innovation*, Kluwer Academic Publishers, 1998.
[119] Olivier Crevoisier "Innovation and the City," in Malecki and Oinas, eds., *op. cit.*

relationships.[120] Clusters are characterized by a range of formal and informal networks across the various business and nonbusiness organizations.

Clusters are found in every industry, and develop for any combination of reasons, including:

- access to a key input, such as a natural resource (e.g., oil), university researchers, skilled labor, parts suppliers, or specialized physical infrastructure (e.g., a port);
- access to primary customer markets;
- the appearance of one radically innovative firm (e.g., Microsoft);
- specialized local demand;
- prior existence of suppliers, related industries, or related clusters; and
- some element of chance.

Regional clusters provide two important advantages to firms—greater access to valuable knowledge and agglomeration economies of scale. The primary stimulant to greater access to valuable knowledge is geographic proximity. Proximity supports and encourages the development of business and social relations, of a variety of networks that include customers, goods and services suppliers, competitors, and public R&D institutions, often facilitated by mediating organizations such as trade associations and technology business councils.

Important knowledge of various types is transmitted through these networks and professional relations. As discussed, these connections facilitate the transfer of tacit technical knowledge. To give but one example, Zucker, Darby and Armstrong find that 81 percent of authors who enter GenBank (the annotated collection of all publicly available DNA sequences) for the first time are co-writing with authors already in GenBank.[121]

The second type of knowledge obtained through cluster connections is tacit knowledge of a procedural sort. Such knowledge includes how to "transcode" new information, how to collaborate effectively with other researchers within and without one's own organization, and how to successfully interact with important nontechnical actors (e.g., financing organizations, government, training programs). Moreover, Lawson and Lorenz note, learning how to cooperate with the members of another organization amounts to a significant dedicated investment with uncertain returns. This uncertainty can inhibit a firm from seeking benefit from establishing relations with other possible

[120] The discussion of clusters is drawn from Porter and from Edward M. Bergman and Edward J. Feser, "Industrial and Regional Clusters: Concepts and Comparative Applications," in *The Web Book of Regional Science*, Regional Research Institute, West Virginia University (1999), at http://www.rri.wvu.edu/WebBook/Bergman-Feser/contents.htm.

[121] Lynne Zucker, Michael Darby, and Jeff Armstrong, "Commercializing Knowledge: University Science, Knowledge Capture, and Firm Performance in Biotechnology," National Bureau of Economic Research, Working Paper 8499, October 2001.

partners. In a cluster, learning how to cooperate becomes a sunk cost, freeing firms to more fully pursue new relationships and gain access to region's knowledge base.[122]

Third, geographic proximity enables researchers to become aware of, and make use of, available publicly available explicit knowledge. Several studies have found that the frequency with which patents and published technical articles are cited in other researchers' patents and articles in the same or nearby area is far greater (relative to the number of researchers) than elsewhere.[123]

The geographic dynamics of licensing illustrate the benefits of proximity across several of these dimensions. In a study of 124 technologies licensed from the Massachusetts Institute of Technology, geographic proximity improves the likelihood and extent of commercial product success. Mowery and Ziedonis indicate that the frequency of technology licensing from the University of California, Stanford University, and Columbia University declines with distance, particularly for exclusive licensing. They suggest that successful exploitation of a license requires the transfer of tacit knowledge from the inventor, over and above the explicit knowledge provided through the licensing contract: ". . . (T)he incomplete nature of licensing contracts limits the ability of more distant firms to exploit such advances. . . . This result (the study finding) seems to reflect the necessarily incomplete nature of licensing contracts, as well as the need for licensees to maintain access to know-how that is difficult to transmit through documents, faxes, or even phone or e-mail communication."[124] Left unsaid by the authors is the possibility that proximity to these universities also enhances licensee tacit knowledge about how to manage a license relationship with universities in general, and these universities in particular.

Firms are also attracted to the nonknowledge agglomeration economies of clusters. Clusters offer superior access to a variety of important inputs, usually at lower cost due to economies of scale. (Improved access also means transaction costs are lower as well.) For example, clusters tend to have robust labor markets in relevant technical and nontechnical occupations and a critical mass of organizations offering highly specialized services for cluster members (e.g., intellectual property law, marketing, training, finance, political representation). Certain clusters may have a significant number of suppliers, allowing firms to transform ideas into new inputs quickly and at a reasonable cost. Many firms highly value being near relevant training and degree programs.[125]

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[122] Lawson and Lorenz, *op. cit.*
[123] See David C. Mowery and Arvids A. Ziedonis, "The Geographic Reach of Market and Non-Market Channels of Technology Transfer: Comparing Citations and Licenses of University Patents," National Bureau of Economic Research, Working Paper 8568, October 2001; Almeida, Dokko, and Rosenkopf, *op. cit.*; Adam B. Jaffe, Michael S. Fogarty, Bruce A. Banks, "Evidence from Patents and Patent Citations on the Impact of NASA and Other Federal Labs on Commercial Innovation," National Bureau of Economic Research, Working Paper 6044, May 1997.
[124] Mowery and Ziedonis, *op .cit.*
[125] Attila Varga, "Regional Economic Effects of University Research: A Survey," Regional Research Institute, University of West Virginia, Working Paper 9729, October 1997.

Small firms in particular are attracted to locate in a cluster. New firms that spin off from existing firms in a cluster of course will find it easiest to remain where they are. Small firms, as noted, value networks more than larger firms for their knowledge sharing potential. Small firms seek outside suppliers and services that larger firms may have internally. Further, small firms often find facilitating organizations such as regional trade associations to be of great value in gaining useful technical and market information. In general, the networks offered by clusters aid small firms in reducing uncertainty and unknowns.[126]

While innovative firms can experience substantial benefits from being in specialized clusters, research shows they also can gain significant advantage from being in a diversified environment. The argument is that local diversity increases the probability of combining different types of knowledge in innovative ways. A diversified city is likely to facilitate the transfer of know-how from one area of industry to others that are unrelated in terms of final products. By offering a greater number and variety of problems to be solved, a much wider pool of expert knowledge and other resources, and a larger set of unrelated novel ideas that in turn can be connected to stimulate more ideas, a diversified city can only increase the probabilities of new combinations.[127] Adams sees "cross-industry spillovers", not specialization, as the primary driver of regional growth.

Large metropolitan areas provide a supportive context for innovation in part because of their greater diversity. In addition, through another set of agglomeration economies, large areas can provide access to a full array of important economic resources not specific to one industry. Such resources can include financial services, marketing expertise, an airport with excellent connections, temporary staffing agencies without limit, and quality-of-life elements such as arts, entertainment, and private education.

Innovative clusters can begin in any setting. However, those clusters that grow to become world-class competitive tend to be located in large metropolitan areas, primarily the diversity and general economic resource assets of these areas better nurture and support the development of innovative technology in the early stages of its life cycle. Once a cluster in a large metro area reaches a critical mass, its growth can become reinforcing. Firms with a choice of locations locate there to garner the proximity benefits; the larger the cluster, the greater the proximity benefits, the more growth it attracts. This is more than just a mechanical process. Adams notes that firms actively seek new information and increase their learning efforts when there is more to learn and more to be

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[126] Clive Lawson, "Towards a competence theory of the region," *Cambridge Journal of Economics*, Vol. 23, 1999, pp. 151-166.

[127] Pierre Desrochers, "Local Diversity, Human Creativity, and Technological Innovation," *Growth and Change*, Vol. 32 (Summer 2001), pp. 369-394; Bennett Harrison, Maryellen R. Kelley, Jon Gant, "Innovative Firm Behavior and Local Milieu: Exploring the Intersection of Agglomeration, Firm Effects, and Technological Change," *Economic Geography*, Vol. 72, Issue 3 (July 1996), pp. 233-258; James D. Adams, "Endogenous R&D Spillovers and Industrial Research Productivity," National Bureau of Economic Affairs, Working Paper 7484, January 2000; James D. Adams, "Comparative Localization of Academic and Industrial Spillovers," National Bureau of Economic Affairs, Working Paper 8292, May 2001.

gained by learning. Responding to these opportunities, firms amplify the effects of spillovers on their patenting and information.[128]

The result is that any given industry has only a handful of major clusters, located almost always in large metropolitan areas.[129] Audretsch and Feldman indicate that over half the innovations in any industry can be found in two or three states.

While the data show that, and the literature explains why, large metropolitan areas obtain a disproportionate show of innovation, the data also make clear that the range of innovative activity across metro areas is quite wide even when size is accounted for. The data indicate, for instance, that some large metro areas do not have a particularly high level of innovative activity and that some smaller metro areas do have competitive innovative clusters, with more than a handful of firms. Thus, metro size is the most important, but not the only, determinant of innovative activity. The data analysis suggests that other quantifiable factors, specifically educational attainment, the presence of advanced technology industries, and industrial R&D, also positively affect innovation rates. The literature also indicates that the extent of the presence of knowledge- and information-intensive business services, e.g., financial and legal services, correlates with the level of innovative activity.[130] (Even so, it should be kept in mind that all these factors correlate to some degree with metro size.)

Numerous authors suggest that regional differences in rates of innovation can be attributed to differences in regional competencies for learning. Oinas and Malecki say that regions differ in terms of their competitiveness and innovative activity to the extent of their respective capacities to act as a "collective entrepreneur," with firms, interfirm associations, worker organizations, financial institutions, and governmental agencies playing supporting roles. The extent to which a region is an "innovative milieu" is a function of the ability of the region to promote interaction and learning. (A science park is not by definition an innovative milieu, despite the hopes of some economic developers.) Interaction and learning in turn are facilitated by proximity (which we have discussed) and the extent to which actors are socialized with regards to tacit knowledge-based skills of learning, cooperation, and risk-taking. Learning is seen as the "ultimate virtue", as it reflects the capacity "to respond to new situations, new opportunities, and to participate in the process of creating new technologies."[131] So, de la Mothe and Pacquet say, actors need to be provided with the opportunity to learn how to learn. Interfirm

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[128] Adams, 2000, *op. cit.*

[129] David Audretsch and Maryann Feldman, "R&D Spillovers and the Geography of Innovation and Production," *The American Economic Review*, Volume 86, Issue 3 (June 1996), pp. 630–640; David B. Audretsch and Paula E. Stephan, "Company-Scientist Locational Links: The Case of Biotechnology," *The American Economic Review*, Volume 86, Issue 3 (June 1996), pp. 641–652; Joseph Cortright and Heike Mayer, "Signs of Life: The Growth of Biotechnology Centers in the U.S.," The Brookings Institution, June 2002.

[130] Edward J. Malecki, "Creating and sustaining competitiveness: Local knowledge and economic geography," in John R. Bryson,, et al., eds., *Knowledge, Space, Economy*, Routledge, 2000, and Varga, 2000, *op. cit.*

[131] Oinas and Malecki, *op. cit.*

organizations and government agencies play an important role in this regard, aiding in the development of "communities of practice."[132]

Lawson speaks similarly, saying the region, as a productive system, is an "ensemble" of technical, absorptive, and governance competencies that emerge from social interaction. These competencies are enhanced as they are applied and shared.[133] And Malecki says that successful regional economies are "associational economies", part way between state-led and market-led economies, a more social and collaborative mode of operation. Social and economic success depends on regional capability in trust-based relationships, learning, and network competence.[134] In sum, then, the literature suggests, regional innovation levels are very much a function of the institutional capacity for learning of the region as a whole.

What are the characteristics of regions filled with organizations that know how to learn and effectively apply that learning? Malecki, as a solo author and with Oinas, provides a number of answers. Malecki speaks of the need for a "social entrepreneur" or "animateur." He says that regional economies are animated by social entrepreneurs who work for collective benefit. Such people serve as "gatekeepers" in knowledge networks; they have extensive personal contacts, serve as a bridge between organizations and across sectors, translate discipline-specific terminologies and organization cultures, and actively seek external information (inside the region and out) to pass on to others. They help form links that might not have developed otherwise, among firms, and with politicians and other sources of financial support. Gatekeepers see their sharing of information as a means of building trust in counterparts in other organizations. The role of the gatekeeper may be quite informal, and "extracurricular" to the person's formal job of business or political executive. Also, nonprofit and quasipublic organizations can act as institutional gatekeepers.[135]

Malecki talks about the importance of culture in creating an innovative milieu. One crucial ingredient is the presence of extroverted firms and other organizations, ones willing and motivated to learn (as discussed in the previous section). In particular, organizations in the region need to embrace change and disequilibrium. Once they do, the conditions for learning can develop where knowledge development is paramount in the culture and, consequently, in policies and actions of the region's firms and institutions.[136]

Oinas and Malecki identify several characteristics of networks in innovative milieu. Networks are "embedded," that is, they are very much a part of the structure of the region. Networks have "institutional thickness." More specifically, there are a variety of organizations participating, with high levels of interaction, diverse strengths, and a shared sense of group interest. These networks have widely shared and understood

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132 De la Mothe and Pacquet, *op. cit.*
133 Lawson, *op. cit.*
134 Malecki, 1999, *op. cit.*
135 Malecki, 2001, *op. cit.* Douglas Henton, John Melville, and Kimberly Walesh speak of the important role of "civic entrepreneurs" in a somewhat similar fashion. (*Grassroots Leaders for a New Economy*, Jossey-Bass, 1997).
136 Malecki, 1999, *op. cit.*

conventions (expectations, routines, and practices) to facilitate cooperative activity and mutual understanding in idea exchange. And they have strong external relations, links to nonregional networks which provide access to a diversity of ideas and bases for comparison with local practices.[137]

Andersson suggests several other characteristics important to innovative milieu, including high levels of competence, widely shared perceptions of unsatisfied market needs, and enough structural instability so that positive organizational change can take place in response to the unsatisfied needs.[138]

Collaborative Economics points to the need for the leaders of the associational economy to collectively scan their situation and environment on a regular basis to identify assets, threats and opportunities, and prepare, implement, and regularly update a vision and roadmap on the basis of that scan. This process results in a shared regional "narrative" that frames, guides, and motivates collaborative action. The firm also indicates the need to proactively renew regional leadership.[139]

Maskell and Malmberg say that regional history, in the development of organizations, technology, culture, and space, plays a critical role in economic development, for this history sets in place the trajectory down which places learn and apply that learning. This trajectory is "path-dependent," once history sets it in place, it is difficult to radically change.

Moreover, these authors say, once competitive advantage is in place, it is difficult for other regions to dislodge. Sustainable regional competitive advantage comes about only if localized capabilities have four qualities—they are valuable (profitable), rare, not subject to substitution, and imperfectly imitated (i.e., not readily copied). Factors that hamper imitation include asset mass efficiency (there is a large stock of R&D and experience-based knowledge), time compression diseconomies (as it takes a long time to build up an endowment), and interconnectedness of assets stocks (it is difficult to duplicate the comprehensive pattern of internal coordination and learning as well as similar systems of a more or less tacit nature).[140]

Oinas and Malecki identify factors that seem to inhibit some regions that do have the necessary agglomeration from becoming innovative milieu. Characteristics include organizations not to be open to outside ideas, unable to unlearn old ways, and prefer top-down, rather than bottom-up, network structures.

These authors go on to say that regions "below best practice" can become positive environments for adapting (rather than creating) innovations, developing the ability to

[137] Oinas and Malecki, 1999, *op. cit.*
[138] A.E. Andersson, "Creativity and regional development," *Papers of the Regional Science Association*, 1985, Vol. 56, pp. 5–20.
[139] Collaborative Economics, *Strategic Planning in the Technology-Driven World: A Guidebook for Innovation-Led Development*, 2001, prepared for the U.S. Economic Development Administration, Washington, D.C.
[140] Maskell and Malmberg, 1999, *op. cit.*

learn from innovative firms in other places. While these are not the best innovative environments, they can be economically competitive and provide well-paying skilled jobs. [141] We add to this that such regions can take two other types of steps. One is to learn from the areas of "best practice." The second is to aid firms in developing links to valuable external sources of information, as discussed at the end of the previous section.

Research could not be found that quantifies the extent to which technology-developing firms voluntarily relocate operations, particularly from outside to inside large innovation clusters. Anecdotal evidence indicates technology business relocations regularly occur, particularly for small firms.

Research literature also could not be found that examines in detail the geography of commercialization, either in terms of the location of personnel that facilitate and oversee commercialization (e.g., product and process engineers, business and marketing consultants, venture capitalists, intellectual property lawyers) or of the location of the outcomes of commercialization (e.g., manufacturing, distribution, management). Literature cited above tends to either ignore the question or assumes that commercialization processes and outcomes take place at the site of technology development. Moreover, the literature cited does not address the implications of the very high failure rate in the commercialization process.

Regarding the location of personnel facilitating and overseeing commercialization, observations and logic suggest that certain dynamics may be at work. For many of the technical, management, and financial aspects of commercialization, it would seem that proximity to the technology developers would be preferred, but is not absolutely necessary.[142] It also would seem that clusters of highly specialized commercialization functions could be economically supported by ***local*** clients only in the larger centers of innovations (e.g., Boston, San Diego).[143] Many of these firms go on to serve clients in other locations. Concentrations of commercialization service firms that serve ***national*** markets also can be found in large metro areas not particularly well-known for innovation. For instance, because of their size, Chicago and New York are home to significant management consulting expertise; Washington, DC, because of its proximity to the U.S. Patent Office, has a concentration of intellectual property law firms. In general, it would seem, the lower the concentration of innovative activity in an area and the smaller the metro area, the more likely that technology developers would need to use commercialization services located elsewhere. In certain instances, anecdotes suggest, commercializing firms decide to move operations to be closer to large innovation centers and their commercialization resources.

The literature is only beginning to look specifically at the geography of the outcomes of technology commercialization in any systematic way. In a recently released

[141] Oinas and Malecki, *op. cit.*
[142] Research indicates that venture capitalists tend to be highly localized in their investment patterns: Over half the venture-backed firms have a venture investor who serves as a board member based within 60 miles of the firm. Josh Lerner, "Venture Capitalists and the Oversight of Private Firms," *Journal of Finance*, 50, pp. 301-318.
[143] Over half of venture capital funding has been located in California and Massachusetts.

study, Sommers and Carlson indicate that the employment impacts of successful technology commercialization increasingly are spread geographically.[144] While technology development may take place largely in innovation clusters, the various manufacturing, administrative, and distribution functions required for successful commercialization are more and more likely to occur elsewhere, in places with competitive advantage for those particular functions. Firms are more likely to outsource to other firms and to geographically fragment operating units, splitting key functions throughout the United States and abroad. "The cluster phenomenon is still alive and well, but it increasingly revolves around portions of firms and functions within firms—from data processing to distribution—rather than whole companies and industries."

The result, Sommers and Carlson say, is that regions that are not innovative clusters now have an opportunity to specialize in functions that support commercialization. For instance, Louisville, Kentucky, has made a concerted effort to specialize in distribution.

Also not well researched as yet is the trend in relocations subsequent to large corporate acquisitions of resource-poor startup firms with commercially promising technologies. Such acquisition can mean relocation and fragmentation of both technology development and commercialization functions.

3.3.3 The Geography of Technology Transfer from Public R&D Institutions

The data analysis shows that while a significant portion of public R&D expenditures occur in smaller metro areas, and while public R&D does seem to have a positive impact on local patenting activity, patenting activity is far more concentrated in large metro areas. This finding is supported by Varga, who suggests that in impact of university research on local innovation activity falls dramatically with metro area size. For instance, he says that $300 million in university research yields 112 innovations for tier one (the largest) cities, only 16 for tier two, five for tier three, and two for tier four. Essentially, he notes, university research has little local impact outside the largest cities.[145]

A number of researchers do conclude that firms are much more likely to interact with sources of public R&D that are relatively close by.[146] (The range varies from study to study; the median distance is 75-100 miles.) University research is relatively tacit, knowledge about how to apply university research is relatively tacit, and knowledge about how to manage a relationship with a university is relatively tacit, so proximity is preferred. The desire for proximity to university research appears greater for small firms

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[144] Paul Sommers and Daniel Carlson, "What the IT Revolution Means for Regional Economic Development," The Brookings Institution, February 2003.

[145] Varga, 2000, *op. cit.* Varga uses a 1982 Small Business Administration innovation database.

[146] Anthony Arundel and Aldo Geuna, "Does Proximity Matter for Knowledge Transfer from Public Institutes and Universities to Firms?," Science and Technology Policy Research, Electronic Working Paper Series, Paper No. 73, October 2001 (draft); Varga, 1997, *op. cit.*; Mansfield, *op. cit.*; Mowery and Ziedonis, *op. cit.*; Adams, 2001, *op. cit.*

than for large ones, for reasons discussed earlier. In addition, firms find proximity to applied research more important than to basic research.

However, while firms interested in using public R&D prefer proximity, they also find advantage in being near other firms in their industry, a diverse environment, and business services. For reasons also described previously, such needs are best met in larger cities. So while public R&D in any location can stimulate industrial innovation, its impact tends to diminish in smaller areas.

Chapter Four
A Typology of Technology Transfer and Commercialization Programs

4.1 Introduction

All across the United States, a wide variety of programs have been created by public purpose organizations to facilitate technology transfer and commercialization to businesses. These programs operate at the "retail" level; that is, they seek to connect individual businesses aiming to develop and commercialize technology with individual resource providers, including sources of technology.

The large majority of technology transfer and commercialization programs exist outside of mainstream economic development organizations. Sponsors include federal, state, and local governments, public and private universities, chambers of commerce, public-private regional partnerships, and other nonprofits. For the most part, these programs have been developed in response to the increased value-added opportunities offered by technology development and commercialization and to perceived market failures, i.e., the inability of the private sector on its own to see that all technology development and commercialization opportunities are realized. In addition, some programs have been developed by public purpose technology development organizations (e.g., universities) to gain the financial benefits of technology transfer.

The aim of this chapter is to provide a typology of technology transfer and commercialization programs, so that practitioners and policy makers may understand the breadth and variation of programs operating. While Chapter Two examined the type of technology transfer and commercialization activities, this chapter looks at the various ways these activities are sponsored and bundled institutionally.

This typology is offered as a descriptive, not an evaluative or prescriptive, tool. Relatively few independent evaluations of such programs have been carried out, and the literature as yet does not offer comparative evaluations. Moreover, it should be recognized, different models and options are likely to be appropriate in different economic and institutional circumstances (e.g., size of metro area, existing clusters, lead development organization, relations between public and private sector, programs offered by state government). Essentially, the nature of the programs developed needs to fit the nature of the opportunities present and the market barriers to taking advantage of these opportunities. The relationship between opportunities, barriers, and program design is deserving of further research.

Having said this, several findings of previous chapters do have implications for the success of regional technology transfer and commercialization efforts. These include

- the importance of metro area size for technology development;
- the high failure rate of commercialization efforts;

- the massively larger scale of resources required for successful commercialization as compared to technology development;
- lack of access by many small firms with promising technologies to such resources, which often leads to being acquired by a more established firm, and at times involves relocation;
- the relative lack of sophisticated commercialization services outside of major innovation centers; and
- the increasing geographic fragmentation of the outcomes of commercialization (e.g., manufacturing, distribution, service, administration).

In contradiction to these findings, many of the regional and state technology transfer and commercialization programs identified appear to assume that

- technology transfer and commercialization are linear, mechanical processes that are quite often successful;
- location is not a major factor in the probability of success;
- technology-developing firms are not likely to relocate;
- technology-developing firms can locally obtain commercialization resources needed to be successful; and
- the corporate functions that grow out of commercialization (manufacturing, distribution, administration, service) are likely to be sited in the same locale as technology development.

That a significant number of programs originally identified during the research phase of this project no longer exist may speak, in part, to the inaccuracy of these assumptions.

However, that these assumptions are incorrect should not be taken to mean it is fruitless to create technology transfer and commercialization programs for rural and smaller metro areas. But it may mean that technology transfer efforts and commercialization efforts should be separate programs, given that the geographic dynamics of each phase are quite different. Any future research agenda should include an examination of which types of programs are appropriate for economic regions of varying size and location.

It is also helpful to understand that the efficacy of any technology transfer and commercialization program is improved to the extent its design and operations are consistent with a thoughtful regional development strategy. Practitioners and policy makers often confuse economic development tools with strategies. Technology transfer and commercialization programs are tools; strategy is determining how these tools are best used, independently and in conjunction with other tools promoting development.

As outlined in the box below, the typology is structured around four major categories concerning the nature of the organization sponsoring the program. Within each category, subcategories are provided; depending on the category, subcategories are organized by nature of activity, sponsoring organization, source of technology, or mission.

Typology Of Technology Transfer And Commercialization Programs

1) Programs sponsored by public R&D institutions to promote transfer of internally-held knowledge
   a) Cooperative R&D centers
   b) Technical assistance programs – some with dedicated technical staff; others matching businesses with appropriate technical expertise with public R&D organization
   c) Technology transfer offices – primary focus on licensing

2) Services at entrepreneurship and business development centers
   a) Small Business Development Centers – supported by U.S. Small Business Administration
   b) University-based entrepreneurship & business development centers
   c) Independent entrepreneurship and business development centers
   d) Industry-specific technology business development organizations

3) External technology transfer and commercialization intermediaries
   a) Intermediaries working with technologies from all sources
   b) Federal technology transfer intermediaries – focus on transferring technology from federal laboratories
   c) Federal technology contract intermediaries – focus on assisting businesses in obtaining Small Business Innovation Research and Small Business Technology Transfer contracts

4) Technology business membership organizations
   a) Technology-based regional development councils – businesses and development agencies working together to promote technology-led development
   b) Technology business councils – technology business advocacy groups
   c) Technology entrepreneur networks
   d) Industry-specific associations and networks
   e) Professional associations and user groups

A detailed articulation of this typology is provided below. Programs named are for illustration only, and do not represent a full list of existing operations appropriate to each category.[147,148] Moreover, a program's inclusion is not to suggest it is exemplary—none were assessed in terms of impacts. To keep the focus on efforts with the primary purpose of promoting technology transfer and/or commercialization, the discussion does exclude organizations with the sole mission of providing access to one of the factors of production needed for commercialization (i.e., financial capital, physical facilities, or

[147] For the most part, the programs in the typology were identified in 1999 and 2000. While an effort has been made to remove programs no longer in existence, some discontinued programs may have been missed. Moreover, some programs still in existence may have been modified since that time. In a symbol of the times subsequent to the "technology bust", a visible number of organizations previously identified have indeed gone out of existence.

[148] Case profiles of 21 technology transfer and commercialization programs are provided in Appendix C and examined in Chapter Five. The purpose of the cases is to identify lessons learned regarding how these programs work with economic development agencies.

skilled workforce). Thus, for example, while they may be beneficial to the commercialization process, state venture capital funds, research park corporations, and customized workforce training programs are not included.

4.2 Programs Sponsored by Public R&D Institutions to Promote Transfer of Internally Held Knowledge

The large majority of public R&D institutions have programs to promote the transfer of technology held internally. While these programs are highly diverse in nature, most can be grouped into one of three categories, by type of primary activity: cooperative R&D centers, technical assistance efforts, and technology transfer offices (with a primary focus on licensing).

4.2.1 Cooperative R&D Centers

R&D centers undertake cooperative research with industry. Most, but not all, are within a university; others are established as independent R&D institutions, often with participation of multiple universities; at least one is a state government-sponsored organization. Many are industry-specific, but a number are multidisciplinary. Most cooperative R&D programs are not explicitly created for purposes of local technology transfer; members may be located across the nation, even the world.

There are over 1,000 ***university-based*** cooperative R&D centers around the United States. Almost all are industry- or field-specific. Currently, 135 are funded through National Science Foundation (NSF) research center programs (e.g., Industry-University Cooperative Research Centers, State/Industry/University Cooperative Research Centers, Science and Technology Centers, and Engineering Research Centers); others began with and have "graduated" from NSF funding. Some cooperative R&D centers have been developed through state centers of excellence programs (e.g., in New Jersey, New York, Utah, Colorado, Kansas, Virginia, Georgia, Montana, and New Mexico). Many have been developed and maintained on the initiative of the sponsoring university and key faculty, with industry support. (Further details on university-industry cooperative R&D centers is provided in Chapter Two.)

Independent cooperative R&D organizations typically have a specific mission to work with industry (and often more of a regional economic development mission). Many are sponsored by, or have active, cooperative links with, one or more universities. Examples include the following:

- University City Science Center in Philadelphia (founded 1963), collectively owned by 28 research institutions (including hospitals) located between Washington and New York
- Houston Advanced Research Center (founded 1982), with links with ten universities, not all in the Houston area

- Biomedical Research Foundation of Northwest Louisiana (1986), linked with Louisiana State University Medical Center
- Ohio Aerospace Institute, a state-chartered organization promoting cooperative R&D among ten universities, two federal laboratories, and a number of corporate members

Others are industry-only R&D consortia with a national scope and operating with active federal government involvement and encouragement. Examples include the following:

- International SEMATECH, based in Austin, Texas and originally founded to reinvigorate the U.S. semiconductor industry, is a consortium of ten corporations.
- Microelectronics and Computer Technology Corporation (MCC), also based in Austin, is an R&D consortium of advanced electronics manufacturers.
- The United States Council on Automotive Research, a partnership of Ford, General Motors, and DaimlerChrysler, sponsors ten R&D consortia (e.g., automotive composites, advanced batteries, low emission technologies).

4.2.2 Technical Assistance Programs

Technical assistance programs in public R&D organizations are of two basic types. Some have dedicated technical staff; others offer a service to match businesses with appropriate technical expertise among the organization's researchers and staff. Programs typically have an economic development purpose and a statewide focus (except for certain federal efforts, which have a nationwide focus).

***Dedicated Technical Staff*.** Certain technical assistance programs in public R&D organizations have dedicated professional, nonfaculty applications engineers with the mission to assist businesses on technical issues. There are four types of such programs. The first is university-based; the second is as part of a Manufacturing Extension Partnership (MEP) organization; the third is through a dedicated independent nonprofit organization; and the fourth in the Defense Technical Information Center network sponsored by the Department of Defense. Technical assistance programs in the first three categories are primarily statewide in coverage.

University-based technical assistance programs are of two types. The first is ***applications engineering programs***, in which engineering staff work with clients at the clients' sites. Examples of such programs abound, and can be found at Purdue University, Oklahoma State University, North Dakota State University, and Rose-Hulman University in Indiana. Often, these efforts are called "engineering research centers" (not to be confused with National Science Foundation Engineering Research Centers). Some university-based programs are industry-specific. For example, Pennsylvania State University at Erie sponsors a Plastics Technology Deployment Center.

University-based programs may provide other services in addition to In addition to applications engineering. For example:

- The Center for Industrial Research and Service at Iowa State University and the Engineering Research Center at the University of Maryland facilitate university-industry R&D.
- The Arkansas Center for Technology Transfer at the University of Arkansas offers assistance in technology transfer and commercialization.

The second type of university-based technical assistance program is the ***advanced manufacturing center***, or "teaching factory," to which clients travel to receive direct assistance. Often, these centers are involved in product prototyping. Examples can be found at New Mexico State University and University of Missouri-Rolla.

Several ***Manufacturing Extension Partnership programs*** say they provide direct assistance in product development. Usually, a program provides some combination of referrals to private providers and access to in-house engineering staff.

- The Industry Network Corporation, which provides MEP services for five states in the West, says it assists in new product development.
- Similarly, the Mid-America Manufacturing Technology Center, which provides MEP services in four states (Missouri, Kansas, Colorado, and Wyoming), offers product development and testing services.
- The Illinois Manufacturing Extension Center says it provides product development assistance.

Finally, there are a number of ***independent nonprofit*** technical service providers. These usually work statewide; several were founded by state government and spun off; all identified are industry-specific:

- Microelectronic design centers in Indiana, Mississippi (Institute for Technology Development), and North Carolina
- Software assistance center run by SCRA in South Carolina
- Colorado Advanced Photonics Technology Center

The ***Defense Technical Information Center*** of the U.S. Department of Defense has chartered 13 discipline-specific Information Analysis Centers (IACs) staffed by information specialists, scientists, and engineers to help businesses access, analyze and use scientific and technical information in a specialized subject area. IACs maintain comprehensive knowledge bases, including historical, technical, scientific, and other information pertinent to their respective technical communities. They also collect, maintain, and develop analytical tools and techniques, including databases, models, and simulations. While established to aid defense contractors, many IAC information services are available to businesses at large nationwide. Among the 13 IAC disciplines are advanced materials and processing technology, software, manufacturing technology, nondestructive testing, reliability analysis, human systems, and infrared technology.

Technical Expert Matching Services. Instead of (or alongside) having an in-house staff of experts and researchers, some public R&D organizations have programs that match businesses with appropriate researchers and technical staff. While most programs are for expert technical assistance, some also facilitate user facilities and cooperative R&D. Programs can be found within single universities, consortia of universities, state science and technology agencies, and federal laboratories.

University technical expert matching programs aim to link businesses to appropriate faculty and staff. Most programs have statewide coverage and are found at public universities, mainly in Midwest and Plains states. (States with programs include Nebraska, North Dakota, South Dakota, Montana, Wisconsin, Indiana, Missouri, Colorado, Maryland, and New York.) Several university offices offer services in addition to expert matching. For example:

- University of Maryland and North Dakota State University combine a matching service with applications engineering programs.
- University of Wisconsin-Madison and Colorado State University house their matching programs in the university technology transfer office.
- Indiana University also offers assistance in obtaining Small Business Innovation Research (SBIR) contracts.
- University at Buffalo Business Alliance combines a technical assistance matching program with a number of other technology transfer activities, as well as an incubator.

Several ***multiuniversity*** programs seek to match businesses with technical experts. For example:

- Strategic Partnership for Industrial Resurgence provides a matching program across four State University of New York (SUNY) engineering schools, and offers access to user facilities.
- New Hampshire Industrial Research Center, based at University of New Hampshire (UNH), matches businesses with faculty at UNH and Dartmouth College.
- Consortium for Education, Research and Technology of North Louisiana serves as a portal to the expertise, training, and equipment resources of ten academic institutions.

Some ***state science and technology agencies*** provide a matching service to assist businesses in finding a researcher or technical expert among the state's universities. As examples, the Washington Technology Center and Virginia's Center for Innovative Technology offer such programs.

Each ***federal laboratory*** has an Office of Research and Technology Applications (ORTA) to facilitate all aspects of technology transfer from the institution, including access to technical assistance, cooperative R&D, licensing, and access to technical assistance, user facilities, and written materials. Some laboratory technical assistance programs (e.g., Pacific Northwest National Laboratory) have a local focus.

4.2.3 Technology Transfer Offices

Every research university, federal laboratory, and major nonprofit research institute has an office with the mission of promoting access to internally developed technologies. These offices have a fiduciary responsibility to pursue the financially advantageous selling of licenses, regardless of location of the licensee. However, in addition to licensing, many of these offices do take on a range of technology transfer functions with a state or local economic development focus.

The primary mission of most ***university*** technology transfer offices is to promote the licensing of university technologies.[149] Many university technology transfer offices (mainly ones with small technology portfolios) provide additional services linking businesses to internal technical resources. These services can include promoting business spinoffs, facilitating cooperative R&D, and offering technical assistance matching and commercialization services. For instance:

- The Center for Economic Renewal and Technology Transfer, Montana State University-Bozeman, facilitates industry-university collaborations in R&D, and assists in product commercialization.
- The Center for Innovation, North Dakota State University, takes on a broad role in business development, commercialization (with incubator).
- The Center for Advanced Technology Development, Iowa State University, handles technology transfer for the university and federal Ames Laboratory, and arranges technical assistance and cooperative R&D.
- The University at Buffalo Business Alliance offers MEP, technical assistance matching, and an incubator.
- The Cornell Office of Technology Assessment and Business Assistance promotes technology transfer and commercialization to outside businesses, and encourages faculty and staff spinoffs.
- The Colorado Institute for Technology Transfer and Implementation, Colorado State University, provides business development assistance (including spinoffs from university), technical expert matching service, and regional technology business strategy.

[149] For a list of university technology transfer offices, see the Web site maintained by the Association of University Technology Managers: www.autm.net.

- The Office of Economic Development and Technology Assessment, Louisiana State University, manages university intellectual properties and aids firms and individuals seeking research assistance.
- The Carnegie-Mellon University Technology Transfer Office promotes business spinoffs from the university.
- The Office of Research, Nebraska State University, arranges cooperative R&D.
- The University of Wisconsin-Madison provides a technical expert matching service.[150]

Each ***federal laboratory*** ORTA facilitates all aspects of technology transfer, including licensing, cooperative R&D, and access to technical assistance, user facilities, and written materials. For the most part, licensees are sought nationwide. Periodically, some laboratories make a particular effort to find local licensees (e.g., Los Alamos National Laboratory, Air Force Research Laboratory).

4.3 Services at Entrepreneurship and Business Development Centers

Across the United States are a multitude of public purpose centers for promoting entrepreneurship and small business development. These centers work directly with current and potential business owners and managers. Some assist businesses in all fields, others focus on technology businesses. Typically, the mission of these centers is to promote economic development at the state or substate level.

As part of their service offerings, many entrepreneurship and business development centers facilitate technology transfer and commercialization, for example, matching businesses with technology providers, assisting in technology transfer agreements, and, as part of commercialization, aiding in technical and market assessments. Centers may work statewide or locally.

Unlike programs in the prior section, it is difficult to classify entrepreneurship and business development centers by the nature of their technology transfer and commercialization activities. These activities are but part of a far broader mission; moreover, there is substantial variety among centers in the bundle of services they offer. In this section, then, the centers are classified primarily by type of sponsor. Categories include centers sponsored by the U.S. Small Business Administration, universities, and independent nonprofit organizations. An additional category of industry-specific programs (e.g., biotechnology, environmental) does differ in form from the center model of the preceding categories.

[150] A separate internal intermediary, the Technology Enterprise Cooperative in the School of Engineering, has the sole purpose of promoting business spinoffs.

4.3.1 Small Business Development Centers

The Small Business Development Center (SBDC) Program is overseen by the U.S. Small Business Administration. An SBDC network is available in each state, usually with a university playing the lead role. The national network has over 1,100 service locations. Funding comes from the federal government and state and local public and private sources. The SBDC Program is designed to deliver up-to-date counseling, training, and technical assistance in all aspects of small business management. Services include, but are not limited to, assisting small businesses with financial, marketing, production, organization, engineering and technical problems, and feasibility studies.

A number of SBDC programs and locations offer some combination of technology transfer and commercialization services. Several SBDC sites actively facilitate technology transfer and commercialization as a major part of their mission. Examples include Lehigh University SBDC (Pennsylvania); Technology Assistance Center, Dallas Community College SBDC (Texas); Center for Technology and Small Business Development, Central Missouri State University; ACCELERATE SBDC, University of California-Irvine; and the Entrepreneurship Center at George Mason University (Virginia).

Some state SBDC systems provide broad tech transfer and commercialization support. Examples include Mississippi, North Carolina, Idaho, and Washington. Other state systems offer support that is more focused. Examples include Nevada (aid in obtaining SBIR funding) and the Small Business Research & Information Center at University of Missouri-Rolla (offering information searches for technology transfer and commercialization). In Minnesota, one local SBDC offers statewide services on facilitating access to SBIR and STTR (Small Business Technology Transfer) funding.

4.3.2 University-Based Entrepreneurship and Business Development Centers

A number of universities operate entrepreneurship and business development centers. (Many of these centers have been funded by foundations with a particular interest in entrepreneurship, primarily the Kauffman and Coleman Foundations; a number also act as SBDCs.) A number of these centers offer technology transfer and commercialization services. These centers are of three types. The first type promotes entrepreneurship generally, and includes a technology transfer and commercialization effort specifically targeted to technology business development. Examples include centers at George Mason University and the University of Wyoming.

The second type focuses specifically on technology business development. Examples include the University of California at San Diego, the University of South Carolina, Rensselaer Polytechnic Institute, and the University of North Dakota. The third type has a general entrepreneurship/business development program without a defined tech business component, but a large portion of their clientele are technology businesses. Universities in this category include the University of Maryland and Case Western Reserve University (which also operates a technology incubator).

4.3.3 Independent Entrepreneurship and Business Development Centers

There are a number of independent nonprofit and public entrepreneurship and business development centers, some with statewide and others with local coverage. Most focus primarily on technology businesses. Functionally, these centers are of two types. One type provides direct assistance through personal services such as counseling and education; the other only offers information search services (e.g., sources of technology, patent information).

Examples of states with programs providing ***direct assistance*** (guidance and consulting) to technology businesses include the following:

- Connecticut Entrepreneurial Resources for Technology, which operates like a statewide SBDC for technology businesses
- The Oregon Innovation Center, a nonprofit aimed at helping technology businesses (partly through SBDC links), with a product development component
- Louisiana Partnership for Technology and Innovation, a nonprofit with state and private funding providing assistance for technology startups and commercialization

Examples of local centers offering direct assistance include Enterprise Corporation of Pittsburgh, Council for Entrepreneurial Development in the Research Triangle area, The Enterprise Network in San Jose, California (with incubator), and Technology 2020 in the Oak Ridge, Tennessee, area (with incubator).

A number of states support ***information resource centers*** for technology businesses to facilitate market research, patent searches, and so forth. Examples include Montana Business Connections, the Business and Technical Information Services program of Minnesota Technology, Inc., and the Connecticut Technology Assistance Center of Connecticut Innovations, Inc. As an example of a local program, the economic development agency in Littleton, Colorado, carries out information searches for technology businesses.

4.3.4 Industry-Specific Technology Business Development Organizations

There are many industry-specific programs to promote technology business development, with technology transfer and commercialization elements. Typically, these are not business development centers; that is, they do not have staff counselors to guide entrepreneurs. However, they offer access to various services, in-house or through referral, to support technology transfer and commercialization.

Some of these efforts have a statewide purview; examples include MdBio in Maryland (with incubator and capital programs) and the Edison Biotechnology Center in Ohio. Others are local in focus and sponsorship. Examples include Border Environmental

Commerce Alliance in southern California (with incubator), Positioning Information Technology Cluster in San Jose, and Pittsburgh Biomedical Development Corporation.

4.4 External Technology Transfer and Commercialization Intermediaries

In recent years, numerous organizations have been created with an express mission to promote technology transfer and commercialization at a regional, state, or multistate level. These organizations differ from those in the previous section in that they focus primarily on technology development, rather than on business development; they differ from intermediaries discussion in section I in that they are external to and independent of public R&D organizations.

The most meaningful distinction among these organizations is the source of technology they are aiding businesses in accessing and commercializing. The largest number seek out available technology from all public and private sources. Some focus solely on federal laboratory technology transfer. Some work exclusively in helping clients obtain federal technology development contracts that provide for a two-way transfer. Within the first group, multiple distinctions can be made regarding sponsorship and nature of technology transfer and commercialization activity.

4.4.1 Intermediaries Working with Technologies from All Sources

Technology transfer and commercialization intermediaries that work with technologies from any source can by distinguished in six ways, by:

- geographic coverage (multistate, state, local);
- role of state government in initiation (yes, no);
- sponsorship (state, nonprofit, university);
- industry coverage (all, specific);
- technology transfer and commercialization activities supported (e.g., all, commercialization only, information search only); and
- revenue sources (public funding, fee-for-service, equity, royalty).

Below, intermediaries are categorized by nature of geographic coverage, with further distinctions made within each category.

Intermediaries with Statewide Coverage. There are a number of statewide intermediaries that facilitate technology transfer and commercialization from a wide variety of sources. Some are operated as nonprofits, some as quasipublic organizations, and some by public universities. Some are MEP affiliates. Several are industry-specific. And some provide only commercialization services.[151]

[151] A recent review of statewide organizations identified in the research undertaken in 1999-2000 indicates that a number no longer exist.

Several states are home to ***nonprofit*** organizations that provide statewide technology transfer and commercialization services. Examples include

- Wisconsin Business Innovation Corporation,
- Northwest Innovative Business and Technology Center (Oregon), and
- Louisiana Partnership for Technology and Innovation (nonprofit with state support).

Other states support ***quasi-public*** technology transfer and commercialization entities. Examples include the Maryland Science and Engineering Technology Development Corporation and the Virginia Center for Innovative Technology.

State universities manage technology transfer and commercialization intermediaries. For instance:

- The University of Arkansas operates the Arkansas Center for Technology Transfer (as part of the state MEP network).
- The Florida EDA University Center at the University of Florida (managed by the Southern Technology Applications Center) promotes transfer and commercialization of technologies from ten Florida universities.

Manufacturing Extension Partnership/Management Services, Inc. (MEP/MSI) is a nonprofit consulting firm that provides staffing, consulting and business management services to individual state-based ***MEP programs*** (managing agent in Maine, Massachusetts, New Hampshire, Arizona, New Mexico, and Florida, plus active contracts with MEP centers in seven other states). The organization says it provides technology transfer and commercialization services for and through its MEP clients.[152]

Examples of statewide ***industry-specific*** technology transfer and commercialization efforts were found in Maine and Georgia. Maine efforts include ones for biotechnology, aquaculture, and precision manufacturing. Two in Georgia cover biomedical and telecommunications (includes incubator and university-industry center R&D grants).

Certain statewide entities provide ***commercialization*** services only. Several are MEP affiliates. Examples include the following:

- Innova Commercialization Group of the West Virginia High Technology Foundation Consortium
- CONNSTEP, Inc. (Connecticut's MEP affiliate)
- Oklahoma Technology Commercialization Center (state-initiated and owned)

[152] See http://www.mepmsi.org/index.php?page=enterprise#TechnologyTransfer.

- Missouri Enterprise Innovation Center at the Missouri Enterprise Business Assistance Center (nonprofit)

Intermediaries with Local Coverage. Technology transfer and commercialization intermediaries with local coverage may be state-initiated and locally operated or locally initiated and operated.

Several ***states*** have chartered a statewide network of locally operated nonprofits to promote technology transfer and commercialization. For instance:

- Enterprise Florida has created a series of Innovation and Commercialization Centers across the state (five nonprofit, one at a university).
- Pennsylvania has four Ben Franklin Technology Centers (several with satellite operations) that aim to grow technology firms through technology transfer and commercialization assistance. Most of the Centers also offer tangible assets, such as an incubator, access to capital, and research grants.
- The Kansas Technology Enterprise Corporation (KTEC) charters local Innovation and Commercialization Corporations that provide services to small technology companies, including tech transfer and commercialization. Typically, these centers are partnerships involving KTEC, a local economic development organization, and the local state university.
- The New York State Office of Science, Technology and Academic Research (NYSTAR) supports a statewide network of ten nonprofit regional technology development centers. While each of these centers provides industrial extension services, most also facilitate certain technology transfer and commercialization activities. The nature of activity varies by center.

Examples of ***locally*** initiated and operated transfer and commercialization efforts include the following:

- Gulf Coast Alliance for Technology Transfer, involving six academic institutions and seven federal laboratories promoting technology transfer in northwest Florida and southeast Alabama
- Technology Commercialization Center, Massachusetts Biomedical Initiatives, provides technology transfer and commercialization assistance in central Massachusetts for the biomedical industry
- Cincinnati Network for Product Development, Inc., a network of experts to help in commercialization

Sometimes, state and local organizations combine to create a local intermediary. For example, the state of Washington and seven universities in eastern Washington jointly chartered the Spokane Intercollegiate Research and Technology Institute to provide commercialization services.

4.4.2 Federal Technology Transfer Intermediaries

Subsequent to the passage of the Stevenson-Wydler Act and other legislative and executive acts to promote federal technology transfer, several types of third-party intermediaries have been established to promote such transfer. These include Regional Technology Transfer Centers funded by the National Aeronautics and Space Administration (NASA), state-sponsored federal technology transfer efforts, federal agency-specific intermediaries, and intermediaries working on behalf of one federal laboratory.

NASA funded six ***Regional Technology Transfer Centers*** (RTTCs) that in combination cover the whole of the United States. While NASA-funded and NASA-focused, the RTTCs are charged with helping businesses find appropriate technology resources across the federal government. RTTCs typically also will assist businesses in finding technology resources outside of the federal government as well. The organization operating each RTTC is selected through a competitive process. Some are nonprofits, others are operated out of a university (e.g., Georgia Institute of Technology, University of Southern California).

Each RTTC sees that each state in its region is covered by one or more local affiliate organizations or field agents. Five of the RTTCs are linked to local independent affiliate organizations. The Center for Technology Commercialization (covering New England, New York, and New Jersey) has created its own field organizations (some of which are separately incorporated).

In addition, NASA and the Department of Defense fund a de facto seventh RTTC, TechLink at Montana State University, which provides federal technology transfer and commercialization services to five upper Plains and Mountain states (in Mid-Continent RTTC territory).

A number of ***state-sponsored*** organizations, including quasi-publics, state agencies, and public universities, actively promote federal technology transfer within their respective states. Examples include the following:

- FedTECH Program, Massachusetts Technology Collaborative (quasi-public)
- Louisiana Technology Transfer Office, Louisiana Department of Economic Development (which has a direct contract with NASA)
- The Center for Industrial Services, University of Tennessee
- Southern Technology Applications Center, University of Florida

Several ***federal agencies*** have established intermediaries that promote transfer of technology developed only at agency laboratories. For example:

- The Environmental Protection Agency (EPA), supports the Environmental Technology Commercialization Center, managed by Battelle Memorial Institute to link private companies with innovative EPA-developed technologies.
- The Office of Naval Research maintains the McConnell Technology & Training Center, operated by Innovative Productivity, Inc., to promote the transfer of Navy technologies.

Several intermediary organizations promote technology transfer from ***one federal laboratory***. For instance:

- The Wright Technology Network seeks to move technology out of the Air Force Research Laboratory in Dayton, Ohio, to businesses in a multistate area.
- The New York State Technology Enterprise Corporation performs the same role for the Air Force Research Laboratory in Rome, New York.

4.4.3 Federal Technology Contract Intermediaries

Some intermediaries have a sole focus of helping firms get federal technology development contracts. Such contracts are seen as having multiple value—bringing money to firms and allowing firms to learn from external sources in the process of providing technology to the federal government. The primary focus of these efforts is obtaining SBIR and STTR awards. Efforts also exist to help businesses obtain technology contracts outside of SBIR/STTR.

For the most part, ***SBIR/STTR*** intermediaries operate at the state level. Examples include the Arizona Innovation Network, the Wisconsin Small Business Innovation Consortium, and the Hawaii High Technology Development Corporation. The Alaska Technology Transfer Center divides its effort time between two functions—SBIR assistance and serving as the Alaska agent for the Far West RTTC. Many state development agencies have an office specifically aimed at helping businesses obtain SBIR and STTR funding, e.g., Ohio.

The McConnell Technology & Training Center in Lexington, Kentucky, assists firms in the region in obtaining contracts with local Navy research facilities.

4.5 Technology Business Membership Organizations

Technology business membership organizations are largely advocacy and networking organizations. The networking opportunities provided, both formal and informal, are important means of facilitating technology transfer and commercialization between firms. No other category of technology transfer and commercialization program explicitly plays this role.

The various models of technology business membership organizations include technology-based regional development councils (public-private membership organizations with some development policy role), technology business councils (business advocacy organizations), entrepreneurship networks, industry-specific associations and networks, and profession-specific associations and networks.

4.5.1 Technology-Based Regional Development Councils

Technology-based regional development councils include businesses and development agencies working together to promote technology-led development. These councils can be found at the state level (e.g., New Hampshire, Arkansas, Georgia) and the local level (e.g., Virginia's regional technology councils system, Gallatin Valley Technology Alliance in Montana).

4.5.2 Technology Business Councils

Technology business councils differ from technology councils in that they are primarily business advocacy groups, acting like a technology chamber of commerce. A large number of these councils exist at local level (e.g., Cape Cod Technology Council, Santa Cruz Technology Alliance). Pennsylvania and Maryland have fostered a series of local councils across their states. There are at least nine statewide technology business councils.

An interesting variation on the local model is the Technolink Association in southern California, with a primary function is to facilitate partnerships among members, including technology businesses and technology business service providers.

4.5.3 Technology Entrepreneur Networks

Technology entrepreneur networks aim to support members in their efforts to start and sustain technology businesses. Many are independent; for example, statewide associations in New Mexico and New Jersey, and local ones in Atlanta, Gainesville, Florida, and southern California. Other entrepreneur networks are affiliated with a national organization, for example, the MIT Enterprise Forum, the Young Entrepreneurs Organization, the Council of Growing Companies, and the Association for Corporate Growth.

4.5.4 Industry-specific Associations and Networks

Industry-specific associations and networks can be found all across the United States. Technology industry business associations include those in software, information technology, biotechnology, biomedical, optics and photonics, new media, telecommunications, plastics, and computers. Associations exist at the state and substate levels. For the most part, substate associations are in metro areas with an agglomeration in the industry. However, a few rural ones exist (e.g., in Oregon, New Hampshire, and

Massachusetts). There are several multistate organizations (e.g., Northwest Environmental Business Council, Environmental Business Council of New England).

The Institute of Electrical and Electronics Engineers, Inc. (IEEE) supports a number of entrepreneur networks around the country (e.g., in Boston). Also, a few independent industry-specific entrepreneurship networks exist as well (e.g., Nashua, New Hampshire software).

4.5.5 Professional Associations and User Groups

Finally, there are a multitude of technical professional associations and user groups around the United States. Most technical professional associations are state and local chapters of national organizations (e.g., IEEE). User groups tend to be independent (e.g., Colorado Software Process Improvement Network, Boulder Java Users Group) and with an express mission of knowledge transfer.

Chapter Five
Technology Transfer and Commercialization Programs and Economic Development Agencies

5.1 Introduction

The technology transfer and commercialization programs described in the previous chapter for the most part operate outside of mainstream economic development agencies. As discussed in Chapter One, development agencies tend to be generalists, responsible for developing and implementing broad strategies, and marketers and facilitators, helping businesses find the resources (e.g., land, labor, or capital) needed to be successful and contribute to the local economy. Few have staff with the technical training needed to manage technology transfer and commercialization. Moreover, the geography covered by place-based technology transfer and commercialization programs is often different from (usually larger than) that covered by development agencies.

While technical skill requirements may necessitate that technology transfer and commercialization programs operate outside of development agencies, that both types of efforts share a similar economic development mission strongly suggests that there should be significant linkage between the two worlds. However, a project survey and field experience suggests that coordination and cooperation between these programs and agencies are not optimal. Many development practitioners do not have a full understanding of the ways in which they might fruitfully interact with technology transfer and commercialization programs.[153] While some agency staff say they are adept at taking advantage of these programs, and a few have played a role in their creation and operation, these are the exception rather than the rule. A number even say that they are not aware of the full array of such programs in their area. Many, even those who work with these programs, say they do not completely understand the processes of technology transfer and commercialization and need to learn more.

To overcome the gap in the literature regarding how development agencies work with technology transfer and commercialization programs, a series of 21 case profiles were carried out. Each profile, available in the Appendix C, provides background regarding the region or state, an overview of the technology transfer and commercialization program, a discussion of how the program works with local development agencies, and a summary of lessons learned. The 21 organizations profiled are listed in the box below, organized by the typology presented in Chapter Four. The set of organizations was selected for geographic and programmatic diversity.[154]

[153] Through economic development trade associations, several thousand development agencies were asked to respond to a survey regarding the nature of their interaction with technology transfer and commercialization programs. The level of returns was disappointing—102 surveys were returned.

[154] The case profiles were carried out in the spring of 2000. While certain information may be out of date, the breadth of activity identified and lessons learned remain valid. The analysis did not examine the impacts of the technology transfer and commercialization efforts.

Case Profile Organizations, by Technology Transfer and Commercialization Typology

1) Programs sponsored by public R&D institutions to promote transfer and commercialization of internally held knowledge
   a) Cooperative R&D centers – Biomedical Research Foundation of Northwest Louisiana (Shreveport, Louisiana); Center for Advanced FiberOptic Applications (Southbridge, Massachusetts); Edison Biotechnology Center (Ohio); Georgia Research Alliance
   b) Technical assistance programs – Engineering Research Center, University of Maryland
   c) Technology transfer offices – Office of Economic Development, Cornell University (Ithaca, New York); Industrial Business Development, Los Alamos National Laboratory (Santa Fe, New Mexico)
2) Services at entrepreneurship and business development centers
   a) Small Business Development Centers – North Carolina Small Business and Technology Development Center
   b) University-based entrepreneurship & business development centers – Missouri Small Business Technology Center, Central Missouri State University
   c) Independent entrepreneurship and business development centers – Louisiana Partnership for Technology and Innovation
3) External technology transfer and commercialization intermediaries
   a) Intermediaries working with technologies from all sources
      i) Intermediaries with statewide coverage – Louisiana Partnership for Technology and Innovation; Oklahoma Center for the Advancement of Science and Technology
      ii) Intermediaries with local coverage – Colorado Institute of Technology Transfer and Implementation, University of Colorado at Colorado Springs; North Florida Technology Innovation Corporation (Gainesville, Florida)
   b) Federal technology transfer intermediaries – Agri-Business Commercialization and Development Center (Richland, Washington); Engineering Technology Transfer Center, University of Southern California; Technology Transfer Committee, Huntsville/Madison Chamber of Commerce (Huntsville, Alabama)
4) Technology business membership organizations
   a) Technology-based regional development councils – Industry and Technology Council of Central Ohio (Columbus, Ohio)
   b) Technology business councils – Gallatin Valley Technology Alliance (Bozeman, Montana); Telecom Corridor Technology Business Council (Richardson, Texas).
   c) Industry-specific associations and networks – Arizona Optics Industry Association (Tucson, Arizona); Great Nashua Software Entrepreneurs Group (Nashua, New Hampshire).

5.2 Economic Development Agency Roles in Technology Transfer and Commercialization

The case profiles suggest that state and regional economic development agencies play two major roles regarding technology transfer and commercialization organizations. One is a ***leadership*** role, with subroles that can include catalyzing the creation of the technology transfer and commercialization organization (either within or outside the development agency), managing that organization, and providing financial support. The second role is ***cooperating*** with the technology transfer and development programs in development-related efforts. Possible subroles include referring clients, being assisted on particular projects, co-investing in business and technology development facilities, and coordinating activities through participating on the boards, committees, and working groups of the other organization. The various roles are explored in more detail below.

5.2.1 Leadership Roles

Economic development agencies can play an important leadership role in the creation and operation of technology transfer and commercialization organizations. In certain instances, the development agency creates and sponsors the technology transfer and commercialization effort ***within*** its own organization. For example:

- In 1990, the Huntsville/Madison Chamber of Commerce created a Technology Transfer Committee after being asked by NASA's Marshall Space Center to facilitate transfer of NASA technology to local firms. Committee members included representatives from federal laboratories, universities, and corporations. After assisting 600 firms, the committee's functions were relocated to the local Manufacturing Extension Partnership (MEP) affiliate in 1996.
- The Telecom Corridor® Technology Business Council (TBC) was created in August 1994 by the Richardson (Texas) Chamber of Commerce to enhance technology and telecommunication growth in the area. The TBC was created as a division of the Chamber to avoid the duplicative costs of operating two organizations and to build on the existing strengths of the Chamber and its partnerships with the City of Richardson, the University of Texas at Dallas, and local technology firms. The TBC is composed of technology firms and technical resource providers (e.g., engineering consultants) and has its own board of directors.

In other instances, the development agency plays a role in creating a new ***external*** technology transfer and commercialization organization. The development agency may be the ***primary catalyst***. The new organization may begin within the development agency, but is spun out as soon as feasible. Even though the new organization is legally independent, the development may have a continuing role in management, financial support, or as a landlord. It is not unusual for each organization to be represented on the board of the other. Examples of development agencies being the primary catalyst in creating external technology transfer and commercialization organizations include the following:

- The Biomedical Research Foundation of Northwest Louisiana was created in 1986 through the efforts of the Greater Shreveport Chamber of Commerce. The chamber had commissioned a study to examine ways in which the region might diversify beyond natural resource industries; the study recommended utilizing the concentration of health care institutions to promote development of a biomedical industry. The Foundation, with $42 million in assets, has in turn created a biomedical research institute, an R&D consortium, a center for biomedical technology commercialization, and a research park.
- The Greater Nashua Center for Economic Development (CED), a nonprofit development agency in southern New Hampshire, facilitated the creation of the Greater Nashua Software Entrepreneurs' Group (GNSEG) in 1992 as a vehicle for small software startup companies to meet and discuss issues. GNSEG acts as a loose network of software entrepreneurs and professionals who provide key commercialization resources (e.g., lawyers, consultants); it also hosts an annual software conference. CED continues to provide administrative and financial support to GNSEG.
- The Industry and Technology Council of Central Ohio (ITC), a nonprofit technology business organization, was created as an arm of the Greater Columbus Chamber of Commerce, then spun off as an independent organization in 1993. ITC's mission was to strengthen the local economy through assisting Columbus's technology-based companies, and helping existing businesses better use technology. ITC was co-located with the Chamber; the president of the chamber served on the ITC board, and the director of the ITC was on the chamber board.[155]

Even when a technology transfer and commercialization program is created within the catalyzing organization, a spin off may occur. As noted earlier, the functions of the Huntsville Technology Transfer Committee eventually were spun out to the local MEP affiliate. TBC created its own spinoff, a wholly owned for-profit subsidiary of the Richardson Chamber to help create new companies through commercializing patents.[156]

In some instances, the regional development is a ***partner*** with other organizations, including local government, state government, and public R&D institutions, in creating a new technology transfer and commercialization organization. For example:

[155] Since the case profile was written, the Industry and Technology Council of Central Ohio has merged with the Columbus Technology Leadership Council to form the Columbus Technology Council.

[156] Since the case profile was written, this subsidiary in turn has created a nonprofit foundation to promote technology entrepreneurship development.

- The Agri-Business Commercialization and Development Center (ABCD) was established in Richland, Washington, in 1995 to help entrepreneurs and existing industry to put agricultural research technology to commercial use. ABDC was formed by six organizations: the Pacific Northwest National Laboratory (PNL), Battelle (which operates PNL), the U.S. Department of Energy (the owner of the laboratory), Washington State University, the Tri-City Industrial Development Council (TRIDEC), and the Port of Benton. ABCD was a unit of PNL until 1999, when it was spun out as an independent nonprofit.
- The Center for Advanced FiberOptic Applications (CAFA) in south-central Massachusetts was a nonprofit corporation created in the mid-1990s to promote cooperative R&D among local fiber-optic firms. CAFA was overseen by 12 fiber-optic companies in partnership with the Tri-Community Area Chamber of Commerce, local government, and the University of Massachusetts. The chamber played a key role in CAFA's development. The executive director of CAFA was vice chairman of the chamber's board of directors.[157]

In certain instances, a local development agency provides ***funding*** to a local technology transfer and commercialization organization to support its services, even when the agency was not involved in the creation of the program. For instance, the Ocala/Marion County Economic Development Council helps fund the North Florida Technology Innovation Corporation, which was originally founded as part of a state program.

Among the 21 case profiles, it is interesting to note that of the eight technology transfer organizations were catalyzed in whole or in part by a development organization, in five instances, the catalyzing agency was a chamber of commerce, and in three, a public-private partnership nonprofit played a role. The possibility that nonprofit development agencies in general, and chambers of commerce in particular, are more likely to develop or spin off technology transfer organizations than are government development agencies may be worth further examination.

5.2.2 Cooperating Roles

Regional economic development agencies can cooperate with technology transfer and commercialization programs in four ways, including exchanging client referrals, receiving assistance from these programs in particular efforts, co-investing in development facilities, and coordinating interests and activities through dual participation in boards, committees, and working groups.

It is fairly common for economic development agencies and technology transfer and commercialization organizations to ***refer*** clients to one another. As most economic

[157] Since the case profile was written, CAFA went out of existence.

development agencies do not offer technology transfer and commercialization services in-house, they are pleased to be able to refer a company to an organization that offers such services. Among the case profiles, 12 economic development organizations indicate they refer clients to the local technology transfer and commercialization organization. A number noted that the referral process works in both directions, with the technology transfer and commercialization organization guiding clients to the development agency for particular services.

The Engineering Technology Transfer Center (ETTC) at the University of Southern California provides an interesting example of a referral relationship. The ETTC operates as the Far West Regional Technology Transfer Center (RTTC) for NASA in eight states. Local economic development organizations will contact the ETTC to serve as the local organization's technology transfer unit. The local organization will review its technology cluster strategy with the ETTC so that the ETTC understands which technology clusters (e.g., environmental technology, electronic commerce) are being targeted. In turn, the ETTC will narrow its focus toward five or six technologies that are especially relevant for companies in these clusters. Then the local organization will link the ETTC with local small and medium-size companies or entrepreneurs with defense conversion or other business problems that meet the technology cluster profile. Often these companies or entrepreneurs need repositioning away from a mature or declining industry. The ETTC meets with the companies, matches NASA or other technologies to the companies' needs and capabilities, and assists with intellectual property issues. The local economic development organization retains management of the relationship with the company.

Economic development agencies can ***receive assistance*** from technology transfer and commercialization organizations for particular efforts in the field. The case profiles yield a number of examples in which the geographic area covered by technology transfer and commercialization organization is far greater than that of the development agency. This pattern suggests that statewide or large regional technology transfer and commercialization organizations can have the resources and economies of scale to assist development agencies covering smaller areas and for which such resources would be out of the question. (The ETTC example above is consistent with this pattern as well.) For example:

- The Oklahoma Technology Commercialization Center, a state-sponsored organization, provides technical and management assistance in the operation of three research parks around the state.
- The Louisiana Partnership for Technology and Innovation, a statewide nonprofit, helps regional development agencies set up technical assistance services for businesses.
- The North Carolina Small Business and Technology Development Center advises the Greater Winston-Salem Chamber of Commerce on technology-based development activities.
- The Edison Biotechnology Center, a statewide biotechnology development organization, is actively involved in the biotechnology

cluster development effort managed by the Greater Cleveland Growth Association.

- The North Florida Technology Innovation Center (NFTIC), one of six regional centers in the state, advises local development agencies on technology development issues.
- The Georgia Research Alliance (GRA) provides training to local development agencies in technology-based development and helps municipalities solve technical problems relevant to development.

In the case profiles, no examples were found in which a development agency provided technical assistance to a technology transfer and commercialization organization in the pursuit of a particular project. This is of course not to say that such examples do not exist.

Economic development agencies and technology transfer and commercialization organizations can ***co-invest*** in incubators and research parks, physical facilities that support technology business development, transfer, and commercialization. The two types of organizations joining forces is logical in that each brings unique resources to the effort—the development agency in facilities development and the technology organization in technology development. Among the case profiles, examples of co-investment efforts include the following:

- The Greater Colorado Springs Economic Development Corporation and the Colorado Institute of Technology Transfer and Implementation at the University of Colorado at Colorado Springs cooperated in the development of a high-technology business incubator.
- The Cornell University Office of Economic Development and the Tompkins County Area Development Agency have co-invested in the Business Innovation Center, an incubator designed to support the creation of technology-based businesses.
- The Biomedical Research Foundation of Northwest Louisiana co-developed a 2,400-acre research park with the Greater Shreveport Chamber of Commerce, three development agencies, city governments, parish governments, the metropolitan planning commission, business organizations, downtown development authority, the state economic development department, and the electric utility.

Finally, economic development agencies and technology transfer and commercialization organizations can ***coordinate*** interests and activities through dual participation in boards, committees, and working groups. In a number of instances, a representative of one organization is on the board of the other. For example:

- Representatives of the ITC and the Greater Columbus Chamber of Commerce sat on each others' boards. (The Chamber implemented portions of an ITC-sponsored strategic plan.)
- The director of CAFA was on the board of the Tri-County Area Chamber of Commerce.
- The president of NFTIC sits on the boards of local development agencies.
- A member of the ETTC is on the board of California Association for Local Economic Development.
- GRA board members are on the boards of state and local development agencies.

Cross-representation also takes place on working groups and committees. For example:

- The director of the Los Alamos Commerce and Development Corporation is a member of Los Alamos National Laboratory external advisory board.
- The chair of the Arizona Optics Industry Association is the optics cluster leader for the Greater Tucson Economic Council (and is former chair of the Council board).
- A representative from the North Carolina Small Business and Technology Development Center sits on the emerging technologies committee of the Greater Winston-Salem Chamber of Commerce.
- The Cornell University Office of Economic Development participates in a multiagency Economic Development Working Group.
- Representatives of ABCD sit on a number of TRIDEC committees.

As in certain other roles, it appears from the case examples that regional development agencies are somewhat more likely to have technology organization representatives on their boards and working groups than vice versa. It would seem that this is so because the technology organizations are more likely to be narrowly and technically focused organizations (e.g., Arizona Optics Industry Association), often not stand-alone organizations (as in the case of Cornell), and covering a large (often statewide) area. When the technology organization is local independent nonprofit with a broad, rather than industry-specific, technology focus, it is much more likely that a local development agency is on its board (e.g., northwest Louisiana, ITC). Development agencies are more likely to have technology organizations on their boards and committees as the agencies are generalists, with a broad development mission, and seek the participation of the various specialist service providers in an area.

5.3 Lessons Learned

The case profiles make clear the variety of interactions that can take place between development agencies and technology transfer and commercialization organizations. The nature of these interactions would seem to be a function of the economic opportunities and institutional realities in each particular situation.

The question arises as to how development agencies and technology transfer and commercialization organizations can choose interactions that are both appropriate to the circumstances and effective in execution. A review of the 21 case profiles identifies several broad lessons learned.

First, adequate ***education*** is paramount. Development agencies and technology transfer and commercialization organizations need to be active, extroverted learners. Development agencies need to understand the realities of the technology development and commercialization process, and not get caught up in unrealistic thinking. They also need to become aware of the types of services that technology transfer and commercialization organizations offer, or could offer. On the latter point, they need to become more cognizant of models and options for technology transfer and commercialization as implemented in various regions around the United States, so that they might press for appropriate services in their respective areas.

Conversely, technology transfer and commercialization organizations need to better understand the breadth of economic development agency mission and services, and the incentives under which they operate, so that they might better meet agency needs. Moreover, they need to more fully comprehend the role that technology can and cannot play in the larger economy, and recognize that other sectors are important as well.

Second, good ***communication*** is key. Each organization needs to regularly update the other regarding its activities, services, results, and clients. Good communication allows each organization to better determine when to call on the other for assistance, or provide a referral.

The third lesson is ***collaboration***. The organizations need to move beyond understanding to action on particular projects. Each can benefit from the other's resources, expertise, and perspective, whether working with clients, developing new programs, or building new infrastructure.

The fourth lesson is the need for ***coordination***. The policy and strategy of each organization needs to recognize, and to the extent possible, be consistent with the other. Cross-representation on boards and committees facilitates coordination.

The final lesson is the need for ***leadership***. Through the leadership of a handful of individuals, a number of development agencies were responsible for creating a new technology transfer and commercialization organization. Good leadership brings about education, communication, collaboration, and coordination. It is the “meta” characteristic without which the others would not exist.

These lessons hold even if, as is so often the case, the technology organization covers a larger area than the development organization. In such instances, the local development agencies may be more dependent on the technology organization than vice versa. However, if a technology organization has statewide coverage, the state development agency should be actively working with it as well in the realms of education, communication, collaboration, and coordination.

Chapter Six
Concluding Remarks

This research report began by noting that the globalized economy has caused a large-scale economic restructuring of U.S. regions, that this restructuring is ongoing, and that regions can best adjust by moving up the ladder of value-added activities. It further suggested that technology development and commercialization activities are means for moving up this ladder, and that public purpose technology transfer and commercialization programs are a popular tool for promoting such activities.

The report articulated a typology of technology transfer and commercialization and then explored the geography of innovation. Analysis concluded that, as technology transfer is significantly facilitated by geographic proximity, a strong centripetal force pulls a disproportionate share of technology development and commercialization activity (as measured by patents) into larger urban areas. Also, recent literature and anecdotal evidence were cited which indicate the substantial resource requirements and uncertainty of commercialization activity, and the geographic fragmentation of the outcomes of such activity. More research is needed to quantify the extent and better understand the dynamics of the dispersion of commercialization activity and its outcomes away from the site of technology development.

Chapter Four makes clear that throughout the 1990s a wide diversity of technology transfer and commercialization programs were actively operating in states and regions across the nation. While the chapter's typology is intended as description rather than evaluation, one is struck by the widespread optimism regarding the efficacy of these programs, irrespective of location, and the inconsistency of this newly formed cross-country institutional infrastructure with the geographic dynamics of technology development and commercialization cited earlier. Thus, it was not surprising to find that, since being identified, a number of these programs have disappeared or been transformed.

In light of the geographic patterns of technology transfer and commercialization, perhaps states and regions should be advised to separate technology transfer efforts from commercialization efforts, and to have a difference in emphasis and orientation that realistically reflects the local opportunities offered by each. Significant technology transfer programs are appropriate where innovation clusters currently exist, or appear possible. Other regions certainly should take steps to promote technology transfer, but they need to be more strategic and realistic about what can be accomplished. All regions, but the latter in particular, might do well to explore ways to facilitate increased local firm access to technology developed elsewhere. That is, they should explore the ways in which technology transfer efforts can emphasize "demand-pull" rather than "supply-push." The primary focus in some regions on transferring technology from a local public R&D institution seems misplaced.

States and regions should consider adjusting the nature of their commercialization strategies from ones emphasizing the commercialization of locally developed technologies to ones emphasizing aiding the successful commercialization of technologies developed elsewhere. Sommers and Carlson note that, with the geographic fragmentation of the outcomes of commercialization, regions that do not contain major innovation clusters have an opportunity to implement some aspect of commercialization (e.g., manufacturing, distribution, marketing, service, administration) in which they excel. These strategies would focus more on a region's facilitating certain firm functions rather than growing new local firms. It is quite important that regions be fully realistic about the substantial difficulties inherent in the achieving, and reaping the benefits of, successful commercialization of home-grown technology.

In adjusting technology transfer and commercialization tools and strategies in light of experience and new economic realities, regions would benefit from studying efforts in other regions that have proven effective in circumstances similar to theirs. The field of technology transfer and commercialization program development itself suffers from inefficiencies in knowledge transfer. Too often, it appears (and is often the case in economic development generally), a particular tool is widely copied without full understanding of the appropriateness of such a tool in a local setting and, if appropriate, how to manage it effectively. Regions could benefit from a set of "best practice" profiles, or perhaps a comprehensive inventory of existing programs organized by economic and institutional circumstances, to facilitate a greater understanding of models and options.

With increased globalization, the need for regions to develop and protect higher value-added industries only grows. To respond, regions must have a thoughtful, strategic, quick-acting economic development process; to be effective, such a process must involve collaboration among all relevant parties, including those involved in technology development and commercialization.[158] To a significant extent, technology transfer and commercialization programs operate with insufficient linkage to regional economic development agencies. While a number of development agencies have close relations with technology transfer and commercialization efforts, many do not. Moreover, given the number of such efforts at the local and state level, it may be difficult for development agencies to maintain links with, or even be aware of, all such efforts.

Even so, as the primary facilitators of overall regional strategy, economic development agencies have a responsibility to identify the need for and proper design of local technology transfer and commercialization efforts, to see that any programmatic gaps are filled (even if by state programs), and to ensure that representatives of such efforts are active partners in strategic planning and implementation.

In economic development, the widespread optimism of the 1990s is giving way to a more somber realism that there are no "magic bullets." Technology transfer and commercialization are difficult processes with uncertain endings. Thus, it becomes clear

[158] The nature of such a process is laid out in detail in a recently released document commissioned by the Economic Development Administration: Collaborative Economics, *Strategic Planning in the Technology-Driven World: A Guidebook for Innovation-Led Development*, 2001.

that regional economic well-being is best served if development agencies work hard to educate themselves about the art of the possible in technology transfer and commercialization, and actively work with relevant partners so that those possibilities can become realities.

Appendix A
Summary of Federal Technology Transfer and Commercialization Legislation[1]

A.1 NASA Space Act of 1958

The origin of the active involvement of the federal government in technology transfer and commercialization is commonly associated with the National Aeronautics and Space Act of 1958 [P.L. 85-568]. Relatively little federal legislation was passed during the 1960s and 1970s. Extensive fundamental federal legislation addressing a wide variety of technology transfer and commercialization issues was passed during the 1980s.

National Aeronautics and Space Act of 1958

The National Aeronautics and Space Act established the civilian federal agency known as the National Aeronautics and Space Administration (NASA). Several important provisions related to the early concepts of technology transfer were embodied in this Act, including

- directive to NASA to provide for the widest practicable and appropriate dissemination of information concerning its activities and the corresponding results;
- authorization to enter into and perform such contracts, leases, cooperative agreements, or other transaction as may be necessary in the conduct of NASA's work, on terms NASA deems appropriate, with any agency or instrumentality of the U.S., or with any state, territory, or possession, or with any person, firm, association, corporation, or educational institution;
- directive to the NASA administrator to allocate contracts, leases, and other transactions in a manner to enable small business concerns to participate equitably and proportionately;
- authorization for the administrator to waive all or any part of the rights to inventions made in the performance of work under a NASA contract; and
- authorization for the administrator to determine, and promulgate regulations specifying, the terms and conditions upon which licenses can be granted for the practice by any person of any invention for which NASA holds a patent on behalf of the U.S.

[1] Federal legislation related to technology transfer and commercialization is continually evolving. Every effort has been made for this compendium to be current through mid-2001.

Transactions that became known as Space Act Agreements were authorized by Section 305(a) of the National Aeronautics and Space Act and allow NASA to tailor the allocation of intellectual property rights according to the nature of the particular agreement and contributions of the parties. Space Act Agreements were the forerunner to the well-known cooperative research and development agreements (CRADAs) authorized by the amendments to the Stevenson-Wydler Technology Innovation Act of 1980 by the Federal Technology Transfer Act of 1986. Provisions of the University and Small Business Patent Procedures Act of 1980 superseded and repealed the authorization for the NASA administrator to establish the terms and conditions of licenses to inventions patented by NASA.

A.2 Federal Support for Technology Transfer, Cooperative Research Programs, and Management of Intellectual Property

Federal legislation adopted during the past two decades affecting technology transfer and commercialization is intimately linked to the policy, procedures, and practices related to the ownership and disposition of inventions and technology originating from publicly sponsored research. The Stevenson-Wydler Technology Innovation Act of 1980 [P.L. 96-480] and the University and Small Business Patent Procedures Act of 1980 (commonly referred to as the Bayh-Dole Act for Senators Birch Bayh of Indiana and Robert Dole of Kansas) [P.L. 96-517] established an initial foundation for technology transfer and commercialization. Considerable subsequent legislation during the past 20 years has expanded this foundation, including a series of amendments to the Stevenson-Wydler Technology Innovation Act.

<u>Stevenson-Wydler Technology Innovation Act of 1980</u>

The Stevenson-Wydler Technology Innovation Act contained a number of important provisions, including

- establishment of Offices of Research and Technology Applications (ORTA) at federal laboratories;
  - all agencies with annual budgets greater than $20 million were required to have one full-time professional within the ORTA; and
  - subsequent to September 30, 1981, each federal agency operating one or more laboratories was required to make available not less than 0.5% of its budget to support technology transfer;
- establishment of the Office of Industrial Technology within the U.S. Department of Commerce;
- authorization for the secretary of commerce to provide assistance for the establishment of Centers for Industrial Technology at universities and nonprofit institutions;
- granting the Centers of Industrial Technology the option of acquiring title to any invention conceived or made under the auspices of the

Center that was supported at least in part by federal funds, subject to certain conditions;

- authorization for the National Science Foundation to provide assistance for the establishment of Centers for Industrial Technology at universities and nonprofit institutions;
- establishment of the Center for the Utilization of Federal Technology emphasizing the collection, dissemination, and transfer of information on federally owned technologies having potential applications to state and local governments and private industry;
- establishment of a program to foster the exchange of scientific and technical personnel among academia, industry, and federal laboratories;
- creation of the National Industrial Technology Board;
- creation of the National Technology Medal; and
- authorization of appropriations to the secretary of commerce for five fiscal years beginning with the fiscal year ending on September 30, 1981, to carry out the provisions of the Act.

<u>Federal Technology Transfer Act of 1986</u>

Significant amendments to the Stevenson-Wydler Act were contained in the Federal Technology Transfer Act of 1986 [P.L. 99-502]. Among the most important provisions in this Act were

- authorization of federal agencies to permit the directors of government-owned and -operated laboratories to enter into cooperative research and development agreements (CRADAs) with other federal agencies; units of state and local government; industrial organizations; public and private foundations; nonprofit organizations, including universities; and other persons, including licensees of inventions owned by the federal agency;
- authorization of federal agencies to permit the directors of government-owned and -operated laboratories to negotiate licensing agreements for government-owned inventions made at their laboratories;
- authorization for a government-owned and -operated laboratory to accept, retain, and use funds, personnel, services, and property from collaborating parties and to provide personnel, services, and property to collaborating parties under a CRADA;
- authorization to agree to grant in advance to a collaborating party under a CRADA patent licenses or assignments, or options thereto in any invention made in whole or in part by a federal employee under a CRADA subject to certain rights reserved for the federal government;
- authorization to waive in advance, in whole or in part, to a collaborating party under a CRADA any right of ownership which the

federal government may have to any invention made under a CRADA by a collaborating party or an employee of a collaborating party;

- established the Federal Laboratory Consortium (FLC) whose purpose was to facilitate technology transfer from federal laboratories and established a funding mechanism for the FLC for Fiscal Years 1987 through 1991 based on a percentage (0.005%) of the research and development budgets of the participating laboratories;
- made technology transfer, consistent with the mission of a federal laboratory a responsibility of each laboratory science and engineering professional;
- made efforts to transfer technology a positive consideration in laboratory job descriptions, employee promotion policies, and job performance evaluations of the science and engineering professional staff;
- established a cash awards program in laboratories operated by a federal agency with expenditures in excess of $50 million in a fiscal year for inventions, innovations, or other outstanding contributions due to commercial application, contributions to the mission of the agency, or exemplary activities promoting transfer of science and engineering development and result in use of such science and technology by non-federal parties;
- established minimum royalty sharing practices (nominally 15%) to the inventors for income a federal agency derived from an invention made while the inventor was an employee of the federal agency;
- in the event a federal agency which has a right of ownership to an invention chooses to not file a patent application or otherwise promote commercialization of an invention, the agency shall allow the employee who made the invention to retain title to the invention subject to certain rights reserved by the federal government;
- required federal agencies to ensure that personnel polices allow employees and former employees to engage in technology commercialization activities provided that potential conflict of interest issues are resolved;
- changed the requirement from expenditures of $20 million to 200 or more full-time equivalent scientific, engineering, and related technical personnel to staff the ORTA with a minimum of one full-time professional; and
- established a funding mechanism for the FLC based on a percentage (0.005%) of the research and development budget of participating federal agencies.

Executive Order No. 12591

Executive Order No. 12591 issued by President Reagan in 1987 was focused on facilitating access to federal science and technology. This Executive Order directed federal agencies to delegate authority to government-owned and -operated laboratories to enter into CRADAs with other federal laboratories, state and local governments, universities, and the private sector. In addition, federal agencies were also directed to delegate authority to government-owned and -operated laboratories to license, assign, or waive rights to intellectual property developed by the laboratory under a CRADA or from within the laboratory (compare, for example, related provisions contained in the Federal Technology Transfer Act of 1986). Other directives to federal agencies included

- identifying and encouraging persons to act as conduits between and among federal laboratories, universities, and the private sector for the transfer of technology developed from federally funded R&D;
- promoting commercialization of patentable results of federally funded research by granting to all contractors, regardless of size, the title to patents made in whole or in part with federal funds, subject certain rights reserved by the federal government; and
- implementing, as expeditiously as practicable, royalty sharing programs with inventors who were employees of the federal agency at the time the invention was made.

<u>Title III of Public Law 100-519</u>

Title III of Public Law 100-519 (October 24, 1988) extended the rights of federal laboratories to negotiate licenses covering intellectual property other than inventions or patents and allowed directors of federal laboratories to determine the rights to other intellectual property developed under CRADAs. The sharing of royalty payments or other income received by federal agencies derived from inventions was also extended by Title III to nongovernment employees who have assigned their rights in the invention to the U.S. government. Computer software was added to the list of qualifying achievements to be considered under the cash awards program in laboratories operated by a federal agency with expenditures in excess of $50 million in a fiscal year as established by the Federal Technology Transfer Act of 1986.

<u>Water Resources Development Act of 1988</u>

The Water Resources Development Act of 1988 [P.L. 100-676] authorized the Army Corps of Engineers laboratories and research centers to undertake cost-shared collaborative research and development with non-federal entities including state and local governments, colleges and universities, and corporations, partnerships, sole proprietorships, or trade associations for the purpose of improving the state of engineering and construction in the U.S. This Act specifically authorized the secretary of defense to allow the Army Corps of Engineers laboratories and research centers to enter into CRADAs consistent with creation of this mechanism established under the Federal Technology Transfer Act of 1986 [P.L. 99-502]. No more than 50% of the cost of research and development under any CRADA could be provided by the federal government and not less than 5% of the share of the costs to be provided by the non-federal entity must be in the form of cash.

National Competitiveness Technology Transfer Act of 1989

Title XXXI of the National Defense Authorization Act for Fiscal Years 1990 and 1991 [P.L.101-189], cited as the National Competitiveness Technology Transfer Act of 1989, contained further amendments to the Stevenson-Wydler Act. These amendments extended the activities authorized under the Federal Technology Transfer Act of 1986 for government-owned and -operated laboratories to government-owned, contractor-operated (GOCO) laboratories as follows:

- authorization of federal agencies to permit the directors of GOCO laboratories to enter into cooperative research and development agreements (CRADAs) with other federal agencies; units of state and local government; industrial organizations; public and private foundations; nonprofit organizations, including universities; and other persons, including licensees of inventions owned by the federal agency;
- authorization of federal agencies to permit the directors of GOCO laboratories to negotiate licensing agreements for inventions made at their laboratories;
- authorization for a GOCO laboratory to accept, retain, and use funds, personnel, services, and property from collaborating parties and to provide personnel, services, and property to collaborating parties under a CRADA;
- authorization to agree to grant in advance to a collaborating party under a CRADA patent licenses or assignments, or options thereto in any invention made in whole or in part by a laboratory employee under a CRADA subject to certain rights reserved for the federal government; and
- authorization to waive in advance, in whole or in part, to a collaborating party under a CRADA any right of ownership which the federal government may have to any invention made under a CRADA by a collaborating party or an employee of a collaborating party.

In addition, the National Competitiveness Technology Transfer Act of 1989 allowed trade secrets or commercial or financial information that is privileged or confidential which is obtained from a non-federal party participating in a CRADA or is developed under a CRADA to not be disclosed. This Act also made technology transfer a mission of the nuclear weapons laboratories (i.e., Lawrence Livermore National Laboratory, Los Alamos National Laboratory, and Sandia National Laboratories) operated by the U.S. Department of Energy.

National Defense Authorization Act for Fiscal Year 1991

Title VIII of the National Defense Authorization Act of 1991 [P.L. 101-510] amended the Stevenson-Wydler Act to allow, subject to the approval by the affected federal agency, federal laboratories and federally funded research and development centers (FFRDCs) to enter into a contract or memorandum of understanding with a partnership intermediary to perform services that increase the likelihood of success in the conduct of cooperative or joint activities undertaken by the federal laboratory or FFRDC with small business firms. For the purposes of this Act, a partnership intermediary is an agency of a state or local government, or a nonprofit entity, that assists, counsels, advises, evaluates, or otherwise cooperates with small business firms that need or can make demonstrably productive use of technology-related assistance from a federal laboratory or FFRDC.

Also, as part of the amendments to the Stevenson-Wydler Act, Title VIII directed the secretary of commerce, in consultation with the secretary of defense and the secretary of energy, to establish model programs for national defense laboratories, involving federal laboratories, small businesses, and partnership intermediaries, to demonstrate successful relations between the federal government, state and local governments, and small businesses which encourage economic growth through the commercial application of technology resulting from federally funded research. For the purposes of the Act, a national defense laboratory is any laboratory, FFRDC, or other center established under section 6 or 8 of the Stevenson-Wydler Act owned by the federal government, operated either by the federal government or a contractor, under the jurisdiction of the secretary of defense or the secretary of energy so long as the primary function of the laboratory, FFRDC, or other center is to support national defense activities of the Departments of Defense or Energy.

In addition, Title VIII directed the secretary of defense, in coordination with the secretary of commerce and the secretary of energy, to develop and implement a National Defense Manufacturing Technology Plan to, among other things, analyze the role of manufacturing extension services in improving the manufacturing quality, productivity, technology and practices of defense subtier suppliers and disseminating to such suppliers manufacturing concepts such as best manufacturing practices, product data exchange specifications, computer-aided acquisition and logistics support, and rapid acquisition of manufactured parts. The National Defense Manufacturing Technology Plan was also intended to provide a link between defense manufacturing technology program and the Regional Centers for the Transfer of Manufacturing Technology established by the Department of Commerce under the Omnibus Trade and Competitiveness Act of 1988.

<u>Intermodal Surface Transportation Efficiency Act of 1991</u>

Title VI of the Intermodal Surface Transportation Efficiency Act of 1991 [P.L. 102-240] authorized the Secretary of the Department of Transportation to undertake cost-shared collaborative research and development with non-federal entities including state and local governments, foreign governments, colleges and universities, and corporations, institutions, partnerships, sole proprietorships, or trade associations for the purposes of encouraging innovative solutions to highway problems and stimulating the marketing of new technology by private industry. This Act specifically authorized the Secretary of the Department of Transportation to enter into CRADAs consistent with creation of this mechanism established under the Federal Technology Transfer Act of 1986 [P.L. 99-502]. No more than 50% of the cost of research and development under any CRADA could be provided by the federal government; except that, if there is a substantial public interest or benefit, the Secretary could approve a higher federal share.

American Technology Preeminence Act of 1991

Title III of the American Technology Preeminence Act of 1991 [P.L. 102-245] contained a number of amendments to the Stevenson-Wydler Act. These amendments included

- extension of the Federal Laboratory Consortium through Fiscal Year 1996;
- expansion of the resources able to be provided by the government and non-federal parties as part of a CRADA to include intellectual property as well as personnel, services, equipment, and other resources previously identified in the Federal Technology Transfer Act of 1986; and
- authority for a director of a federal laboratory or the head of any federal agency or department to give title to research equipment that is excess of their needs to an educational institution or nonprofit organization for the conduct of technical and scientific education and research activities.

National Defense Authorization Act for Fiscal Year 1993

Title XXXI of the National Defense Authorization Act for Fiscal Year 1993 [P.L. 102-484] further amended the Stevenson-Wydler Act to require

- submission of any cooperative research and development agreement (CRADA), along with the required joint work statement, proposed by any non-federal entity operating a laboratory pursuant to a contract with a federal agency with a small business to the federal agency; and
- review and approval, request for specific modifications to, or disapproval of the proposed CRADA and joint work statement within 30 days after submission to federal agency.

This Title also directed the Secretary of the Department of Energy to

- establish a program to facilitate and encourage the transfer of technology to small businesses; and
- issue guidelines relating to this program no later than May 1, 1993.

In addition, funds authorized to be appropriated to the Department of Energy, and made available for laboratory directed research and development, be available for CRADAs or other arrangements for technology transfer.

Title XLII of the National Defense Authorization Act for Fiscal Year 1993 directed the secretary of defense to

- encourage, to the extent consistent with national security objectives, the transfer of technology between laboratories and research centers of the Department of Defense and other federal agencies, state and local governments, colleges and universities, and private persons;
- examine and implement methods that will enable Department of Defense personnel to promote technology transfer;
- establish a program, known as the Federal Defense Laboratory Diversification Program, to encourage greater cooperation in research and production activities carried out by defense laboratories and by U.S. private industry in order to enhance and improve the products of such research and production activities; and
- establish in the Office of the Secretary of Defense an Office of Technology Transition to ensure, to the maximum extent practicable, that technology developed for national security purposes is integrated into the private sector to enhance national technology and industrial base, reinvestment, and conversion activities.

Under the Federal Defense Laboratory Diversification Program, the defense laboratories, in cooperation with the Office of Technology Transfer in the Office of the Secretary, were directed to carry out cooperative activities with private industry to promote the transfer of defense or dual-use technologies to private industry and the development and application of such technologies for the purpose of commercial utilization by private industry. Promotion of technology transfer was to be accomplished by the use or exchange of patents, licenses, CRADAs, and other cooperative agreements and by the use of symposia, meetings, and other similar mechanisms. In this context, a defense laboratory is any laboratory owned or operated by the Department of Defense that carries out research in Fiscal Year 1993 in an amount in excess of $50 million.

<u>National Defense Authorization Act for Fiscal Year 1994</u>

Title 31 of the National Defense Authorization Act for Fiscal Year 1994 [P.L. 103-160] amended the Stevenson-Wydler Act broadened the definition of a federal laboratory to include U.S. Department of Energy weapons production facilities.

<u>National Technology Transfer and Advancement Act of 1995</u>

The National Technology Transfer and Advancement Act of 1995 [P.L. 104-113] amended a number of sections of the Stevenson-Wydler Act. Many of these amendments clarified the language of existing provisions. The most substantive amendments involved title to intellectual property arising from cooperative research and development agreements (CRADAs) and distribution of income received by federal laboratories from intellectual property. Among the most important amended provisions are

- option for a collaborating party to choose an exclusive license for a pre-negotiated field of use for any invention made under a CRADA;
- establishment of a limited right of the federal government to require a collaborating party holding an exclusive license to grant to an responsible applicant a nonexclusive, partially exclusive, or exclusive license in exceptional circumstances of public health or safety, failure by the collaborating party to meet public use requirements of federal regulations, or failure of the collaborating party to meet requirement of substantially manufacturing products embodying inventions made under a CRADA in the U.S.;
- opportunity for collaborating parties to retain title to any invention made solely by its employees under a CRADA in exchange for granting the federal government a nonexclusive, nontransferable, irrevocable, paid-up license to practice, or to have practiced on its behalf, the invention;
- payment of the first $2,000 income received from the licensing or assignments of inventions made by federal laboratories to the inventor(s) and thereafter at least 15% of the royalties or other payments;
- increase in the allowed maximum income received annually by inventors from $100,000 to $150,000; and
- specific authorization for federal laboratories to use income from licensing of intellectual property for scientific research and development consistent with the research and development missions and objectives of the laboratory.

<u>Technology Transfer Commercialization Act of 2000</u>

The Technology Transfer Commercialization Act of 2000 [P.L. 106-404] amended a number of sections of the Stevenson-Wydler Act. Among the most important amendments are

- authority to grant a license to a federally owned invention for which a patent application was filed prior to the signing of a cooperative research and development agreement (CRADA) to collaborating party in advance if the invention is directly within the scope of the work under the CRADA;
- requirement for each federal agency with a federally funded laboratory that has CRADAs in effect to report to Congress on the general policies and procedures used to gather and consider the views of other agencies with respect to major proposed CRADAs involving national

security technology or potentially having a significant impact on domestic or international competitiveness;

- requirement for the Committee on National Security of the National Science and Technology Council, in consultation with federal agencies and laboratories, to determine the adequacy of existing procedures and methods for interagency coordination and awareness with respect to CRADAs and to establish specific criteria to indicate the necessity for gathering and considering the views of other agencies on joint work statements or CRADAs;
- extension of the definition of a partnership intermediary partnership performing services to increase the likelihood of success in the conduct of cooperative or joint activities undertaken by the federal laboratory or FFRDC with small business firms to include institutions of higher education;
- requirement for each federal agency engaged in technology transfer activities under sections 207 or 209 of title 35 of the U.S. Code report on the activities for the preceding fiscal year as part of its annual budget submission to the Office of Management and Budget, including the number of patent applications filed, the number of patents received, the number of fully executed licenses receiving royalty income, the time elapsed from the date the license was requested in writing to the date the license was executed, the total earned royalty income, the disposition of the royal income received, and the number of licenses terminated for cause; and
- requirement for the secretary of energy to direct the director of each national laboratory of the U.S. Department of Energy to appoint a technology partnership ombudsman to hear and help resolve complaints from outside organizations regarding policies and actions with respect to technology partnerships (including CRADAs), patents, and technology licensing.

A.3 Uniform Patent and Licensing Policies and Procedures

University and Small Business Patent Procedures Act of 1980 (Bayh-Dole Act)

In contrast to programmatic focus of the Stevenson-Wydler Technology Innovation Act, the Bayh-Dole Act amended existing patent and trademark laws (Title 35, United States Code). According to the Bayh-Dole Act, the policy and objective of Congress is to use the patent system to promote the utilization of inventions arising from federally supported research or development to

- encourage maximum participation of small business firms in federally supported R&D;

- promote collaboration between commercial concerns and nonprofit organizations, including universities;
- ensure that inventions made by nonprofit organizations and small business firms are used in a manner to promote free competition and enterprise;
- promote the commercialization and public availability of inventions made in the U.S. by U.S. industry and labor;
- ensure that the federal government obtains sufficient rights in federally supported inventions to meet the needs of the government and protect the public against nonuse or unreasonable use of inventions; and
- minimize the costs of administering policies in this area.

The changes most relevant to technology transfer and commercialization (Chapter 38) included

- establishment of a uniform government policy regarding patent rights to inventions resulting from federally supported research and development (R&D);
- allowance for small business firms, universities and other institutions of higher education, 501(c)(3) nonprofit organizations exempt from federal taxation, and nonprofit scientific or educational organization qualified under a state nonprofit organization statute to elect to retain title to any invention conceived or made through performance of experimental, developmental, or research work funded in whole or in part by the federal government, subject to certain conditions;
- authorization for federal agencies to withhold from disclosure to the public information disclosing any invention in which the federal government owns or may own a right, title, or interest for a reasonable time in order for a patent application to be filed;
- authorization for the administrator of General Services to promulgate regulations specifying the terms and conditions upon which any federally owned invention may be licensed on a nonexclusive, partially exclusive, or exclusive basis;
- grant of first preference in the exclusive or partially exclusive licensing of federally owned inventions to small business firms, subject to certain conditions;
- precedence of this Act over any other Act requiring a disposition of rights in subject inventions of small business firms or nonprofit organizations (as defined by this Act) in a manner that is inconsistent with this Act; and
- precedence over any future Act unless that Act specifically cites this Act and provides that it shall take precedence over this Act.

For the purposes of the Bayh-Dole Act, a small business firm is, as defined by the Small Business Act (15 USC 632), one which is independently owned and operated and which is not dominate in its field of operation. The administrator of the Small Business Administration specifies detailed definitions or standards by which a business concern may be determined to be a small business for the purposes of the small Business Act.. These standards may utilize appropriate factors such as number of employees, dollar volume of business, net worth, or net income. Effective October 1, 2000, all small business size standards are based on the North American Industry Classification System (NAICS). In most instances, the size standards are based on the number of employees and annual revenues. For manufacturing businesses, the factor is number of employees and ranges from 500 to 1,500 depending on the NAICS code, with 500 being the most common maximum number of employees.

In addition to these provisions, the Bayh-Dole Act also

- empowered the U.S. Patent and Trademark Office to revise patent fees;
- established procedures to enable any party to request reexamination of a patent for validity; and
- redefined limitations on owners of copies of copyrighted computer programs.

Public Law 98-620

Some of the provisions of the Bayh-Dole Act were altered by Public Law 98-620 that amended existing patent and trademark law. This Act [P.L. 98-620], in part, clarified patent and trademark law in reference to government-owned, contractor-operated (GOCO) federal laboratories. The provisions most important for technology transfer and commercialization included

- allowance for universities and nonprofit institutions operating federal laboratories to retain title to inventions subject to certain limitations;
- allowance of decisions regarding licensing inventions to be made at the laboratory level in GOCO laboratories;
- allowance for contractors operating GOCO laboratories to receive royalties from licensed technology and use these funds for scientific research, development, and education consistent with the mission of the laboratory including activities to increase the licensing potential of other inventions; and
- authorization for any for-profit firm to obtain an exclusive license to federally owned inventions.

Technology Transfer Commercialization Act of 2000

The Technology Transfer Commercialization Act of 2000 [P.L. 106-404] rewrote a major part (35 USC 209) of the Bayh-Dole Act that addresses licensing of federally owned inventions and associated preferences, procedures, and restrictions. No substantive changes in policies governing licensing practices were incorporated in the new language.

A.4 Public Funding for Technological Innovations by Small Businesses

Small Business Innovation Act of 1982

Given the provisions of the Bayh-Dole Act, a number of funding programs targeted at small business firms have been authorized by Congress to accelerate the creation and commercialization of technology sponsored by federal funds. Ownership of the technology by the small business firm would not have been possible prior to the passage of the Bayh-Dole Act. The first of these initiatives originated under the Small Business Innovation Act of 1982 [P.L. 97-219], which contained amendments to the Small Business Act [15 U.S. Code 631-638]. The purpose of this Act was to strengthen the role of small, innovative firms in federally funded R&D and to utilize federal R&D as a base for technological innovation to meet agency needs and to contribute to the growth and strength of the U.S. economy. Increasing private-sector commercialization of innovations derived from federal R&D was a primary objective of this Act.

Provisions of the Small Business Innovation Act included

- creation of the Small Business Innovation Research (SBIR) Program;
  - all federal agencies with extramural budgets for research or R&D in excess of $100 million in Fiscal Year 1982, or any fiscal year thereafter, were required to expend not less than 0.2% of their extramural budget in Fiscal Year 1983, or in such subsequent fiscal year as the agency has such budget;
  - a schedule for increased commitments was adopted as follows: not less than 0.6% in the second fiscal year thereafter; not less than 1.0% in the third fiscal year thereafter; and not less than 1.25% in all subsequent fiscal years;
  - any federal agency with an extramural budget for research or R&D in excess of $10 billion in Fiscal Year 1982 was required to expend not less than 0.1% of its extramural budget in Fiscal Year 1983;
  - a schedule for increased commitments from these agencies was adopted as follows: not less than 0.3% in the second fiscal year thereafter; not less than 0.5% in the third fiscal year thereafter; not less than 1.0% in the fourth fiscal year thereafter; and not less that 1.25% in all subsequent fiscal years;

- any federal agency with an extramural budget for research or R&D in excess of $20 billion for any fiscal year beginning with Fiscal Year 1983 or subsequent fiscal year was required to establish goals specifically for funding agreements for research or R&D to small business concerns, with no goal being less than the percentage of its budget expended under funding agreements with small business concerns in the immediately preceding fiscal year;

- sunset of the SBIR program effective October 1, 1988, through the repeal of the subject sections of the Small Business Act; and
- requirement for the Comptroller General to submit , not later than five years after the enactment of this Act, a report to Congress describing the implementation of, and the nature of the research conducted under, this Act, including judgments of the heads of federal agencies as to the effect of this Act on research programs.

<u>Public Law 99-443</u>

The Small Business Innovation Act of 1982 was amended by P.L. 99-443 to extend the sunset of date of the SBIR Program from October 1, 1998, to October 1, 1993. The submission date of the required report by the Comptroller General was changed to no later than December 31, 1988. The report content was expanded to include evaluations of the effectiveness of phase one and phase two of the SBIR Program and the extent to which the goals of the SBIR Program are being met. The quality of the research supported by the SBIR Program was to be compared to that traditionally supported by the affected federal agencies. This report was to be updated no later than December 31, 1991. The report update was to include an evaluation of phase three of the SBIR program and a discussion of the aggregate commercial trends for products currently in, or completed under, phase three of the SBIR program.

<u>Small Business International Trade and Competitiveness Act</u>

Title VIII of the Omnibus Trade and Competitiveness Act of 1988 [P.L. 100-418], cited as the Small Business International Trade and Competitiveness Act, required the Comptroller General to include in the report to Congress on the implementation of the Small Business Innovation Act of 1982, and the nature of the research conducted hereunder, recommendations as to the advisability of amending the SBIR Program to

- increase each agency's share of R&D expenditures devoted to the SBIR Program by 0.25% per year until the percentage reaches 3.0% of the total extramural R&D funds, and targeting a portion of the increment at products with commercialization or export potential;
- make the SBIR program permanent with a formal congressional review every 10 years, beginning in 1993;

- allocate a modest but appropriate share of each agency's SBIR fund for administrative purposes for effective management, quality maintenance, and the elimination of program delays; and
- include within the SBIR Program all agencies expending between $20 million and $100 million in extramural R&D funds annually.

Technical and Miscellaneous Revenue Act of 1988

The Small Business Innovation Act of 1982 was further amended by the Technical and Miscellaneous Revenue Act of 1988 [P.L. 100-647] to extend the submission date of the report on the SBIR Program required of the Comptroller General, including the provisions of the Small Business International Trade and Competitiveness Act, to July 31, 1989.

Small Business Research and Development Enhancement Act of 1992

The Small Business Research and Development Enhancement Act of 1992 [P.L. 102-564] further amended the Small Business Act to provide the administrator of the Small Business Administration continued authority to administer the SBIR Program. Title I of the Small Business Research and Development Enhancement Act is cited as the Small Business Innovation Research Program Reauthorization Act of 1992 with the purposes of

- expanding and improving the SBIR Program;
- emphasizing the goal of increasing private-sector commercialization of technology developed through federal R&D;
- increasing small business participation in federal R&D; and
- improving the federal government's dissemination of information concerning the SBIR Program, especially with regard to participation by women-owned and economically disadvantaged small business concerns.

Major provisions of Title I included

- extension of the SBIR Program through September 30, 2000;
- revisions of the annual allocations to the activity for agencies with extramural budgets for research or R&D in excess of $100 million for Fiscal Year 1992 or any fiscal year thereafter;
  - not less than 1.5% of such budget in Fiscal Years 1993 and 1994;
  - not less than 2.0% in Fiscal Years 1995 and 1996; and
  - not less than 2.5% in each fiscal year thereafter;
- modifications of policy directives to ensure, to the extent practicable, that an agency which intends to pursue research, development, or production of a technology developed by a small business concern under an SBIR grant enters into follow-on, non-SBIR funding

agreements with the small business for such research, development, or production; and

- an increase to $100,000 in the amount of funds which an agency may award in first phase SBIR grants and to $750,000 in the second phase, with adjustment of such amounts once every five years to reflect economic adjustments and programmatic considerations.

In addition, each federal agency participating in the SBIR Program was authorized to select a vendor to provide technical assistance to first phase SBIR award recipients in an amount not to exceed $4,000 over and above the amount of the recipient's award.

Small Business Reauthorization Act of 2000

Appendix I of Public Law 106-554 is cited as the Small Business Reauthorization Act of 2000. Title I of this Act addresses the Small Business Innovation Research (SBIR) Program. This title amended the Small Business Act to extend the SBIR Program through September 30, 2080. A number of other provisions are included in the Act, such as

- established a searchable, electronic public database including recipients of phase one and phase two SBIR awards, project abstracts, award amounts, and business concerns established for the commercial application of a product or service for which an SBIR award is made;
- established a confidential database for the sole purpose of SBIR program evaluation under the auspices of the Small Business Administration
- required the head of each federal agency with a SBIR Program budget in excess of $50 million in Fiscal Year 1999 to enter into an agreement with the national Academy of sciences to conduct a comprehensive study of how the SBIR Program has stimulated technological innovation and used small business to meet federal research and development needs, including the economic and noneconomic benefits of the SBIR Program;
- established the Federal and State Technology Partnership (FAST) Program to strengthen the technological competitiveness of small businesses through outreach efforts, financial support, and technical assistance to small businesses participating in or interested in participating in the SBIR Program;
- authorized the establishment of Mentoring Networks as part of the FAST Program consisting of volunteers who have successfully completed one or more SBIR or Small Business Technology Transfer (STTR) funding agreements willing to provide business advice and counsel to high-technology small businesses interested in participating in the SBIR or STTR Programs; and

- authorized appropriations of $10 million for Fiscal Years 2001 through 2005 for the FAST Program and Mentoring Networks.

Small Business Technology Transfer Act of 1992

Title II of the Small Business Research and Development Enhancement Act is cited as the Small Business Technology Transfer Act of 1992. This Title established a new pilot program known as the Small Business Technology Transfer (STTR) Program. This program established awards to small business concerns for cooperative research and development involving a research institution in which not less than 40% of the work is performed by the small business while not less than 30% of the work is performed by the research institution. Qualified research institutions included nonprofit organizations as defined in the Stevenson-Wydler Act and federally funded research and development centers (FFRDCs) as identified by the National Science Foundation. Other major provisions of Title II were

- all federal agencies with research or R&D budgets in excess of $1 billion in Fiscal Year 1994, 1995, or 1996 were authorized to participate in the STTR Program:
- a schedule of commitments was adopted as follows: not less than 0.05% of such budget in Fiscal Year 1994; not less than 0.1% in Fiscal Year 1995; and not less than 0.15% in Fiscal Year 1996.

Small Business Programs Improvement Act of 1996

Division D of Public Law 104-208, cited as the Small Business Programs Improvement Act of 1996 [P.L. 104-208], amended the Small Business Act to extend the Small Business Technology Transfer (STTR) Program through Fiscal Year 1997 at the level of 0.15% of the research or R&D budgets in excess of $1 billion.

Small Business Reauthorization Act of 1997

Title V of the Small Business Reauthorization Act of 1997 [P.L. 105-135] amended the Small Business Act to extend the Small Business Technology Transfer (STTR) Program through Fiscal Year 2001 at the level of 0.15% of the research or R&D budgets in excess of $1 billion in Fiscal Years 1998 through 2001. Other major provisions of Title V were

- required all federal agencies participating in the STTR Program to collect data from awardees to assess the STTR Program outputs and outcomes and include information on the STTR program in their annual performance plan and submit this information to Congress;
- established an assistance program for states in which the value of STTR contracts were less than $5 million in Fiscal Year 1995 with annual expenditures for all states not to exceed $2 million provided

that any eligible state makes available matching funds from non-federal sources in an amount not less than one-third of the federal funds and that the federal funds allocated to any single state do not exceed $100,000.

A.5 Other Technology Transfer and Commercialization Initiatives

National Cooperative Research Act of 1984

Cooperative research programs among private-sector firms were stimulated by the National Cooperative Research Act of 1984 [P.L. 98-462]. This Act replaced the treble damage recovery for claims under antitrust law embodied in the Clayton Act [15 U.S.C. 12] and the Federal Trade Commission Act [15 U.S.C. 45] with actual damages resulting from conduct within the scope of a joint R&D venture, provided that a notice of which had been properly filed with the Federal Trade Commission and the Attorney General. For the purposes of this Act, a joint research and development venture is any group of activities, including attempting to make, or performing a contract, by two or more persons for the purposes of

- theoretical analysis, experimentation, or systematic study of phenomena or observable facts;
- development or testing of basic engineering techniques;
- extension of investigative findings or theory of a scientific nature into practical application for experimental and demonstration purposes, including experimental production and testing of models, prototypes, equipment, materials, and processes;
- collection, exchange, and analysis of research information; or
- any combination of these activities.

In addition, this Act established a "rule of reason standard." That is, in any action under federal antitrust laws, or any similar state law, the conduct of any person in making or performing a contract to carry out a joint research and development venture shall not be deemed illegal per se. Such conduct shall be judged on the basis of its reasonableness, taking into account all relevant factors affecting competition, including, but not limited to, effects on competition in properly defined, relevant R&D markets.

The National Cooperative Research Act was instrumental in the formation of the Semiconductor Research Corporation (SRC) and the Microelectronics and Computer Consortium (MCC). The MCC is widely credited with being an important catalyst in the growth of the high-technology component of the Austin, Texas, economy.

Omnibus Trade and Competitiveness Act of 1988

The Omnibus Trade and Competitiveness Act of 1988 [P.L. 100-418] contained a variety of provisions related to technology transfer and commercialization. Title V, Subtitle B, Part I of this Act is known as the Technology Competitiveness Act. Major provisions of the Technology Competitiveness Act include

- changed of the name of the National Bureau of Standards to the National Institute of Standards and Technology (NIST);
- established Regional Centers for the Transfer of Manufacturing Technology with the objective of enhancing productivity and technological performance in U.S manufacturing through
  - transfer of manufacturing technology and techniques developed at NIST to manufacturing companies;
  - participation of individuals from industry, universities, sate governments, NIST, and other federal agencies in cooperative technology transfer activities;
  - efforts to make new manufacturing technology and processes to small and medium-sized companies;
  - active dissemination of scientific, engineering, technical, and management information about manufacturing to industrial firms, including small and medium-sized manufacturing companies; and
  - utilization of the expertise and capability of federal laboratories other than NIST;
- created technical assistance to state technology programs to help businesses, particularly small- and medium-sized businesses to enhance their competitiveness through application of science and technology;
- authorized cooperative agreements with state technology extension services to demonstrate methods by which states can in cooperation with federal agencies increase the use of federal technology by businesses to improve industrial competitiveness or to help businesses take advantage of the services and information offered by the Regional Centers for the Transfer of Manufacturing Technology;
- established a Non-Energy Inventions Program within NIST modeled after the Energy-Related Inventions Program established under the Federal Nonnuclear Energy Research and Development Act of 1974 [P.L. 93-577] and operated by the U.S. Department of Energy to financially support the application of inventions;
- through an amendment to the Stevenson-Wydler Act, established within the Office of Productivity, Technology, and Innovation in the U.S. Department of Commerce a Clearinghouse for State and Local Initiatives on Productivity, Technology, and Innovation as a central repository for information on initiatives by state and local governments to enhance the competitiveness of U.S. industry;

- established within NIST the Advanced Technology Program to aid joint research and development ventures through mechanisms such as partial start-up funding, providing a minority share of the cost of such joint ventures for up to five years, and making available equipment, facilities, and personnel provided that emphasis is placed on areas in which NIST has scientific or technical expertise, on solving generic problems of specific industries, and on making those industries more competitive in world markets; and
- altered the percentage of the research and development budget (0.005%) of federal agencies participating in the Federal Laboratory Consortium (FLC) to support the function of the FLC to 0.008% of the budget of the federal agency from any federal source, including related overhead.

The Regional Centers for the Transfer of Manufacturing Technology were authorized to

- establish automated manufacturing systems and other advanced production technologies, based on NIST research, for the purpose of demonstrations and technology transfer;
- actively transfer and disseminate research findings and Center expertise to a wide range of companies and enterprises, especially small and medium-sized manufacturers; and
- make loans, on a selective short-term basis, of advanced manufacturing equipment to small manufacturing firms with less than 100 employees.

Title VI, Subtitle B, Chapter 1 is known as the Training Technology Transfer Act of 1988. This Act established an Office of Training Technology Transfer in the Office of Educational Research and Improvement in the U.S. Department of Education. The director of the Office of Training Technology Transfer was directed to compile and maintain a current and comprehensive clearinghouse of all knowledge and education and training software developed or scheduled for development by or under the supervision of federal agencies. In addition, each federal agency that develops knowledge for or uses education and training software was required to designate an education and training software transfer officer.

Furthermore, Title VI, Subtitle C, Chapter 4 of the Omnibus Trade and Competitiveness Act of 1988 authorized the establishment of regional technology transfer centers administered by the U.S. Department of Education. The centers to be operated by a university or college, a consortium of such institutions, or a university-related research park or center were to be designed to

- promote the study and development of programs and depositories necessary to further the transfer of technology relevant to a region's economy;
- assist in developing incubator facilities to encourage new economic initiatives;
- provide technical assistance linking university expertise and private-sector resources to solve technical, marketing, and manufacturing problems associated with technology-transfer and start-up businesses; and
- ensure consideration of the economic development needs of rural as well as urban areas within the region.

Public Law 100-519

Title II of Public Law 100-519 (October 24, 1988) established a Technology Administration under the U.S. Department of Commerce, which absorbed the functions of the Office of Productivity, Technology, and Innovation originally established by the Omnibus Trade and Competitiveness Act of 1988. The Technology Administration embodies the National Institute of Standards and Technology, the National Technical Information Service, and the Office of Technology Policy.

Appendix B: Reference Data Tables for Unit Areas

Table B.1: Selected Data for Unit Areas

Unit Area	Metro Area Jobs, 1999[a]	Unit Area Jobs, 1999 [a]	Patents, 1999[b]	Patents per 100,000 jobs, 1999	High Tech as % of Gross Metro Product[c]	% Adults with Bachelors Degree, 2000[d]	Academic/ Nonprofit R&D ($000), 1998[e]	Academic/ Nonprofit R&D/ 100,000 Jobs, 1998[f]	Federal Intramural R&D ($000), 1998[g]	Federal R&D/ 100,000 Jobs, 1998[f]
New York, NY PMSA	9,926,248	4,383,585	1,704	38.9	5.6	29.2	1,115,688	26.1	24,214	**7.0**
Nassau-Suffolk, NY PMSA	9,926,248	1,239,946	753	60.7	13.6	31.3	205,508	**21.5**	296,000	24.7
Newark, NJ PMSA	9,926,248	1,012,063	1,136	112.2	14.7	31.5	164,173	**21.5**	133,300	13.4
New Haven-Bridgeport-Stamford-Danbury-Waterbury, CT NECMA	9,926,248	856,161	1,033	120.7	17.7	33.9	270,332	31.9	16,800	**7.0**
Bergen-Passaic, NJ PMSA	9,926,248	674,818	502	74.4	11.3	32.5	394	**21.5**	0	**7.0**
Middlesex-Somerset-Hunterdon, NJ PMSA	9,926,248	649,846	1,091	167.9	16.1	37.4	197,053	31.0	0	**7.0**
Monmouth-Ocean, NJ PMSA	9,926,248	393,298	537	136.5	10.1	27.6	382	**21.5**	135,800	35.0
Jersey City, NJ PMSA	9,926,248	253,943	72	28.4	5.4	25.3	12,944	**21.5**	0	**7.0**
Trenton, NJ PMSA	9,926,248	206,561	345	167.0	16.5	34.0	121,996	60.1	74,970	36.9
Newburgh, NY-PA PMSA	9,926,248	140,678	92	65.4	4.5	22.1	0	**21.5**	0	**7.0**
Dutchess County, NY PMSA	9,926,248	115,349	368	319.0	50.7	27.6	596	**21.5**	0	**7.0**
Los Angeles-Long Beach, CA PMSA	7,150,946	4,354,161	2,348	53.9	13.0	24.9	1,102,468	25.7	1,861,155	43.4
Orange County, CA PMSA	7,150,946	1,453,540	1,473	101.3	21.2	30.8	140,575	**19.2**	0	**27.7**
Riverside-San Bernardino, CA PMSA	7,150,946	1,039,844	351	33.8	7.1	16.3	94,763	**19.2**	19,600	**27.7**
Ventura, CA PMSA	7,150,946	303,401	328	108.1	17.0	26.9	0	**19.2**	48,800	**27.7**
Chicago, IL PMSA	4,755,659	4,370,923	2,929	67.0	11.4	30.1	668,592	15.5	520,052	12.0
Gary, IN PMSA	4,755,659	282,638	66	23.4	2.5	17.7	571	**14.2**	0	**11.1**
Kenosha, WI PMSA	4,755,659	56,505	46	81.4	NA	19.2	187	**14.2**	0	**11.1**
Kankakee, IL PMSA	4,755,659	45,593	10	21.9	11.7	15.0	0	**14.2**	0	**11.1**
Washington, DC-MD-VA-WV PMSA	4,262,884	2,882,717	1,299	45.1	20.2	41.8	1,492,616	53.4	4,667,931	167.0
Baltimore, MD PMSA	4,262,884	1,312,985	664	50.6	9.0	29.2	603,046	**50.6**	536,280	**125.7**

Hagerstown, MD PMSA	4,262,884	67,182	6	8.9	NA	14.6	0	**50.6**	0	**125.7**
San Francisco, CA PMSA	3,754,251	1,139,470	1,700	149.2	14.0	43.6	553,964	50.0	8,243	**38.2**
Oakland, CA PMSA	3,754,251	1,074,503	1,589	147.9	13.6	35.0	420,619	**40.5**	920,400	88.2
San Jose, CA PMSA	3,754,251	1,039,363	5,664	544.9	57.8	40.5	451,353	43.9	468,200	45.5
Santa Rosa, CA PMSA	3,754,251	200,060	141	70.5	12.3	28.5	194	**40.5**	0	**38.2**
Vallejo-Fairfield-Napa, CA PMSA	3,754,251	190,669	66	34.6	5.0	22.7	0	**40.5**	0	**38.2**
Santa Cruz-Watsonville, CA PMSA	3,754,251	110,186	245	222.4	20.7	34.2	56,533	51.8	2,700	**38.2**
Boston-Worcester-Lawrence-Lowell-Brockton, MA-NH NECMA	3,321,855	3,321,855	3,806	114.6	20.8	34.4	2,140,547	65.7	527,986	16.2
Philadelphia, PA-NJ PMSA	3,078,948	2,489,846	1,849	74.3	14.3	27.7	764,318	31.3	32,426	**1.5**
Wilmington-Newark, DE-MD PMSA	3,078,948	334,436	419	125.3	10.9	27.6	73,396	**27.7**	1,400	**1.5**
Atlantic-Cape May, NJ PMSA	3,078,948	194,196	50	25.7	3.6	19.7	0	**27.7**	11,000	5.7
Vineland-Millville-Bridgeton, NJ PMSA	3,078,948	60,470	10	16.5	NA	11.7	0	**27.7**	0	**1.5**
Dallas, TX PMSA	2,799,162	2,008,205	1,644	81.9	19.1	30.0	195,678	10.1	2,363	0.1
Fort Worth-Arlington, TX PMSA	2,799,162	790,957	286	36.2	14.1	25.1	31,121	**8.4**	0	**0.1**
Detroit, MI PMSA	2,728,335	2,243,759	1,964	87.5	6.5	22.8	186,855	**26.2**	31,763	**1.7**
Ann Arbor, MI PMSA	2,728,335	301,347	488	161.9	11.9	36.9	511,245	177.2	13,400	4.6
Flint, MI PMSA	2,728,335	183,229	87	47.5	4.1	16.2	733	**26.2**	0	**1.7**
Houston, TX PMSA	2,304,052	2,130,690	1,567	73.5	10.2	27.2	575,968	**29.2**	1,389,200	66.4
Galveston-Texas City TX PMSA	2,304,052	94,729	58	61.2	NA	22.7	86,488	90.0	2,700	**61.4**
Brazoria, TX PMSA	2,304,052	78,633	89	113.2	13.0	19.6	0	**29.2**	0	**61.4**
Atlanta, GA MSA	2,284,401	2,284,401	1,045	45.7	10.0	32.0	544,463	24.8	159,480	7.3
Seattle-Bellevue-Everett, WA PMSA	1,919,299	1,469,450	1,296	88.2	23.7	35.9	583,561	40.8	55,654	3.9
Tacoma, WA PMSA	1,919,299	271,572	64	23.6	5.5	20.6	0	**31.2**	3,600	**3.6**
Olympia, WA PMSA	1,919,299	89,144	12	13.5	NA	29.8	630	**31.2**	3,800	4.4
Bremerton, WA PMSA	1,919,299	89,133	46	51.6	8.9	25.3	0	**31.2**	5,222	5.9
Minneapolis-St. Paul, MN-WI MSA	1,799,069	1,799,069	2,181	121.2	13.4	33.3	367,369	20.9	20,182	1.2
Miami, FL PMSA	1,761,900	1,065,449	262	24.6	6.8	21.7	158,222	15.3	25,000	2.4
Fort Lauderdale, FL PMSA	1,761,900	696,451	339	48.7	8.5	24.5	2,636	**9.4**	1,000	**1.5**
Phoenix-Mesa, AZ MSA	1,601,963	1,601,963	1,152	71.9	18.4	25.1	99,289	6.4	15,740	1.0
Cleveland-Lorain-Elyria, OH PMSA	1,568,096	1,224,075	786	64.2	7.7	23.3	293,924	24.3	220,300	18.2

Akron, OH PMSA	1,568,096	344,021	284	82.6	7.3	24.3	34,204	**21.2**	0	**14.2**
Denver, CO PMSA	1,458,162	1,205,502	572	47.4	11.1	34.2	83,204	**29.8**	192,412	**21.9**
Boulder-Longmont, CO PMSA	1,458,162	179,990	476	264.5	39.6	52.4	334,533	194.4	115,200	66.9
Greeley, CO PMSA	1,458,162	72,670	95	130.7	20.8	21.6	736	**29.8**	0	**21.9**
St. Louis, MO-IL MSA	1,405,976	1,405,976	743	52.8	10.9	25.3	332,921	24.0	3,000	0.2
San Diego, CA MSA	1,350,806	1,350,806	1,748	129.4	16.8	29.5	733,648	56.3	361,719	27.8
Tampa-St. Petersburg-Clearwater, FL MSA	1,222,031	1,222,031	386	31.6	12.2	21.7	104,325	8.9	10,400	0.9
Pittsburgh, PA MSA	1,157,790	1,157,790	809	69.9	9.4	23.8	366,769	32.2	70,603	6.2
Portland-Vancouver, OR-WA PMSA	1,155,058	1,006,096	930	92.4	20.6	28.8	189,339	19.1	13,603	1.4
Salem, OR PMSA	1,155,058	148,962	34	22.8	38.9	20.8	340	**16.7**	0	**1.2**
Cincinnati, OH-KY-IN PMSA	1,054,809	921,797	782	84.8	9.5	25.3	194,789	21.5	132,000	14.6
Hamilton-Middletown, OH PMSA	1,054,809	133,012	168	126.3	NA	23.5	6,738	**19.5**	0	**12.8**
Kansas City, MO-KS MSA	1,012,729	1,012,729	277	27.4	6.9	28.5	24,760	2.5	4,800	0.5
Milwaukee-Waukesha, WI PMSA	988,521	903,355	530	58.7	8.7	27.0	91,445	10.3	3,000	0.3
Racine, WI PMSA	988,521	85,166	94	110.4	NA	20.3	0	**9.4**	0	**0.3**
Indianapolis, IN MSA	918,531	918,531	544	59.2	7.8	25.8	9,180	1.0	4,000	0.4
Orlando, FL MSA	917,971	917,971	200	21.8	10.1	24.8	35,530	4.1	7,050	0.8
Columbus, OH MSA	908,050	908,050	344	37.9	8.6	29.1	410,848	46.5	5,468	0.6
Charlotte-Gastonia-Rock Hill, NC-SC MSA	859,237	859,237	260	30.3	7.6	26.5	10,968	1.3	40	0.0
Sacramento, CA PMSA	846,284	753,866	295	39.1	22.8	25.9	290,706	40.5	23,889	3.3
Yolo, CA PMSA	846,284	92,418	103	111.5	6.4	34.1	0	**36.1**	0	**3.0**
Norfolk-Virginia Beach-Newport News, VA-NC MSA	841,797	841,797	132	15.7	7.7	23.8	77,452	9.3	275,390	33.1
San Antonio, TX MSA	773,578	773,578	257	33.2	7.7	22.4	119,568	15.9	37,600	5.0
Las Vegas, NV-AZ MSA	759,197	759,197	165	21.7	4.2	16.4	16,912	2.4	230	0.0
Salt Lake City-Ogden, UT MSA	742,726	742,726	474	63.8	13.0	26.5	143,956	19.8	6,300	0.9
Nashville, TN MSA	713,471	713,471	140	19.6	5.1	26.9	158,961	22.9	7,700	1.1
Raleigh-Durham-Chapel Hill, NC MSA	702,139	702,139	939	133.7	33.6	38.9	963,967	141.7	251,719	37.0
Greensboro--Winston-Salem--High Point, NC MSA	695,834	695,834	224	32.2	5.8	22.9	97,607	14.3	0	0.0

Austin-San Marcos, TX MSA	670,341	670,341	1,571	234.4	36.2	36.7	345,842	54.5	3,000	0.5
New Orleans, LA MSA	664,510	664,510	136	20.5	3.2	22.6	95,421	14.4	27,930	4.2
Hartford, CT NECMA	646,469	646,469	485	75.0	14.6	29.8	2,000	0.3	448	0.1
Memphis, TN-AR-MS MSA	629,848	629,848	168	26.7	4.6	22.7	83,948	13.6	2,000	0.3
Grand Rapids-Muskegon-Holland, MI MSA	599,961	599,961	372	62.0	6.1	22.9	2,842	0.5	0	0.0
Louisville, KY-IN MSA	595,168	595,168	162	27.2	6.0	22.2	39,336	6.7	2,237	0.4
Jacksonville, FL MSA	587,005	587,005	131	22.3	5.6	22.9	6,000	1.0	0	0.0
Richmond-Petersburg, VA MSA	586,774	586,774	146	24.9	7.9	29.2	85,582	14.9	17,800	3.1
Buffalo-Niagara Falls, NY MSA	569,267	569,267	346	60.8	6.2	23.2	202,772	36.1	700	0.1
Oklahoma City, OK MSA	567,657	567,657	146	25.7	9.4	24.4	158,087	28.5	22,000	4.0
Rochester, NY MSA	560,052	560,052	1,568	280.0	31.9	27.1	183,834	33.3	700	0.1
Greenville-Spartanburg-Anderson, SC MSA	516,491	516,491	255	49.4	9.6	20.7	90,672	17.9	2,783	0.6
West Palm Beach-Boca Raton, FL MSA	511,944	511,944	403	78.7	12.9	27.7	14,265	2.9	1,400	0.3
Birmingham, AL MSA	502,440	502,440	87	17.3	2.0	24.7	245,720	49.5	3,000	0.6
Dayton-Springfield, OH MSA	501,986	501,986	325	64.7	7.2	22.1	75,693	15.1	225,950	44.9
Honolulu, HI MSA	466,882	466,882	54	11.6	2.9	27.9	156,977	33.4	8,925	1.9
Albany-Schenectady-Troy, NY MSA	462,700	462,700	445	96.2	12.2	28.2	140,209	31.0	3,900	0.9
Providence-Warwick-Pawtucket, RI NECMA	450,890	450,890	221	49.0	8.5	23.6	136,979	30.8	14,100	3.2
Omaha, NE-IA MSA	449,099	449,099	68	15.1	10.4	28.0	67,343	15.4	2,000	0.5
Tulsa, OK MSA	419,017	419,017	178	42.5	7.1	23.2	8,300	2.0	0	0.0
Fresno, CA MSA	380,130	380,130	48	12.6	4.0	16.8	12,122	3.3	10,700	2.9
Harrisburg-Lebanon-Carlisle, PA MSA	375,017	375,017	143	38.1	6.9	22.6	1,789	0.5	2,140	0.6
Albuquerque, NM MSA	367,690	367,690	228	62.0	22.6	28.4	130,410	35.9	1,031,552	283.8
Syracuse, NY MSA	355,729	355,729	171	48.1	10.8	24.1	88,583	25.3	1,826	0.5
Knoxville, TN MSA	352,601	352,601	198	56.2	9.9	23.5	153,064	44.2	392,089	113.2
Tucson, AZ MSA	352,287	352,287	273	77.5	21.5	26.7	302,328	88.0	10,178	3.0
Toledo, OH MSA	343,484	343,484	223	64.9	4.2	21.6	27,349	8.1	0	0.0
Little Rock-North Little Rock, AR MSA	334,944	334,944	77	23.0	10.1	24.8	43,560	13.2	10,053	3.1

Columbia, SC MSA	325,589	325,589	78	24.0	11.9	29.2	102,585	32.1	2,400	0.8
Baton Rouge, LA MSA	319,730	319,730	160	50.0	6.9	24.9	217,991	70.0	4,266	1.4
Wichita, KS MSA	304,513	304,513	102	33.5	28.6	24.7	15,607	5.1	200	0.1
Des Moines, IA MSA	299,124	299,124	145	48.5	5.5	28.7	4,630	1.6	0	0.0
Madison, WI MSA	296,253	296,253	261	88.1	8.8	40.6	443,695	154.2	29,293	10.2
Scranton--Wilkes-Barre--Hazelton, PA MSA	292,183	292,183	77	26.4	6.3	17.4	0	0.0	0	0.0
Allentown-Bethlehem-Easton, PA MSA	289,747	289,747	299	103.2	10.3	21.2	26,740	9.4	0	0.0
Fort Wayne, IN MSA	288,771	288,771	159	55.1	8.3	19.4	0	0.0	0	0.0
Lexington, KY MSA	288,509	288,509	175	60.7	11.4	28.7	192,008	68.5	1,000	0.4
Charleston-North Charleston, SC MSA	277,672	277,672	69	24.8	7.0	25.0	62,929	23.7	19,700	7.4
Springfield, MA NECMA	276,626	276,626	101	36.5	5.9	24.6	99,463	36.5	1,300	0.5
El Paso, TX MSA	275,909	275,909	34	12.3	4.5	16.6	14,092	5.2	125	0.0
Sarasota-Bradenton, FL MSA	271,740	271,740	132	48.6	9.4	24.6	0	0.0	0	0.0
Colorado Springs, CO MSA	271,426	271,426	270	99.5	27.0	31.8	4,374	1.7	0	0.0
Youngstown-Warren, OH MSA	262,340	262,340	67	25.5	2.6	15.1	898	0.3	0	0.0
Bakersfield, CA MSA	256,938	256,938	56	21.8	5.2	13.5	274	0.1	363,915	143.3
Jackson, MS MSA	248,556	248,556	35	14.1	3.8	28.1	10,291	4.2	2,600	1.1
Chattanooga, TN-GA MSA	247,656	247,656	58	23.4	5.6	19.7	0	0.0	0	0.0
Mobile, AL MSA	243,371	243,371	75	30.8	7.9	19.9	11,990	5.0	305	0.1
Lansing-East Lansing, MI MSA	238,139	238,139	93	39.1	3.8	28.4	202,831	86.7	6,560	2.8
Lancaster, PA MSA	231,941	231,941	153	66.0	7.9	20.5	1,158	0.5	0	0.0
Boise City, ID MSA	227,346	227,346	1,093	480.8	36.0	26.5	3,562	1.6	12,484	5.7
Augusta-Aiken, GA-SC MSA	226,589	226,589	44	19.4	4.6	20.9	39,806	17.9	50,400	22.7
Kalamazoo-Battle Creek, MI MSA	223,946	223,946	143	63.9	7.5	23.5	11,532	5.1	0	0.0
Johnson City-Kingsport-Bristol, TN-VA MSA	212,845	212,845	145	68.1	4.9	16.6	3,152	1.5	350	0.2
Stockton-Lodi, CA MSA	209,142	209,142	44	21.0	5.4	14.5	886	0.4	0	0.0
Appleton-Oshkosh-Neenah, WI MSA	207,536	207,536	213	102.6	4.0	22.4	636	0.3	0	0.0
Spokane, WA MSA	202,882	202,882	51	25.1	11.3	25.0	2,445	1.2	6,600	3.3
Melbourne-Titus.-Palm Bay, FL MSA	195,421	195,421	178	91.1	34.3	23.6	5,848	3.1	242,000	126.3

Davenport-Moline-Rock Island, IA-IL MSA	194,735	194,735	82	42.1	NA	20.3	58	0.0	50	0.0
Reno, NV MSA	194,312	194,312	96	49.4	4.3	23.7	71,326	37.4	18,123	9.5
Lakeland-Winter Haven, FL MSA	194,010	194,010	33	17.0	6.5	14.9	0	0.0	1,200	0.6
Canton-Massillon, OH MSA	192,453	192,453	125	65.0	NA	17.3	0	0.0	0	0.0
Santa Barbara-Santa Maria-Lompoc, CA MSA	191,375	191,375	212	110.8	16.5	29.4	96,034	52.0	71	0.0
Hickory-Morganton-Lenoir, NC MSA	190,657	190,657	54	28.3	3.0	13.6	0	0.0	0	0.0
Huntsville, AL MSA	190,320	190,320	107	56.2	26.1	30.9	37,791	20.2	814,700	435.0
Shreveport-Bossier City, LA MSA	189,388	189,388	14	7.4	4.7	19.1	0	0.0	400	0.2
Biloxi-Gulfport-Pascagoula, MS MSA	188,130	188,130	22	11.7	4.3	17.6	3,000	1.7	55,300	30.6
Saginaw-Bay City-Midland, MI MSA	186,682	186,682	230	123.2	16.4	18.1	1,950	1.1	0	0.0
Rockford, IL MSA	186,442	186,442	131	70.3	7.0	18.5	0	0.0	0	0.0
Peoria-Pekin, IL MSA	182,396	182,396	186	102.0	3.6	21.1	1,493	0.8	26,000	14.2
Salinas, CA MSA	180,077	180,077	61	33.9	8.0	22.5	34,095	19.9	21,210	12.4
Pensacola, FL MSA	177,977	177,977	41	23.0	8.2	21.5	4,294	2.5	11,100	6.4
Montgomery, AL MSA	177,780	177,780	21	11.8	3.7	24.7	1,177	0.7	1,000	0.6
Reading, PA MSA	177,620	177,620	129	72.6	13.2	18.5	0	0.0	0	0.0
Portland, ME NECMA	176,524	176,524	38	21.5	13.2	33.6	3,374	1.9	0	0.0
York, PA MSA	175,600	175,600	91	51.8	6.1	18.4	0	0.0	0	0.0
Corpus Christi, TX MSA	174,752	174,752	25	14.3	NA	17.8	0	0.0	468	0.3
Lafayette, LA MSA	172,905	172,905	60	34.7	NA	17.5	24,768	14.0	0	0.0
Springfield, MO MSA	172,168	172,168	30	17.4	4.4	22.4	1,797	1.1	0	0.0
Fort Myers-Cape Coral, FL MSA	171,693	171,693	57	33.2	7.7	21.1	0	0.0	0	0.0
Modesto, CA MSA	168,783	168,783	40	23.7	NA	14.1	0	0.0	0	0.0
Beaumont-Port Arthur, TX MSA	167,558	167,558	24	14.3	10.7	14.7	3,051	1.8	1,200	0.7
Tallahassee, FL MSA	165,997	165,997	42	25.3	9.7	36.7	115,129	71.6	5,000	3.1
Daytona Beach, FL MSA	165,294	165,294	41	24.8	12.2	18.0	3,213	2.0	0	0.0
Evansville-Henderson, IN-KY MSA	165,178	165,178	64	38.7	10.5	18.5	0	0.0	0	0.0
Macon, GA MSA	165,135	165,135	27	16.4	3.7	19.5	14,995	9.3	2,400	1.5
McAllen-Edinburg-Mission, TX MSA	162,967	162,967	5	3.1	NA	12.9	1,664	1.1	8,600	5.6
Fayetteville, NC MSA	160,461	160,461	9	5.6	5.8	19.1	485	0.3	0	0.0

Fayetteville-Springdale-Rogers, AR MSA	157,232	157,232	34	21.6	NA	22.4	71,686	47.6	1,537	1.0
Lincoln, NE MSA	155,369	155,369	62	39.9	13.4	32.6	118,857	78.5	6,226	4.1
Provo-Orem, UT MSA	154,930	154,930	122	78.7	12.0	31.5	11,963	8.0	882	0.6
Roanoke, VA MSA	151,649	151,649	37	24.4	6.9	22.5	0	0.0	20	0.0
Eugene-Springfield, OR MSA	151,066	151,066	59	39.1	10.0	25.5	47,275	32.0	0	0.0
Green Bay, WI MSA	150,216	150,216	43	28.6	NA	22.5	491	0.3	0	0.0
Killeen-Temple, TX MSA	149,391	149,391	24	16.1	NA	18.1	0	0.0	4,270	2.9
Savannah, GA MSA	149,284	149,284	15	10.0	11.6	23.2	5,001	3.4	73	0.0
Columbus, GA-AL MSA	146,779	146,779	9	6.1	6.0	18.6	0	0.0	990	0.7
Anchorage, AK MSA	144,891	144,891	30	20.7	4.6	28.9	0	0.0	13,000	9.1
South Bend, IN MSA	142,404	142,404	67	47.0	8.4	23.6	28,873	20.4	0	0.0
Charleston, WV MSA	141,513	141,513	45	31.8	NA	20.4	119	0.1	993	0.7
Erie, PA MSA	140,156	140,156	84	59.9	5.2	20.9	0	0.0	0	0.0
New London-Norwich, CT NECMA	138,963	138,963	134	96.4	13.9	25.1	732	0.5	16,400	11.9
Visalia-Tulare-Porterville, CA MSA	138,941	138,941	13	9.4	NA	11.5	0	0.0	0	0.0
Utica-Rome, NY MSA	136,728	136,728	67	49.0	9.6	17.7	2,315	1.7	19,000	14.3
Elkhart-Goshen, IN MSA	129,091	129,091	58	44.9	6.6	15.5	0	0.0	0	0.0
Huntington-Ashland, WV-KY-OH MSA	127,407	127,407	25	19.6	NA	14.4	25	0.0	80	0.1
Cedar Rapids, IA MSA	126,271	126,271	141	111.7	7.8	27.7	0	0.0	0	0.0
Fort Collins-Loveland, CO MSA	124,485	124,485	280	224.9	23.8	39.5	140,179	116.4	41,250	34.2
Gainesville, FL MSA	124,123	124,123	95	76.5	5.2	38.7	274,862	228.6	14,240	11.8
Lubbock, TX MSA	120,898	120,898	29	24.0	6.4	24.4	53,126	44.6	4,197	3.5
Duluth-Superior, MN-WI MSA	120,792	120,792	32	26.5	NA	21.2	383	0.3	13,200	11.0
Binghamton, NY MSA	119,371	119,371	190	159.2	35.9	22.0	20,754	17.9	0	0.0
Asheville, NC MSA	117,384	117,384	41	34.9	11.1	24.5	706	0.6	4,300	3.7
Sioux Falls, SD MSA	116,645	116,645	24	20.6	7.4	25.9	0	0.0	5,771	5.2
Wilmington, NC MSA	115,847	115,847	50	43.2	5.4	26.1	7,208	6.5	0	0.0
Burlington, VT NECMA	115,271	115,271	249	216.0	38.6	37.2	58,432	52.5	1,985	1.8
Springfield, IL MSA	114,848	114,848	17	14.8	6.3	28.1	0	0.0	0	0.0
Brownsville-Har.-San Benito TX MSA	112,488	112,488	9	8.0	NA	13.4	0	0.0	0	0.0

Fort Pierce-Port St. Lucie, FL MSA	110,599	110,599	50	45.2	NA	19.7	2,000	1.9	0	0.0
Myrtle Beach, SC MSA	109,147	109,147	14	12.8	6.3	18.7	0	0.0	0	0.0
Topeka, KS MSA	107,723	107,723	16	14.9	NA	26.0	0	0.0	0	0.0
Lynchburg, VA MSA	107,412	107,412	56	52.1	11.5	19.3	0	0.0	0	0.0
Fargo-Moorhead, ND-MN MSA	107,008	107,008	28	26.2	NA	29.4	41,927	40.1	9,820	9.4
Naples, FL MSA	106,797	106,797	37	34.6	10.7	27.9	0	0.0	0	0.0
Odessa-Midland, TX MSA	106,138	106,138	18	17.0	4.0	18.4	0	0.0	0	0.0
Fort Smith, AR-OK MSA	105,303	105,303	15	14.2	NA	13.8	0	0.0	0	0.0
Champaign-Urbana, IL MSA	103,334	103,334	58	56.1	NA	38.0	329,266	327.8	25,600	25.5
Waco, TX MSA	103,158	103,158	9	8.7	10.7	19.1	2,032	2.0	0	0.0
Amarillo, TX MSA	102,033	102,033	14	13.7	NA	21.0	2,551	2.5	2,490	2.5
San Luis Obispo-Atascadero-Paso Robles, CA MSA	100,878	100,878	61	60.5	7.1	26.7	5,972	6.2	0	0.0
Lafayette, IN MSA	99,604	99,604	74	74.3	11.2	28.2	216,479	221.6	8,700	8.9
Longview-Marshall, TX MSA	97,874	97,874	35	35.8	NA	16.8	0	0.0	0	0.0
Clarksville-Hopkinsville, TN-KY MSA	97,625	97,625	8	8.2	NA	17.0	0	0.0	0	0.0
St. Cloud, MN MSA	96,236	96,236	13	13.5	NA	21.0	1,935	2.1	0	0.0
Yakima, WA MSA	95,546	95,546	15	15.7	NA	15.3	0	0.0	4,200	4.4
Fort Walton Beach, FL MSA	92,905	92,905	26	28.0	13.0	24.2	0	0.0	274,000	300.7
Johnstown, PA MSA	92,594	92,594	21	22.7	NA	12.7	0	0.0	0	0.0
Bloomington-Normal, IL MSA	92,545	92,545	19	20.5	NA	36.2	4,688	5.4	0	0.0
Barnstable-Yarmouth, MA NECMA	91,694	91,694	70	76.3	5.9	33.5	0	0.0	18,800	21.4
Lake Charles, LA MSA	90,312	90,312	18	19.9	7.6	16.9	410	0.5	0	0.0
Charlottesville, VA MSA	90,151	90,151	44	48.8	13.9	40.1	141,911	161.0	7,000	7.9
Ocala, FL MSA	88,946	88,946	18	20.2	NA	13.7	0	0.0	0	0.0
Tyler, TX MSA	86,541	86,541	16	18.5	NA	22.5	0	0.0	0	0.0
Richland-Kennewick-Pasco, WA MSA	86,437	86,437	55	63.6	10.6	23.3	0	0.0	289,500	348.1
Rochester, MN MSA	84,727	84,727	229	270.3	30.2	34.7	206,500	251.4	0	0.0
Tuscaloosa, AL MSA	84,287	84,287	7	8.3	NA	24.0	23,935	28.9	0	0.0
Columbia, MO MSA	84,000	84,000	26	31.0	14.3	41.7	136,331	163.9	11,361	13.7
Eau Claire, WI MSA	83,857	83,857	49	58.4	20.6	22.1	613	0.8	0	0.0

Mansfield, OH MSA	83,686	83,686	17	20.3	NA	11.8	0	0.0	0	0.0
Lima, OH MSA	82,652	82,652	14	16.9	NA	13.4	0	0.0	0	0.0
Joplin, MO MSA	81,939	81,939	18	22.0	NA	16.4	0	0.0	0	0.0
State College, PA MSA	79,935	79,935	63	78.8	16.6	36.3	362,643	467.2	3,200	4.1
Jacksonville, NC MSA	79,406	79,406	1	1.3	NA	14.8	0	0.0	0	0.0
Houma, LA MSA	79,244	79,244	30	37.9	NA	12.3	0	0.0	0	0.0
Santa Fe, NM MSA	78,838	78,838	68	86.3	9.3	39.9	2,850	3.7	1,200,195	1551.4
Athens, GA MSA	78,019	78,019	40	51.3	NA	34.1	217,945	284.7	34,132	44.6
Medford-Ashland, OR MSA	76,457	76,457	14	18.3	11.2	22.3	341	0.5	0	0.0
Chico-Paradise, CA MSA	76,333	76,333	14	18.3	NA	21.8	3,376	4.6	0	0.0
Bryan-College Station, TX MSA	76,052	76,052	52	68.4	7.9	37.0	393,720	516.6	12,603	16.5
Dothan, AL MSA	76,047	76,047	11	14.5	10.2	16.9	0	0.0	16,250	21.7
La Crosse, WI-MN MSA	75,510	75,510	29	38.4	NA	24.6	1,185	1.6	2,100	2.8
Benton Harbor, MI MSA	75,072	75,072	39	52.0	NA	19.6	290	0.4	0	0.0
Waterloo-Cedar Falls, IA MSA	74,897	74,897	18	24.0	NA	23.0	1,682	2.2	0	0.0
Monroe, LA MSA	74,840	74,840	6	8.0	NA	22.7	6,140	8.4	0	0.0
Janesville-Beloit, WI MSA	73,328	73,328	39	53.2	NA	16.7	0	0.0	0	0.0
Iowa City, IA MSA	73,308	73,308	51	69.6	NA	47.6	199,063	278.3	6,500	9.1
Bangor, ME NECMA	72,830	72,830	5	6.9	NA	26.4	33,566	46.9	571	0.8
Parkersburg-Marietta, WV-OH MSA	72,570	72,570	27	37.2	28.2	15.2	0	0.0	0	0.0
Bellingham, WA MSA	72,376	72,376	30	41.5	NA	27.2	3,716	5.3	0	0.0
Terre Haute, IN MSA	71,436	71,436	20	28.0	13.0	18.6	6,290	9.0	0	0.0
Billings, MT MSA	71,259	71,259	6	8.4	NA	26.4	0	0.0	0	0.0
Laredo, TX MSA	71,177	71,177	0	0.0	NA	13.9	0	0.0	0	0.0
Rocky Mount, NC MSA	70,897	70,897	7	9.9	13.7	13.9	0	0.0	0	0.0
Wausau, WI MSA	70,623	70,623	11	15.6	NA	18.3	0	0.0	0	0.0
Panama City, FL MSA	70,258	70,258	32	45.5	NA	17.7	0	0.0	7,000	10.1
Florence, SC MSA	70,022	70,022	22	31.4	8.1	18.7	0	0.0	2,200	3.2
Greenville, NC MSA	69,848	69,848	16	22.9	11.2	26.4	7,644	11.4	0	0.0
Sioux City, IA-NE MSA	69,491	69,491	20	28.8	NA	17.9	0	0.0	0	0.0
Wichita Falls, TX MSA	69,427	69,427	9	13.0	NA	19.7	0	0.0	0	0.0
Bloomington, IN MSA	68,927	68,927	28	40.6	NA	39.6	171,754	255.8	0	0.0

Merced, CA MSA	68,711	68,711	12	17.5	NA	11.0	0	0.0	0	0.0
Wheeling, WV-OH MSA	68,177	68,177	13	19.1	NA	14.6	0	0.0	0	0.0
Pittsfield, MA NECMA	65,909	65,909	27	41.0	NA	24.1	0	0.0	0	0.0
Jackson, MI MSA	64,592	64,592	29	44.9	NA	16.3	0	0.0	0	0.0
Altoona, PA MSA	64,339	64,339	13	20.2	NA	13.9	0	0.0	0	0.0
Sheboygan, WI MSA	63,972	63,972	36	56.3	NA	17.9	0	0.0	0	0.0
Abilene, TX MSA	63,861	63,861	5	7.8	NA	22.5	330	0.5	0	0.0
Albany, GA MSA	63,620	63,620	6	9.4	NA	17.7	1,019	1.6	0	0.0
Redding, CA MSA	62,770	62,770	18	28.7	NA	16.6	0	0.0	1,900	3.1
Jackson, TN MSA	62,738	62,738	21	33.5	NA	20.1	0	0.0	0	0.0
Decatur, IL MSA	62,500	62,500	15	24.0	NA	16.9	0	0.0	0	0.0
Decatur, AL MSA	61,868	61,868	14	22.6	NA	15.8	0	0.0	0	0.0
Alexandria, LA MSA	61,259	61,259	8	13.1	NA	16.5	0	0.0	3,500	5.9
Dover, DE MSA	60,764	60,764	17	28.0	NA	18.6	2,883	4.9	75	0.1
Muncie, IN MSA	60,600	60,600	2	3.3	NA	20.4	2,361	3.9	0	0.0
Las Cruces, NM MSA	60,566	60,566	14	23.1	NA	22.3	77,370	132.7	208,529	357.7
Jamestown, NY MSA	59,703	59,703	12	20.1	NA	16.9	118	0.2	0	0.0
Yuma, AZ MSA	59,649	59,649	3	5.0	NA	11.8	0	0.0	15,000	25.0
Pueblo, CO MSA	59,450	59,450	10	16.8	NA	18.3	824	1.4	0	0.0
Florence, AL MSA	59,235	59,235	15	25.3	NA	16.8	0	0.0	5,000	8.4
Williamsport, PA MSA	56,470	56,470	27	47.8	NA	15.1	0	0.0	0	0.0
Flagstaff, AZ-UT MSA	56,148	56,148	28	49.9	NA	29.5	14,532	26.5	5,306	9.7
Grand Forks, ND-MN MSA	55,643	55,643	11	19.8	NA	24.2	16,938	30.3	7,700	13.8
Kokomo, IN MSA	55,632	55,632	57	102.5	NA	17.1	0	0.0	0	0.0
Texarkana, TX-Texarkana, AR MSA	55,060	55,060	5	9.1	NA	15.0	0	0.0	0	0.0
Anniston, AL MSA	54,834	54,834	2	3.6	NA	15.2	0	0.0	0	0.0
Rapid City, SD MSA	54,791	54,791	6	11.0	NA	25.0	4,550	8.6	2,314	4.4
Hattiesburg, MS MSA	54,605	54,605	10	18.3	NA	24.3	11,117	20.9	0	0.0
Dubuque, IA MSA	54,190	54,190	12	22.1	NA	21.3	0	0.0	0	0.0
Lawton, OK MSA	53,988	53,988	6	11.1	NA	19.1	0	0.0	373	0.7
Bismarck, ND MSA	53,781	53,781	7	13.0	NA	25.5	0	0.0	3,455	6.6
Lawrence, KS MSA	53,515	53,515	26	48.6	NA	42.7	117,115	225.8	1,100	2.1

Steubenville-Weirton, OH-WV MSA	53,319	53,319	15	28.1	NA	12.1	0	0.0	0	0.0
Glens Falls, NY MSA	53,058	53,058	22	41.5	9.3	18.9	0	0.0	0	0.0
Grand Junction, CO MSA	52,878	52,878	11	20.8	NA	22.0	0	0.0	0	0.0
Missoula, MT MSA	52,691	52,691	12	22.8	NA	32.8	20,133	39.7	4,302	8.5
Sharon, PA MSA	52,199	52,199	22	42.1	NA	17.3	0	0.0	0	0.0
Goldsboro, NC MSA	52,197	52,197	6	11.5	NA	15.0	0	0.0	0	0.0
Sumter, SC MSA	50,116	50,116	3	6.0	NA	15.8	0	0.0	0	0.0
San Angelo, TX MSA	49,872	49,872	3	6.0	NA	19.5	0	0.0	0	0.0
Lewiston-Auburn, ME NECMA	49,792	49,792	2	4.0	NA	14.4	682	1.4	0	0.0
St. Joseph, MO MSA	48,598	48,598	11	22.6	NA	17.2	0	0.0	0	0.0
Danville, VA MSA	48,542	48,542	5	10.3	NA	11.3	0	0.0	0	0.0
Yuba City, CA MSA	47,636	47,636	6	12.6	NA	13.2	0	0.0	0	0.0
Sherman-Denison, TX MSA	46,470	46,470	25	53.8	32.6	17.2	0	0.0	0	0.0
Owensboro, KY MSA	46,186	46,186	6	13.0	NA	17.0	0	0.0	0	0.0
Auburn-Opelika, AL MSA	45,520	45,520	19	41.7	NA	27.9	87,768	196.7	5,377	12.0
Elmira, NY MSA	44,926	44,926	46	102.4	20.2	18.6	0	0.0	0	0.0
Cheyenne, WY MSA	43,208	43,208	2	4.6	NA	23.4	0	0.0	3,000	7.1
Jonesboro, AR MSA	42,961	42,961	13	30.3	NA	20.9	0	0.0	0	0.0
Gadsden, AL MSA	41,276	41,276	0	0.0	NA	13.4	0	0.0	0	0.0
Punta Gorda, FL MSA	40,101	40,101	19	47.4	NA	17.6	0	0.0	0	0.0
Cumberland, MD-WV MSA	39,703	39,703	1	2.5	NA	13.4	0	0.0	0	0.0
Great Falls, MT MSA	39,470	39,470	5	12.7	NA	21.5	1,670	4.2	0	0.0
Pine Bluff, AR MSA	39,123	39,123	1	2.6	NA	15.7	4,151	10.6	32,695	83.9
Victoria, TX MSA	38,848	38,848	6	15.4	NA	16.2	0	0.0	0	0.0
Corvallis, OR MSA	38,526	38,526	101	262.2	28.3	47.4	138,240	340.5	36,676	90.3
Casper, WY MSA	33,915	33,915	8	23.6	NA	20.0	0	0.0	0	0.0
Pocatello, ID MSA	33,722	33,722	10	29.7	18.5	24.9	10,016	30.8	0	0.0
Enid, OK MSA	26,907	26,907	2	7.4	NA	19.6	0	0.0	0	0.0

Source and notes:
[a] Bureau of Economic Analysis
[b] U.S. Patent and Trademark Office
[c] U.S. Conference of Mayors
[d] U.S. Census Bureau
[e] National Science Foundation, Association of University Technology Managers, RAND Corporation
[f] Figures in bold are for the metro area. These figures are provided in instances in which the metro-wide rate is greater than the unit area rate.
[g] RAND Corporation

Table B.2: For Patent-Specializing Unit Areas, Leading Patenting Organizations, Percent Patents Provided, 1999								
Unit Area	Unit Area Jobs (000s)	Metro Area Jobs (000s)	Patents	Patents per 100,000 Jobs	Leading Patenting Organization	% Patents[a]	2nd Patenting Organization	% Patents, Two Firms[a]
San Jose, CA PMSA	1,039	3,754	5,664	544.9	IBM	6.2	Sun Microsystems	11.6
Boise City, ID MSA	227	227	1,093	480.8	Micron Technology	76.4	Hewlett-Packard	82.5
Dutchess County, NY PMSA	115	9,926	368	319.0	IBM	69.0	Siemens	81.3
Rochester, NY MSA	560	560	1,568	280.0	Kodak	53.8	Xerox	80.6
Rochester, MN MSA	85	85	229	270.3	IBM	74.2	Mayo Foundation	83.4
Boulder-Longmont, CO PMSA	180	1,458	476	264.5	Storage Technology	4.8	Cirrus Logic	8.8
Corvallis, OR MSA	39	39	101	262.2	Hewlett-Packard	60.4	Micron Technology	74.3
Austin-San Marcos, TX MSA	670	670	1,571	234.4	IBM	27.2	AMD	54.1
Fort Collins-Loveland, CO MSA	124	124	280	224.9	Hewlett-Packard	55.7	LSI Logic	63.9
Santa Cruz-Watsonville, CA PMSA	110	3,754	245	222.4	Seagate	12.2	LSI Logic	18.8
Burlington, VT NECMA	115	115	249	216.0	IBM	73.1	Micron Technology	77.5
Middlesex-Somerset-Hunterdon, NJ PMSA	650	9,926	1,091	167.9	Lucent Technologies	12.0	AT&T	18.8
Trenton, NJ PMSA	207	9,926	345	167.0	Sarnoff Corp.	7.8	Princeton University	14.5
Ann Arbor, MI PMSA	301	2,728	488	161.9	University of Michigan	9.4	Warner-Lambert	17.8
Binghamton, NY MSA	119	119	190	159.2	IBM	74.2	Lockheed-Martin	81.6
San Francisco, CA PMSA	1,139	3,754	1,700	149.2	Sun Microsystems	5.8	University of California	9.6
Oakland, CA PMSA	1,075	3,754	1,589	147.9	University of California	9.3	Sun Microsystems	12.4
Monmouth-Ocean, NJ PMSA	393	9,926	537	136.5	Lucent Technologies	31.8	AT&T	46.4
Raleigh-Durham-Chapel Hill, NC MSA	702	702	939	133.7	Ericsson	18.8	IBM	36.8
Greeley, CO PMSA	73	1,458	95	130.7	Hewlett-Packard	10.5	Lucent Technologies	16.8

San Diego, CA MSA	1,351	1,351	1,748	129.4	Hewlett-Packard	5.3	Qualcomm	10.4
Hamilton-Middletown, OH PMSA	133	1,055	168	126.3	Proctor + Gamble	57.1	General Electric	66.7
Wilmington-Newark, DE-MD PMSA	334	3,079	419	125.3	DuPont	49.4	W.L. Gore	52.7
Saginaw-Bay City-Midland, MI MSA	187	187	230	123.2	Dow Corning	34.3	Dow Chemical	59.6
Minneapolis-St. Paul, MN-WI MSA	1,799	1,799	2,181	121.2	3M	18.3	Medtronic	23.4
New Haven-Bridgeport-Stamford-Danbury-Waterbury, CT NECMA	856	9,926	1,033	120.7	Pitney-Bowes	7.6	U.S. Surgical	13.7
Boston-Worcester-Lawrence-Lowell-Brockton, MA-NH NECMA	3,322	3,322	3,806	114.6	MIT	3.2	General Hospital Corp.	5.3
Brazoria, TX PMSA	79	2,304	89	113.2	Dow Chemical	38.2	Intermedics	60.7
Newark, NJ PMSA	1,012	9,926	1,136	112.2	Lucent Technologies	22.4	AT&T	29.4
Cedar Rapids, IA MSA	126	126	141	111.7	Rockwell	34.8	Norand	50.4
Yolo, CA PMSA	92	846	103	111.5	University of California	29.1	Novo Norkisk	44.7
Santa Barbara-Santa Maria-Lompoc, CA MSA	191	191	212	110.8	University of California	8.0	Raytheon	11.8
Racine, WI PMSA	85	989	94	110.4	S.C. Johnson + Son	47.9	Modine	52.1
Ventura, CA PMSA	303	7,150	328	108.1	Amgen	6.4	Rockwell	10.7
Allentown-Bethlehem-Easton, PA MSA	290	290	299	103.2	Lucent Technologies	36.1	Air Product & Chemicals	57.5
Appleton-Oshkosh-Neenah, WI MSA	208	208	213	102.6	Kimberly Clark	41.3	Fort James	50.2
Kokomo, IN MSA	56	56	57	102.5	Delco	82.5	Pioneer Hi-Bred	87.7
Elmira, NY MSA	45	45	46	102.4	Corning	69.6		69.6
Peoria-Pekin, IL MSA	182	182	186	102.0	Caterpillar	79.6	USDA	84.4
Orange County, CA PMSA	1,454	7,150	1,473	101.3	McDonnell Douglas	3.2	Raytheon	5.6
Colorado Springs, CO MSA	271	271	270	99.5	MCI Communications	12.6	LSI Logic	22.6
New London-Norwich, CT NECMA	139	139	134	96.4	Pfizer	38.1	U.S. Navy	53.7

Albany-Schenectady-Troy, NY MSA	463	463	445	96.2	General Electric	65.4	Plug Power	67.0
Portland-Vancouver, OR-WA PMSA	1,006	1,155	930	92.4	Intel	30.2	Tektronix	37.0
Melbourne-Titusville-Palm Bay, FL MSA	195	195	178	91.1	Harris	38.2	Univ. Central Florida	43.8
Seattle-Bellevue-Everett, WA PMSA	1,469	1,919	1,296	88.2	Microsoft	24.5	Boeing	33.0
Madison, WI MSA	296	296	261	88.1	Wisconsin Alumni Research Foundation	31.4	Kraft Foods	35.2
Detroit, MI PMSA	2,244	2,728	1,964	87.5	Ford	14.5	DaimlerChrysler	23.3
Santa Fe, NM MSA	79	79	68	86.3	University of California	50.0	U.S. Dept. of Energy	52.9
Cincinnati, OH-KY-IN PMSA	922	1,055	782	84.8	Proctor + Gamble	37.5	General Electric	43.1
Akron, OH PMSA	344	1,568	284	82.6	Goodyear	16.2	Bridgestone	23.2
Dallas, TX PMSA	2,008	2,799	1,644	81.9	Texas Instruments	23.2	Lucent Technologies	28.1
Kenosha, WI PMSA	57	4,755	46	81.4	Abbott Labs	13.0	Snap-On	21.7
State College, PA MSA	80	80	63	78.8	Penn State Research Foundation	47.6	North American Refractories	55.6
Provo-Orem, UT MSA	155	155	122	78.7	Novell	27.0	Teksource	31.1
West Palm Beach-Boca Raton, FL MSA	512	512	403	78.7	IBM	13.9	Motorola	27.5
Tucson, AZ MSA	352	352	273	77.5	IBM	19.0	Raytheon	27.8
Gainesville, FL MSA	124	124	95	76.5	University of Florida	45.3	USDA	51.6
Barnstable-Yarmouth, MA NECMA	92	92	70	76.3	Sentinel Products	11.4	Johnson & Johnson	15.7
Hartford, CT NECMA	646	646	485	75.0	United Technologies	22.1	Combustion Engineering	25.8
Bergen-Passaic, NJ PMSA	675	9,926	502	74.4	Conopco	4.8	Becton,Dickinson	8.0
Lafayette, IN MSA	100	100	74	74.3	Purdue Research Foundation	21.6	Eli Lilly	36.5
Philadelphia, PA-NJ PMSA	2,490	3,079	1,849	74.3	SmithKline Beecham	9.8	Merck Pharmaceuticals	14.3
Houston, TX PMSA	2,131	2,304	1,567	73.5	Compaq	13.0	Shell	16.5
Reading, PA MSA	178	178	129	72.6	Lucent Technologies	31.8	Morton	38.8
Phoenix-Mesa, AZ	1,602	1,602	1,152	71.9	Motorola	31.1	Intel	40.2

MSA								
Santa Rosa, CA PMSA	200	3,754	141	70.5	Optical Coating Lab	9.9	Hewlett-Packard	15.6
Rockford, IL MSA	186	186	131	70.3	Sunstrand	25.2	Beloit	34.4
Pittsburgh, PA MSA	1,158	1,158	809	69.9	PPG	11.0	Eaton	18.0
Iowa City, IA MSA	73	73	51	69.6	University of Iowa Research Foundation	47.1	Norand	54.9
Bryan-College Station, TX MSA	76	76	52	68.4	Texas A&M	30.8	Lynntech	50.0
Johnson City-Kingsport-Bristol, TN-VA MSA	213	213	145	68.1	Eastman Chemical	64.1	Siemens	64.8

Sources: Patents, U.S. Patent and Trademark Office; jobs, U.S. Bureau of Economic Analysis

[a] Percentages derived from examining USPTO tables. Effort made to combine figures for related corporations. Data provided only for organizations with at least five patents over the previous five years.

Appendix C: Case Profiles

C.1 Biomedical Research Foundation of Northwest Louisiana, Shreveport, Louisiana

Background

Shreveport is the fourth largest metropolitan area in Louisiana with a population of 250,000. It is located in the less populated northern region of the state. Of the eight metropolitan areas in Louisiana, only two—Shreveport and Monroe—are located in the northern region, and their population is only two percent of that of the metropolitan areas in the southern part of the state.

The state as a whole suffered from the oil collapse of the early 1980s. Even today, the state ranks second to last in percentage of civilian population that are employed. Former downtown business districts were abandoned as old industries failed or moved to rural and ex-urban locations in search of larger lot sizes. Property values slipped in these districts and inner city problems became critical.

Biomedical Research Foundation of Northwest Louisiana

In 1983, the Greater Shreveport Chamber of Commerce commissioned a study to address problems arising from the downturn in the oil and energy-dependent industries. Many of the study's recommendations focused on diversifying the local economy.

One recommendation was to parlay the concentration of health care institutions into the emergence of a new biomedical industry. The Louisiana State University Medical Center in Shreveport (the medical school), Schumpert Medical Center, and Willis Knighton Medical Center employ some 15,000 teaching professionals, researchers, health care providers, and staff. The Biomedical Research Foundation of Northwest Louisiana (the Foundation) was created and incorporated in 1986 originally as a "think tank" to further examine that recommendation. The Foundation received seed moneys from the Caddo Parish Commission and the Greater Shreveport Chamber of Commerce, and other sources.

The Foundation's first attempt to move the mission forward was the establishment of the Virginia K. Shehee Biomedical Research Institute in 1994. The Foundation owns the Institute's 160,000 square foot research facility. It contains 56 laboratories occupied by scientists from Louisiana State University Medical Center in Shreveport. Also located in the Institute is the Positron Emission Tomography Imaging Center, which provides the only diagnostic and research services in Positron Emission Tomography (PET) in Louisiana.

The Center for Biomedical Technology Innovation (the Center) is designed to conduct more applied research that is farther along the commercialization timeline. Created by the Foundation from a grant of $7 million from the U.S. Department of

Energy, the Center supports a broad range of therapeutic and diagnostic applied research, ranging from orthopedic devices to medical robotics to healthcare information systems. Center services include:

- incubator services,
- use of research facilities,
- angel capital, seed capital, venture capital assistance either through referrals, through a newly created Foundation venture capital fund, or through grants and loans
- technology transfer-related intellectual property assistance through general guidelines and referrals to patent attorneys
- business planning assistance
- an understanding of regulatory issues facing biomedical firms

The Center is involved with close to a dozen companies, some of which are operating full flown companies, some are in the developmental stages, and a couple have failed.

The Foundation employs 35 full-time personnel and manages more than $42 million in assets. A 25-member board of directors governs the Foundation.

InterTech and Local Economic Development

The Foundation was concerned that the companies and research resulting from the aforementioned biomedical initiatives would go out of state. Louisiana in general and Shreveport in particular lacked the high technology base and infrastructure to encourage biomedical opportunities to stay in the area. The Foundation did not want to have all the investment made locally only to have another part of the country reap the most of the benefits as a resulting company or technology matured.

The Foundation conceptualized the idea of a research park for biomedical industries in an abandoned area of the downtown business district adjacent to the medical school and centers. The Park would take advantage of intellectual capital and revitalize the area through an urban redevelopment project involving such land use planning elements as rezoning and transportation planning.

To implement the idea, the Foundation helped form an InterTech committee composed of the chamber, city governments, parish governments, the metropolitan planning commission, business organizations, downtown development authority, state economic development department, electric utility, and other groups. Caddo Parish provided a tax millage to support InterTech development in 1992 and renewed it in 1997 for 10 years. In addition, the Foundation obtained grants from the U.S. Environmental Protection Agency for brownfield assessments, and the U.S. Department of Transportation for traffic-related issues. The Foundation used early funds for community visioning and planning. A master plan was developed that addressed environmental issues, green space, and communications technology. The now 2,400-acre development attracted private dollars. As the project grew, its focus expanded beyond biomedical industries to include other advanced technology areas.

One issue facing the Research Park was the lack of a local research university to which the park was tied. The Foundation created the Consortium for Education Research and Technology (CERT) in 1996 to address this void. The consortium serves as a virtual university by linking nine higher educational research institutions in Northern Louisiana. CERT makes university resources available to companies locating in InterTech.

The Foundation has relocated two out-of-state companies to the InterTech. To reach existing firms, the Foundation has reached private and commercial realtors who are helping to sell it. There have not been sufficient entrepreneurs to build a market for InterTech as of yet, although entrepreneurs remain a potential customer segment for InterTech.

Lessons Learned

In a relatively small community, it was important to work together. No one organization had sufficient resources to development technology-based industries in any one place. Collaboration allowed the community to obtain out-of-area grant moneys from state and federal government to support technology-development projects.

References

Interview with Jack Sharp, President, Phone: (318) 675-4100 FAX: (318) 675-4120, 1505 Kings Highway, Shreveport Louisiana, 71105, jsharp@biomed.org, April 14, 2000.

Web site: http://www.biomed.org

C.2 Center for Advanced FiberOptic Applications, Southbridge, Massachusetts

Background

The photonics industry is significant in Massachusetts. Massachusetts anchors a corridor along the northeast coast containing more than one-third of all U.S. photonics firms, and Massachusetts has the highest density of photonics firm per capita of any state in the U.S.—more than five times the national average. Fiber optics, a component of photonic systems, has its origins in the tri-community area of Central Massachusetts (Southbridge, Sturbridge, Charlton). In the 1970s and early 1980s, fiber optics manufacturers received large government contracts to supply components of communications and weapons systems. Declines in defense spending on photonics applications in the late 1980s and early 1990s caused fiber optics firms to seek commercial customers. Commercial customers had product needs that were quite different than defense customers, requiring that the manufacturers undertake costly development to convert their products.

Center for Advanced FiberOptic Applications

The Center for Advanced FiberOptic Applications (CAFA) was established in the mid 1990s to promote joint development of commercial photonics and fiber optic products. CAFA is a non-profit corporation created by the fiber optic industry in partnership with government and the University of Massachusetts. Some 12 companies representing in excess of 1,000 employees are members. Membership dues range from $2,500-$20,000. CAFA member companies also have furnished $250,000 to renovate and equip a facility with office, conference, and product development laboratory space. The state has provided $200,000 annually for operating expenses and authorized a $2 million bond issue administered by the University of Massachusetts for capital equipment. CAFA received additional funding from NASA's Jet Propulsion Laboratory to support components for miniaturized mass spectrometers, joint workshops, and monitoring technology. CAFA has an executive director for day-to-day operations, and each of member's CEO's share responsibility for overall governance.

CAFA and Economic Development Organizations

CAFA has strong ties to state and local economic development organizations. The local organization is the Tri-Community Area Chamber of Commerce. The Chamber is small with less than 600 members. CAFA is one of the Chamber's three main initiatives, the other two being tourism and establishment of a Department of Defense financing and training center. The executive director of CAFA serves as second vice chairman on the Tri-Community Chamber of Commerce Board of Directors.

The Chamber has helped CAFA in several ways. Inquiries come to CAFA as referrals from the Chamber. The Chamber also helped CAFA work with the Massachusetts Office of Business Development, which helped CAFA get its state appropriation and bond support.

Outcomes

One outcome of CAFA has been to obtain financing. This includes the NASA funding, the state funding, and any private sector contracts. A second outcome is joint research and development. One example involves two customers addressing CAFA with a fiber optics problem. "According to Anthony Detarando of Income, 'this will be the first direct source of profits we've seen come out of the CAFA alliance and it looks like the deal will go through successfully thanks to CAFA's coordination efforts.'" (Kreid, p. 32) Yet another positive outcome was that a Harvard Business School study of the Massachusetts photonics industry recommended "If done right, CAFA could serve as a successful prototype and centerpiece for a much larger coordination effort across the entire Massachusetts Photonics Cluster" (Kreid, p. 33).

Lessons Learned

Because of his participation on the Chamber board, CAFA's executive director has learned two main lessons for local economic development organization's technology development efforts. First, it is helpful for the Chamber to be closely aligned with state organizations. The Chamber's relationship with the Massachusetts Office of Business Development helped CAFA secure state funding. Second, it is important for the chamber to pick board members from a broad range of industry sectors. This approach will ensure that technology-based businesses will be included in chamber leadership.

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C.3 Edison Biotechnology Center, Cleveland, Ohio

Background

Ohio is home to regions with widely diverging economies. Cleveland, the largest city, has many large manufacturing and technology companies in a diverse range of industries. The state government and Ohio State University dominate Columbus, although a small number of companies have their headquarters there as well. Cincinnati's economy is dominated by a handful of large corporations, most notably Proctor and Gamble.

Manufacturing has been an important sector of Ohio's economy, with the state having the second largest number of manufacturing employees in the nation. The recession of the early 1980s hit Ohio's manufacturing sector especially hard. The sector began a turnaround after bottoming out in the mid-1980s. Nevertheless, much of the job growth has been in lower wage positions in older industries. One exception is the emerging biomedical industry. Ohio has over 350 companies directly engaged in producing biomedical products. These companies have over $10 billion annually in sales, employ 14,000 persons, and are joined by 15 startups a year.

In response to these trends, the legislature created a task force that conducted an extensive examination of the state's economic development efforts. In 1983, Ohio established the Thomas Edison Program as a partnership between industry, government, and academia. The program was designed to enhance the state's existing commercial and industrial strengths. It also had a parallel mission to foster firms in emerging industries. To address the dual missions involving existing and new business, the Thomas Edison Program developed technology centers, incubators, technology transfer initiatives, and an award program.

Edison Biotechnology Center

The Edison Biotechnology Center (EBTC) was established in 1987 as one of the current seven Edison Technology Centers. EBTC is a private non-profit organization with headquarters in Cleveland and regional offices in Columbus and Cincinnati. The regional offices allow the program to tailor its statewide mission to the unique economic conditions of each major Ohio city. There are some 20 staff members across all three offices, with most personnel located in Cleveland.

EBTC's mission is to work "with medical research institutions, biomed/biotech companies and community development organizations within the state to commercialize research, foster company formation and growth, and promote Ohio resources to regional and national audiences." (EBTC Web site, 2000) Its primary tool is through memberships. EBTC has 119 members that fall into several categories:

- Core industry member organizations, which manufacture a product or provide services used directly in human diagnostic or therapeutic applications

- Professional service advisors such as attorneys and accountants
- Universities
- Research and teaching hospitals.

EBTC offers several services to members. It provides direct assistance such as quick market assessments and invention disclosure reviews. More in-depth market analysis or licensing assistance is typically referred to an external provider. EBTC has served as the temporary technology transfer office for Case Western Reserve University. EBTC also provides funding. The center has a technology development fund to support university technology with commercial product potential. It also operates a small seed capital fund of $100,000, which allows it to award four or five small seed capital grants.

Facilities such as wetlabs are particularly important in the biomedical industry, which means that general business incubators are not very useful for engendering biomedical startups. Thus, the three regions have sought to establish incubators equipped to handle the needs of biomedical startups. In Cleveland, for example, EBTC does not manage an incubator. However, the center was one of the three partners to help bring a biomedical-related incubator into existence. EBTC obtained state and federal funding for construction of BioEnterprise on two floors of a Case Western Reserve University building. The center serves on the management board of the incubator. The center also helped to locate an outside organization, Enterprise Development Inc., to run the Cleveland incubator. EBTC offers membership to incubator tenants (most are tenants are members). Tenant companies are involved in industries including biotechnology, chemical analysis, mechanical systems, and software development. Since its inception in 1986, 32 companies have graduated from the incubator.

A second function of EBTC is a clearinghouse or single point of contact for information in the biomedical area. EBTC manages a database of service providers and technical experts within the university for referrals to biomedical firms. EBTC also runs a calendar of events that includes center- and non-center sponsored meetings and activities. Examples include the Ohio Regulatory Forum, FDA teleconferences, healthcare software roundtable, annual regional breakfast program series, and the annual statewide BioMed Ohio conference. The center maintains a resume book of prospective employees for members with job openings. It produces a directory of biomedical firms. EBTC staff members are involved in most state legislation and local initiatives related to the biomedical industry.

EBTC promotes the industry to national and international audiences. EBTC hosts and supports booths at industry trade shows. It sponsors brown bag series aimed at entrepreneurs for its University members. The EBTC web site has become an important source of information both outside and inside the state. EBTC membership ensures inclusion publications such as the Directory of Ohio’s Biomedical and Biotechnology Industry.

EBTC and Local Economic Development Organizations

EBTC's mission specifically includes community development organizations. EBTC interacts with them for funding for initiatives and trade shows. In addition, many former EBTC staff work currently work for various local economic development organizations. One example of how EBTC supports a local economic development initiative is shown below.

In 1997, the Greater Cleveland Growth Association (which is the chamber of commerce for Cleveland) and the Akron Regional Development Board embarked on a program called the Northeast Ohio Regional Economic Development Strategies Initiative. The initiative—also co-sponsored by Cleveland Tomorrow (a committee of 50 top executives) and the Cleveland-Cuyahoga County Port Authority and funded with $200,000+ in foundation support—was developed to focus on industry clusters which contain a large concentration of employees. The initiative identified several traditional, service and emerging technology clusters, one of which was the biomedical industry.

The Greater Cleveland Growth Association helped form four key industry cluster groups: instruments and controls, insurance, plastics, and biomedical/biotechnology. Business leaders headed each cluster.

The biomedical cluster has been among the more active clusters. The biomedical cluster formed three groups—technology transfer, facilities, and workforce—each headed by business leaders. In the technology transfer area, the cluster organized 25 local biotech executives to create a uniform set of policies, contracts and procedures for local universities and institutions to use to patent and license research. It has produced a service provider referral database and a facilities database. In 1999, the EBTC and Case Western Reserve University held a forum for the biotechnology cluster to promote dialogue among business, researchers, and academics, focusing on workforce issues. EBTC also has had representatives on each of the cluster groups. They have actively supported the chairman of the group and/or have served as members of steering committees. For example, EBTC staff, along with the Greater Cleveland Growth Association, worked with Case Western Reserve University's placement service to design an outreach program that would provide more job opportunities for graduates, co-ops, and interns. Former EBTC employees now serve in various cluster support roles. For example, the Greater Cleveland Growth Association has a former EBTC employee serving as the workforce liaison for the Northeast Ohio Regional Economic Development Strategies Initiative.

Lessons Learned

EBTC's strength is its statewide linkages. Although each region has a unique economic makeup, a statewide network enhances communication across cities and with the state government. EBTC's greatest challenge is to facilitate communication across local technology and economic development organizations. Local organizations risk "reinventing the wheel" with every new initiative. EBTC would like to be regarded as the repository for biomedical-related activities so that information and learning can be better shared, organizations can move in the same direction, and local and state initiatives can be more effective.

One way EBTC has been able to build linkages is through local organizations' hiring former employees. For example, the former EBTC employee now serving as the workforce liaison at the Greater Cleveland Growth has knowledge of EBTC that allows her to make referrals that take advantage of EBTC's services and information collection. She knows who to call at EBTC and how to work with the center.

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C.4 Georgia Research Alliance

Background

By the early 1980s, Georgia had tremendous growth in manufacturing, distribution, and service industries. The state's population growth was 66 percent higher than the national average, but its per capita income was still below the national average.

To obtain higher wage jobs, state economic developers sought to attract technology-based economic development opportunities. Georgia competed for the Microelectronics and Computer Technology Corporation (MCC), which ultimately went to Austin, Texas. Georgia leaders informally learned that the lack of a science and technology-based strategy and poor interaction among the research universities contributed to the state's lack of success with MCC. To address these issues, the state retained McKinsey & Company, which produced a report in 1984 recommending that Georgia invest in research infrastructure and form a single organization to focus science and technology-based economic development activities. A subsequent study by McKinsey & Company suggested that research infrastructure investments be focused in three research areas—"advanced telecommunications," environmental technologies, and human genetics (now broadened to biotechnology)—and further strategic work has resulted in eight more focused clusters that reflect the interplay among the broader research areas. For example, the bioinfomatics cluster reflects the connection between biotechnology and advanced telecommunications.

In the late 1980s, the business community initiated a collaborative program among six research universities, coinciding with several new university presidencies. These research universities eventually formed the nucleus of the Georgia Research Alliance.

Georgia Research Alliance

The Georgia Research Alliance (GRA) was formed in 1990 as a collaborative research initiative among six major research universities in the state of Georgia. GRA was charged to invest in building the state's research infrastructure in targeted areas. The investments were designed to generate economic development results—new company start-ups as well as high technology firm relocations and retention of existing industry.

GRA has several key programmatic elements. Eminent scholars, of whom there are 32 as of April 2000, are recruited in targeted areas based in part on a GRA supplementary endowment to be used for facilities, equipment, and other non-salary expenses. GRA also invests in facilities and specialized equipment such as the 150,000 square foot Georgia Center for Advanced Telecommunications Technology (GCATT) building. GRA's Technology Development Partnership program funds industry-university collaborative research with significant commercial potential. A private non-profit organization consisting of a small staff (president, two program managers, and administrative support) forms GRA management. This group functions as a virtual holding company for the program, develops strategy, finds financial resources, and interacts with state and local economic development organizations. GRA has a board of trustees composed of presidents of the member universities and executives from technology and other businesses who have served in state and local leadership positions.

Besides its direct programmatic elements, GRA has made investments in key aspects of Georgia's technology development infrastructure. In 1994, GRA created Alliance Technology Ventures, the first public initiative to establish an early-stage venture capital fund in the state. GRA has supported investments to expand the Advanced Technology Development Center (ATDC) incubator program (which was established at Georgia Tech in 1980) to convert GRA's research investments at member universities into commercial applications.

Through fiscal year 2000, the state of Georgia has invested $276 million through the GRA in research and development programs at its six member universities, matched by $65 million in private funds. This investment has, in turn, helped to attract over $600 million in additional sponsored research.

State and Local Economic Development Organizations

GRA works with local economic development organizations by making research investments to retain, attract, or develop business. For example, Rhone Merieux (now Merial Limited) was considering relocating out of state its 300-employee facility in Athens, Georgia. Working with the Athens Area Chamber of Commerce and the Georgia Department of Industry, Trade and Tourism, the GRA invested in an endowed chair, research facilities, and collaborative research projects between the company, the University of Georgia, and Emory University for new vaccine research and models to relieve diseases in animals. The company wound up expanding its Athens location, which saved 300 jobs and brought an additional 300 jobs into the community. Another Athens company, AviGenics, Inc., was spun out of the GRA-funded agricultural biotechnology initiatives at the University of Georgia. The company's technologies improve poultry traits and help foster high volume production of proteins in eggs. The company employs 50 people and supports student and faculty research at University of Georgia.

GRA also helps local communities with technology-based strategies and opportunities. When the state of Georgia initiated its regional service delivery strategy in 1999, GRA board members, staff, and eminent scholars participated in the technology-development component. GRA representatives met with the regional advisory councils to make them aware of research and technology infrastructure in their area. When the Metro Atlanta Chamber of Commerce initiated its "Industries of the Mind" strategy after the 1996 Centennial Summer Olympics, the GRA president served on the steering committee that guided the direction of the study underpinning the strategy. GRA has made presentations to local economic development organizations in cities such as Tifton, Savannah, Warner Robins, and Griffin about how to capitalize on the GRA research infrastructure investments in their area. GRA has made eminent scholars available to communities such as Savannah to help them think through strategies for building businesses in specific technology-related industries. GRA researchers have helped cities solve municipal problems such as the city of Douglas's composting treatment system project.

Partnerships and multiple interlocking relationships enable GRA to work with other state and local organizations. GRA board members also serve on the boards of directors of state and local economic development organizations. Interlocking boards are part of the state's vision to establish complementary relationships among Georgia's technology development organizations.

Lessons Learned

Local economic development organizations can have a need to understand the elements required for technology development. For example, a community may want a local technology incubator, but may lack sufficient research infrastructure to ensure that the incubator is used appropriately. GRA presentations to local economic development organizations discuss the innovation continuum from basic research to the development of intellectual property and related commercialization issues. They address the importance of providing funding across the continuum to ensure that the pipeline does not dry up as well as to ensure that research develops into economic development opportunities. This information explains why GRA investments are necessary to ensuring technology-based economic development throughout Georgia.

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C.5 Engineering Research Center, University of Maryland

Background

As part of the Washington D.C. technology metroplex, Maryland has a strong base of high technology firms. High-tech firms employ 54 of every 1,000 private sector workers in Maryland. The American Electronics Association ranked Maryland ranked fifth in employment in software services and also in defense electronics industries. High technology employees in Maryland earned nearly $55,000 in 1997, which was 80 percent more than the average private sector worker earned. Maryland also ranked third in 1998 in terms of the percentage of civilian scientists and engineers in the workforce.

Engineering Research Center

The University of Maryland formed the Engineering Research Center (ERC) in 1984 "to promote interaction in engineering and science between the University of Maryland and the business and industrial community." The ERC houses four main programs:

- Technology Extension Service, which is the state Manufacturing Extension Program (MEP)
- Maryland Industrial Partnerships, which offers matching grants for university-industry research
- Technology Initiatives Program, which funds research capabilities (e.g., laboratories and equipment) in targeted technology areas
- Technology Advancement Program (TAP), a statewide incubator.

All of these programs interact with local economic development organizations through referrals , presentations, and formal and information communication. The program with the most specific linkage is the TAP.

Technology Advancement Program and Local Economic Development Organizations

TAP operates as a statewide incubator program. TAP receives all its funding through the Engineering Research Center. Its annual operating costs equal $200,000, while revenues equal $150,000. The University of Maryland provides the facility, and funds all salary, utility, and maintenance costs.

TAP is focused toward technology-intensive companies in light manufacturing, biotechnology, electronics, and information technology development areas. TAP accepts on-campus or off-campus candidate companies. Those accepted may remain in TAP for a maximum of years. The University of Maryland takes a 1 percent equity share in TAP companies for each year of membership. TAP companies benefit from connections with the university such as access to equipment, facilities, faculty expertise, and student labor.

A total of 60 companies have participated in the program to date. TAP has created some 50 jobs in the incubator and more than 430 jobs via companies that have graduated.

Twenty-eight companies have graduated, two have been acquired by other companies, and eight have been discontinued. TAP's success rate is 80%.

Local economic development directors in all of Maryland's 23 counties may work with TAP. In reality, directors in metropolitan counties surrounding Baltimore and Washington DC most often are involved with TAP. TAP contacts county economic development offices as the incubator company is nearing graduation, the company gives the county official its facility needs, and the county official sets up meetings with commercial landlords. Financing options such as grants or tax abatements are discussed as well.

TAP has an especially strong relationship with the university's home county economic development organization. The Prince George's County Economic Development Corporation (PGCEDC) is a private non-profit organization dedicated to economic development.

The PGCEDC developed 10 strategic initiatives in 1999, one of which specifically focuses on high-tech companies. Under this strategy, the PGCEDC has designated an area called the High-Technology Triangle, which is bounded by the university. The strategy also supports technology transfer from the university as well as from federal government agencies.

An explicit tactic of the PGCEDC high-tech strategic initiative involves developing a plan to keep high technology incubator graduates in the county. To this end, a 1.5 million square foot office development has been constructed adjacent to the university campus. The development is targeted to incubator graduates. It offers flexible lease terms at commercial rates for technology start-up companies. Five incubator graduates of the TAP have established operations in the office development.

Lessons Learned

The main lesson is the importance of communication between the ERC programs and the local economic development organizations. This is critical to understanding each other's needs, potential clients, and other issues. In addition, it is helpful to explaining the benefits of technology-based start-ups to the local economy. Communication involves establishing key contacts at the University and the local economic development organization. Establishing contacts can be challenging, especially at the local level, because of the high rate of personnel turnover common to local economic development organizations.

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C.6 Office of Economic Development, Cornell University, Ithaca, New York

Background

Cornell University is located in the city of Ithaca, New York. The nationally ranked private university dominates the mostly rural local economy, along with tourism associated with the Finger Lakes. Nearly half of all Ithaca employees work in education, many for the University. There were nearly as many students enrolled in Cornell University (20,000) and Ithaca College (5,900) in 1999 as there were residents of the city of Ithaca (30,000 residents).

Cornell Office of Economic Development

Cornell University established an Office of Economic Development (OED) in 1997 specifically to focus the university on developing the local economy. The OED contains four units:

- The Center for Advanced Technology in Biotechnology (CAT) manages research facilities in five areas (analytical chemistry and peptide/DNA synthesis, computing, fermentation, microscopy and imaging, and plant tissue culture and transformation). CAT faculty researchers constitute the program of research symposiums such as the 14th annual Biotechnology Symposium. CAT also provides technology and business assistance to firms in the biotechnology industry. The center has supported the formation of 23 biotechnology firms with 260 employees since 1991 or roughly 2-4 biotechnology start-ups a year.
- The Cornell Office for Technology Access and Business Assistance (COTABA), supports entrepreneurship. It provides direct business assistance (e.g., facility expansion, personnel location, venture capital identification), administers the Technology Development Fund for commercialization of University inventions, operates the Cornell Business Ventures Network, started and supports the Finger Lakes Entrepreneurs Forum, which meets monthly. Some 40 companies, mostly in high-technology manufacturing or computer/Internet industries, receive assistance and are tracked by COTABA.
- The Cornell Research Foundation holds patents and manages licensing agreements. In fiscal year 1998-1999, the Foundation processed 174 patent disclosures, filed 144 patent applications, and managed 422 patents in force.
- The Cornell Business and Technology Park is a 200-acre park established in 1951 to link Cornell University and private research organizations and businesses. The Park currently houses 90 companies that employ some 1,400 workers with an annual payroll of $51 million. Nearly two-thirds of the companies are in technology-based businesses many of which conduct research linked to Cornell. The Park has attracted $28 million in private investment since 1986.

The OED has no separate budget. The 12 faculty members and staff involved have other research and teaching positions at the university and work in the OED as a community service.

Ithaca Economic Development Organizations

Technology-based economic development is an increasing area of emphasis for the local county and city economic development offices (although the local chamber remains focused on tourism). The Tompkins County Area Development Agency and the Ithaca Economic Development Office are involved with the OED in two main initiatives.

The Business Innovation Center is designed to support the creation of technology-based businesses. The county and Cornell University each furnished $60,000 a year for center operations.

The Economic Development Working Group includes representatives from the county, the city, local venture capitalists, the president of the Business Innovation Center, and managers from the Foundation and the Park. The Group meets monthly to discuss strategic economic development issues. The meetings also facilitate collaboration and coordination of efforts.

Lessons Learned

The OED has found that starting a technology development organization requires a formalized system and a devoted group of participants to take on the work; reliance on volunteers can threaten ongoing success. The critical challenge facing OED (in part given that OED is in a university in a rural economy) is finding people with business experience to pair with technology researchers. To obtain business-side expertise, the OED director is establishing linkages with Cornell's Johnson School of Management. The director teaches a course in the school. He has also been involved with the student-formed Small Business Counsel. The Counsel is designed to furnish business advice to startups and existing companies. The Counsel's has done 12-15 projects and its services remain in great demand.

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C.7 Los Alamos Commerce and Development Corporation, Los Alamos, New Mexico

Background

Los Alamos County New Mexico is located in the Santa Fe metropolitan statistical area. The Los Alamos National Laboratory occupies much of the county. The laboratory is owned by the U.S. Department of Energy and operated by the University of California. More than 6,800 scientists, engineers, and others work at the laboratory along with 1,200 contractor personnel. The laboratory's annual budget is around $1.2 billion. Its primary mission is nuclear weapon security.

Los Alamos County New Mexico owes much of its prosperity to the laboratory. The county's per capita income was more than $32,000 in 1997 as a result of the influx of the highly educated scientists and engineers brought in to work in the Laboratory. In contrast, the state average per capita income in 1997 was $19,298, and neighboring Rio Arriba county's per capita income was only $12,858.

The prosperity and the ever-increasing laboratory budget gave little encouragement to efforts to diversify the local economy beyond the laboratory. In addition, the laboratory's weapons mission made it difficult from a security standpoint to transfer work to the outside.

However, in the mid-1990s, the laboratory experienced a budgetary downturn. This downturn motivated efforts to establish local industry outside of the Laboratory. Although the Laboratory's budget has since passed pre-downturn levels, the programs that developed have persisted.

Los Alamos Commerce and Development Corporation

The Los Alamos Commerce and Development Corporation (LACDC) is the local economic development organization for the county. It was formed as a private not-for-profit corporation in 1999 from the merger of the Los Alamos County Chamber of Commerce and the Los Alamos Economic Development Corporation. LACDC has a staff of approximately 10 full time equivalent personnel. Funding comes from membership dues, property management, and service contracts.

Because of the presence of the laboratory, technology-based economic development is critically important to LACDC. LACDC has operated an incubator—the Los Alamos Small Business Center—for more than 10 years. The incubator houses more than 30 start-ups, Many of which are involved in technology-intensive products and services, and some of the businesses involve technology transferred from the laboratory. LACDC also operates the University of New Mexico-Los Alamos Small Business Development Center (SBDC) under contract with the university. It offers general economic and chamber-related programs as well (e.g., meeting and visitors bureau, business retention and expansion service and downtown development, chamber business meetings).

It should be noted that the laboratory is a member of the chamber. The LACDC executive director serves on the 25-member External Advisory Board. The laboratory assembled the Board in 1998 to help use laboratory technologies to nurture entrepreneurship and business growth in Northern New Mexico.

Industrial Business Development

The LACDC works with the laboratory's Industrial Business Development (IBD) unit on business start-up or other requests involving laboratory technology. IBD consists of three offices: Technology Commercialization, Strategic Partnerships, and Partnership Agreements. The 30-person staff provides services such as cooperative research and development agreements (CRADA), licensing, intellectual property management, memoranda and contractual agreements, and other technology transfer mechanisms.

Los Alamos Research Park

The most significant initiative of LACDC has been the creation of the Los Alamos Research Park. For the last 50 years, the U.S. Government has owned virtually all the land in Los Alamos County. After years of negotiation, LACDC negotiated and obtained a 55-year leasehold interest on the land and is the owner/operator of the research park. Tenants will be eligible to use more than 50 laboratories and facilities of the Los Alamos National Laboratory, including the research library and advanced computing power, on a contractual basis. The Research Park will have common areas for training and colloquiums as well as a full-service technology incubator. The Park is scheduled to open in the second half of 2000. (Private capital built the buildings in the Park.)

Outcomes

LACDC does not measure its work to facilitate technology transfer from the laboratory. It does measure SBDC-related activity and outcomes. The SBDC sees about 200 clients a year, conducts about 40 workshops, and stimulates capital formation in the millions of dollars. In the incubator's 12-year history, 30 companies have graduated.

Lessons Learned

LACDC's executive director indicates three main lessons in working with the laboratory on local technology-based economic development. First, despite the existence of the Industrial Business Development unit, there is no single place to go to in the laboratory to work on policy decisions. The local economic development organization has to be prepared to work with units throughout the laboratory because the IBD's Technology Commercialization Office can only make limited commitments. The ability of the local economic development organization to engage in technology transfer is limited by its resources, which are miniscule compared to those of the laboratory. Second, the local economic development organization's technology transfer and entrepreneurship efforts must be balanced by the importance of the laboratory's health as the economic engine for the local economy. The local organization's economic development efforts must be compatible what is in the best interest of the laboratory. Third, it is critical for the local economic development organization to have the right people from the laboratory on its board.

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C.8 North Carolina Small Business and Technology Development Center and The Greater Winston-Salem Chamber of Commerce

Background

North Carolina typifies fast-growing southern state economies. The state ranks sixth in net migration with growth centers in Charlotte, the Raleigh Durham/Research Triangle area, Greensboro, and Winston-Salem. North Carolina has the 8^{th} largest manufacturing base, with more than 12,000 manufacturers including concentrations in textile products, furniture, tobacco (e.g., R.J. Reynolds) industrial equipment, and electronics. Through the Research Triangle Park, North Carolina has attracted major facilities of IBM Corporation (computer and peripheral manufacturing) and Glaxco Wellcome Incorporated (pharmaceuticals) to counter declines in traditional textile and tobacco industries. Nevertheless, the New Economy Index ranks North Carolina 22^{nd} in terms of the percentage of high-technology jobs, and average per capita income for the state as a whole is below the U.S. average.

The state has a long history of state investment in technology-based economic development initiatives. North Carolina established the first state industrial extension service in the 1950s (now part of the U.S. system as the North Carolina Manufacturing Extension Partnership). The Research Triangle Park's first phase began in the 1950s as well. In 1963, the state established a Board of Science and Technology. Other major science and technology investments include MCNC (formerly the Microelectronics Center of North Carolina), the North Carolina Biotechnology Center, Research Triangle Institute, and the North Carolina Alliance for Competitive Technologies.

North Carolina has 100 counties, each of which generally has their own local economic development organization. In addition, the state is divided into seven regions, each with private non-profit economic development commission that receives state and private sector funding.

North Carolina Small Business and Technology Development Center

The North Carolina Small Business and Technology Development Center (SBTDC) calls itself "the only SBDC with a 'T' in its name." SBTDC has had a technology emphasis since 1984, when it was started by the University System to increase technology outreach throughout the state. Today, the SBTDC gets nearly $4 million annually in federal and state support.

Since 1984, the SBTDC has gone through three distinct periods. In the beginning, it primarily worked with inventors, but de-emphasized this service because the unpredictable and small outcomes of inventor products and services had minimal economic impact on the state as a owhole. SBTDC's second phase involved hiring doctoral-level technologists to work on science and technology related problems. However, the SBTDC soon found that its market demanded assistance with key elements of commercialization such as market development and financing, rather than technical issues, about which many entrepreneurs were already knowledgeable. In the current third phase, the SBTDC has staffed-up with MBA graduates with product development expertise. This has allowed the SBTDC to offer more commercialization-related assistance such as (1) identifying and helping with market accessibility, (2) providing financial assistance – e.g., introductions to area venture capitalists and risk capitol providers, assistance in applying for Federal Small Business Innovation Research or Small Business Technology Transfer Research (SBIR/STTR) awards – and (3) helping develop joint venture relationships. The SBTDC serves 400-500 emerging companies per year (with market identification, accessibility, and financing) in the technology arena.

The SBTDC has 11 offices, most of which are located in the business administration schools of regional universities. SBTDC provides technology transfer assistance to these less research intensive regional universities, because these regional universities typically have few technology transfer assistance resources in-house. However, the SBTDC specifically helps North Carolina State University with the provision of spinoff companies.

The SBTDC has established partnerships with non-profit research organizations. The SBTDC receives funding from the North Carolina Biotechnology Center, and the Board of Science and Technology, and has a partnership with MCNC as well. The SBTDC serves as the outreach mechanism for these research centers, giving them a staff presence around the state. The North Carolina Manufacturing Extension Partnership also has a cross-referral relationship with the SBTDC.

Greater Winston-Salem Chamber of Commerce

For most local economic development organizations, the SBTDC has found that technology-based economic development is not a significant area of concentration. However, the Greater Winston-Salem Chamber of Commerce is an exception. Winston-Salem is the fifth largest metropolitan area in the state. The city recently suffered losses in the tobacco industry, and Wachovia Bank (headquartered in Winston-Salem) has concentrated growth outside the state. The chamber decided to reorient its strategy toward technology-based economic development. The chamber hired outside consultants to develop a blueprint for technology development. To implement the blueprint, the chamber called on the SBTDC to provide assistance.

One of the first measures that the chamber undertook to implement the blueprint was the establishment in 1998 of The North Carolina Emerging Technology Alliance, a science and technology advisory roundtable. The SBTDC's local representative (and even state director) actively participates on this committee, which is headed by the president of Wake Forest University. Representatives from the other local universities and business leaders sit on the Alliance as well.

The Alliance manages the Piedmont Triad Research Park in downtown Winston-Salem. Begun in 1995, this park is the foundation of Winston-Salem's technology development efforts. The park's master plan contains 600,000 square feet of research and entrepreneur space in seven buildings. To support the transfer of technology to local entrepreneurs, the Alliance has raised money for Forsyth Angel Investors, a seed capital fund for early-stage technology-based entrepreneurs. A high-capacity telecommunications network connecting the schools, libraries, and government offices is also planned.

The SBTDC has also provided informal advice to the chamber. For example, the SBTDC has helped the chamber with its Web site design. The SBTDC director purposely hosted national training institute focused on technology in Winston-Salem to spotlight the city's technology attributes and initiatives.

Lessons Learned

Based on its assistance to local economic development organizations around the state, the SBTDC has learned several lessons. The first involves selling technology-based economic development to communities based on the focus it gives to economic development initiatives and the higher value jobs it provides. Second, the SBTDC director recommends that communities do strategic thinking about what they want to accomplish by developing a strategic plan. Third, the director recommends that communities learn how to access state resources such as the SBTDC

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C.9 Missouri Small Business Technology Center, Central Missouri State University

Background

Missouri has a service-based economy (34 percent employed in service industries, 21 percent in retail, and 7 percent in wholesale). Less than one-fifth of Missouri's civilian workforce is employed by manufacturing companies with about 18 percent employed in the traditional industries of food processing, apparel and textiles, and paper products. Much of Missouri's manufacturing base is clustered near St. Louis and Kansas City, Missouri.

Services

The Missouri Small Business Technology Center is part of The Center for Technology and Small Business Development at Central Missouri State University. Its mission is to offer assistance to small businesses, which most often is delivered in the form of general business planning, financial, and management assistance. The Center serves product development requests by providing preliminary patent and trade research, and linking the requestor with the Missouri Product Assistance Laboratory at Central Missouri State University for materials testing, design, or prototype development. The Center does work with local economic development organizations, but not specifically on technology transfer or product development concerns, except in the small number of instances in which referrals from the organizations involve product development needs.

Lessons Learned

The Center does little direct technology transfer (about 5 percent of their work load over the last 10 to 12 years). Several years ago, the Center did try to become more involved in technology transfer by attending conferences and promoting the resource. However, it was not able to develop a market for these services. According to Center staff, the main causes were the majority of businesses in Missouri were not in a position to utilize a high level of technology and the fact that Central Missouri State is not a research university. Mark Manley, a consulting engineer at the Center, felt technology transfer was more likely to be needed and successful in high technology areas, such as California or Massachusetts, than in Missouri.

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C.10 Louisiana Partnership for Technology and Innovation

Background

Louisiana is the 22nd largest state in the country based on 1999 population estimates. However, Louisiana ranked 43rd in median household income in the 1996-1998 timeframe, reflecting a lack of higher-wage industry in the state. Louisiana has lacked a research and development base outside of large oil and energy-related firms, which collapsed in the 1980s. The state also has historically received below average amounts of federal research and development funding.

Louisiana Partnership for Technology and Innovation

The Louisiana Partnership for Technology and Innovation (the Partnership) is a statewide organization whose mission is to advance technological opportunities for diversification of the state's economy. The Partnership's history began in the 1960s with its predecessor organization, the Gulf South Research Institute (GSRI). GSRI was established to commercialize university technologies so that they would benefit the Louisiana economy. To expand the state's research base, GSRI set up several research centers. Following declines in the oil and gas markets, GSRI focused its efforts on contract research, but in 1989, GSRI restructured into its present form as the Partnership, which enabled to reorient its mission toward technology-based economic development.

The Partnership is a private non-profit organization staffed by four professionals. Oversight of the Partnership comes from a 21-member board of directors. The Louisiana Department of Development is the Partnership's primary source of funding, though the organization has plans underway to establish a membership program.

The Partnership offers three main services. It provides direct assistance to companies needing technology transfer guidance. The Partnership helps with the development of financial, marketing, staffing, and business plans. The Partnership often helps with intellectual property and contract negotiations, through a government-contracting specialist on staff and relationships with local patent attorneys. In the financing area, the Partnership links clients to sources of venture capital (the Partnership formerly managed a fund for pre-seed capital investments in the early 1990s until funding ran out). Clients typically have technologies with a variety of applications rather than one particular invention. The Partnership currently works in-depth with about 12 clients.

A second service of the Partnership is to provide technology transfer services for university researchers. Typically a professor will contact the Partnership to assist with advancing the commercial potential of research developed at the university. The Partnership may help develop relationships with private industry, identify financial support, help develop marketing packages, and provide advice on business formation and intellectual property considerations.

A third service is research on technology policy issues. The Partnership supports the Louisiana Department of Economic Development's technology planning initiatives. Most recently, the Partnership participated in the development of the strategic plan for the state, known as Vision 2020. A governor-appointed task force, the Louisiana Economic Development Council, coordinated Vision 2020. The Partnership assisted the Council by serving as staff support to the technology task force, conducting focus groups in the northern and southern parts of the state, and submitting a white paper on state technology policy options.

The Partnership also hosts an annual awards program to honor innovative businesses and researchers. The Partnership publishes a Web site and a quarterly newsletter.

Louisiana Partnership and Local Economic Development Organizations

Like many local economic development organizations, Louisiana organizations tend to be focused on traditional recruitment and retention activities rather than technology-based economic development. Nevertheless, several organizations interact with the Partnership at a variety of venues and on a variety of initiatives.

Partnership staff regularly connect with local economic development association meetings. They receive some business client referrals from local economic development organizations. Many of these referrals tend to be small inventors rather than companies or researchers with technologies with significant potential for affecting the economy. These referrals tend to be "hand-offs" rather than the local organization continuing to manage the client relationship.

Most recently, the Partnership has involved local economic development organizations in two major initiatives. A Vision 2020 focus group in Shreveport involved local economic development organizations in inviting private sector and university participants.

The Partnership received a grant in 1999 from the U.S. Department of Commerce's Experimental Program to Stimulate Competitive Technology (EPSCoT) program, in conjunction with state technology organizations in Arkansas and Mississippi. The grant involves piloting various methods of providing technology assistance in three different-sized cities: one with a four-year college, one with a two-year college, and one without a local higher educational institution. To initiate the grant, the Partnership is holding technology-related economic development workshops in each city. Local economic development organizations in the three pilot cities are helping the Partnership with these workshops by providing names of community leaders for invitations and helping with meeting facilities and refreshments. The initiative will offer Web-based synchronous and/or asynchronous training for local economic developers. The pilot will also include community technology assessments and case studies of successful technology-based companies.

Lessons Learned

There is very little knowledge about the importance and role of technology in increasing wealth and incomes in communities. One example concerns what is involved in commercializing an invention. It is believed that that technologies developed at universities can be put on the market right away, though typically university researchers do not usually have a product for market and lack understanding of the degree of competition or size of the market. Thus, it is important to include funding for outreach and educational efforts in technology transfer programs.

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C.11 Oklahoma Center for the Advancement of Science and Technology

Background

The origins of Oklahoma's state technology transfer programs lie in the state legislature's response to downturns in the oil and agricultural industries in the mid-1980s. The state desired to develop its technology sector, but Oklahoma has lacked a research and development base outside of large oil and agricultural firms, and has historically received lesser amounts of federal research and development funding. Oklahoma's per capita income reflects this lack of higher wage industry as the state ranked 45th in median household income in the 1996-1998 timeframe.

The state passed the Economic Development Act of Oklahoma in 1987. This act created "Oklahoma Futures," a public-private organization charged with coordinating economic development strategic planning for the state. This organization spawned the Oklahoma Center for the Advancement of Science and Technology (OCAST), established to promote research and development related economic development by attracting federal research funds, establishing university centers of excellence and administering programs such as the Small Business Innovation Research (SBIR) and the Experimental Program to Stimulate Competitive Research (EPSCoR).

Oklahoma Technology Commercialization Center

Since 1998, OCAST has supported the Oklahoma Technology Commercialization Center (the Tech Center) through a contract with the Oklahoma Technology Development Corporation (a private non-profit corporation). The Tech Center is designed to be a single point of contact for high-tech entrepreneurs and researchers seeking assistance in the commercialization process. The Tech Center received $1.625 million from the state in fiscal year 2000 to support a dozen staff. In addition, the state gave the Tech Center $930,000 to operate an early stage seed financing program (The OCAST Technology Business Finance Program). The Tech Center also generates fee income and can receive royalties from client companies. The Tech Center has a board of directors composed of technology executives, heads of the Tulsa and Oklahoma City chambers of commerce, and other state leaders.

The Tech Center provides services directly and refers in-depth requests to attorneys, accountants, and other outside consultants and providers. Services include technical concept analysis, engineering and prototype design, market research, economic feasibility analysis, strategic marketing and business planning, and access to early stage capital.

In addition to the Tech Center, OCAST manages research and development programs through collaborative general technology- and health-related research grants. It also manages an SBIR seed support program and a manufacturing extension partnership program. OCAST operates a public relations and information program that includes a science and technology month, coordinates community presentations, and disseminates annual reports, brochures, fact sheets, and newsletters.

In its first six months of operation, the Tech Center providing commercialization services to more than 88 firms. The Center helped nine companies acquire early-stage capital and developed a $45 million statewide angel capital network.

Local Economic Development Organizations

The Tech Center works with local economic development organizations primarily in metropolitan areas and their surrounding suburban counties, and communities with local universities. The Center also makes a special effort to target certain key legislative districts.

The Tech Center has assisted local economic development organizations' efforts to create technology-based research parks and incubators. For example, the Oklahoma City Chamber of Commerce joined in a consortium to create a research park formed to turn innovations from health researchers into companies. The Tech Center provides technical and management assistance for the park. The Tech Center is similarly assisting University of Oklahoma (Tulsa) research park, and the Oklahoma Technology and Research Park in Stillwater, which is a partnership among Oklahoma State University, the city of Stillwater, and the Meridian Technology Center.

In addition to research parks, the Tech Center helps communities with other aspects of technology transfer. The Tech Center is involved in developing angel investment networks all over the state, including rural areas. The Tech Center has hosted SBIR workshops in Stillwater. In Lawton, the local economic development organization, Cameron University, and the Tech Center Jointly run an Experimental Program to Stimulate Competitive Technology (ESPCoT) award. OCAST and the Tech Center help Edmond host the annual technology conference by furnishing funds, serving on the steering committee, and assisting with speakers. The Tech Center hosts town meetings and participates in speaking engagements around the state in areas outside of metropolitan areas that are without universities.

Lessons Learned

The most critical lesson is "communicate, communicate, communicate." Communication requires formally involving local leaders in the program. For example, the establishment of the Tech Center (which is located in Oklahoma City) raised concerns in Tulsa that the center would not benefit other parts of the state. The Tech Center recruited Tulsa area leaders to serve on the board of directors, as well as local leaders from Oklahoma City. Communication also involves making right connections with the right people such that roles are understood. This avoids turf battles out of miscommunication and misunderstanding.

In rural parts of the state, acceptance of technology transfer initiatives can be challenging. An educational process is required to help rural areas understand the benefits from these types of programs. Typically OCAST and the Tech Center will look for a local entrepreneur or firm in their area that has received assistance or funding. Or these organizations will present benefits from the programs; for example, the angel network initiative has been successful in rural areas because it involves making money for rural investors.

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Web site: http://www.ocast.state.ok.us

Web site: http://www.ssti.org

C.12 Colorado Institute of Technology Transfer and Implementation, University of Colorado at Colorado Springs

Background

Colorado Springs is the third largest city in Colorado with a population (including the surrounding county) of nearly 500,000. Military bases have significantly influenced Colorado Springs' economy since the 1940s. The city is home to Fort Carson (Army), the Air Force Academy, the Peterson Complex (which includes Peterson Air Force Base, Cheyenne Mountain Air Station and Falcon Air Force Base), and the North American Aerospace Defense Command (NORAD).

With the decommissioning of military bases in the late 1980s and early 1990s, Colorado Springs had a need to diversify its local economy. Through the efforts of the local economic development organizations, defense-dependency was reduced. In 1996, nearly half of the 238,000 employees were in the services or wholesale/retail trade industries, and only 13 percent were employed in military in-service occupations.

Colorado Institute of Technology Transfer and Implementation

The Colorado Institute of Technology Transfer and Implementation (CITTI) was established at the University of Colorado at Colorado Springs (CU-Colorado Springs) in 1990 through a grant from El Pomar Foundation. CITTI's serves as the technology transfer office for CU-Colorado Springs, though because CU-Colorado Springs is not primarily a research university, little patentable research is done on campus. For example, CU-Colorado Springs had only nine invention disclosures among its 258 faculty in 1999.

CITTI's primary mission is to foster local high-technology industries. The Institute's strategy to accomplish this mission is through the creation of a social network of high-technology firms and potential service providers, mentors, advisors, and directors. Much of the assistance involves general business services such as business planning, staffing, financing, and finding commercial space. This is accomplished through programs such as:

- CEO-CEO roundtable: a monthly forum of executives and division heads to share issues and problems. There is an $80 per quarter fee.
- The Software Distinguished Speaker Series that brings in experts from outside Colorado Springs to present at monthly meetings
- Entrepreneurial Boot Camp: a four week training program that addresses issues such as venture capital and angel investment networking, business planning, market research, and product planning.
- CITTI Partner Program: Service providers desiring high technology and entrepreneurial clients pay CITTI an annual membership fee to joint the program and have access to CITTI's entrepreneurial clients. Members tend to be law firms, accounting firms, and commercial realtors.

- CITTI is a major participant in the Rocky Mountain Technology Conference and Expo, which consists of the Rocky Mountain Technology Expo 21, and Celebrate Technology Week (a series of panel discussions, seminars and luncheons with keynote speakers).

CITTI is staffed with three endowed chairs that have full-time teaching responsibilities (and whose salaries are paid by the university). These professors have either started a company or are currently starting a company. In addition, the Institute has a stable of former entrepreneurs who volunteer their time. CITTI does not have to cover the professors' salaries, but they do have operating expenses that are covered through membership fees and donations (either direct donations or percentage of initial public offerings) from former clients. The operating funds that CITTI receives allow it to assist some 10 entrepreneurial clients a month free-of-charge.

Local Economic Development Organizations

Technology-based economic development is a big issue for city government and the Greater Colorado Springs Economic Development Corporation (EDC). It is not as significant to the Greater Colorado Springs Chamber of Commerce because most chamber members are not in high technology industries. Technology-based economic development has been a primary focus for the EDC and the city to accomplish economic diversification.

The main project these organizations are undertaking to further technology-based economic development is the creation of a high-technology incubator. CITTI, the EDC, the city government, and private individuals have created a board of directors and bylaws for the incubator. They are in the process of raising financing for the operation of the incubator. Their three-year plan is to hire an executive director and run the incubator as a virtual service. These organizations also co-sponsor events and cross-refer clients.

Lessons Learned

The biggest challenge that CITTI faces is publicizing their service to entrepreneurs. CITTI mostly uses word-of-mouth, referrals, and other informal means—i.e., visible presence on a major thoroughfare in campus, monthly column in the local newspaper written by the director, event promotion, web page, brochures—because their budget cannot cover direct mailing costs.

CITTI has learned that one-on-one advice to entrepreneurs from mentors is the most effective mechanism for helping high-technology startups. To support this assistance, CITTI builds a social network using Institute Board of Director positions and volunteers to engage mentors for service to startups.

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C.13 North Florida Technology Innovation Corporation, Gainesville, Florida

Background

Florida is the fourth largest, and one of the fastest growing, states in the country. Its technology employment base reflects its size and growth. The American Electronics Association's *Cyberstates 3.0* report indicated that Florida employed the sixth largest number of high-technology workers (194,000 in 1997) in the nation. Florida also created 9,100 new high-technology jobs between 1996 and 1997, the seventh largest increase.

North Florida is one of the lesser-populated regions of the state. The population centers in the northeastern region are Gainesville and Ocala, the 15th and 16th largest metropolitan statistical areas (MSAs) in Florida. Major employers include the University of Florida and Lockheed-Martin circuit card assembly operations.

The state has a unique economic development structure. Its economic development was privatized in the 1990s, becoming Enterprise Florida, Inc. Among the programs that Enterprise Florida operates are the innovation and commercialization centers. Florida has six regional private non-profit innovation and commercialization centers that focus on high-technology start-up creation.

North Florida Technology Innovation Corporation

The North Florida Technology Innovation Corporation (NFTIC) is the innovation and commercialization center for a 10-county region in North Florida. NFTIC has a 14-member board of directors composed of high technology firm executives, university administrators and professors, the director of the NASA Southeastern Technology Applications Center (STAC) (NASA regional technology transfer center), and financial institution executives. Three full-time employees and an intern constitute the NFTIC staff. NFTIC has an annual budget of $400,000, most of which comes from state and local government. Client firms contribute to this budget by compensating for service through stock rather than direct cash outlays.

NFTIC facilitates the growth of local technology-based companies primarily through working with the University of Florida and private sector entrepreneurs. It offers direct services to assist start-up firms survive through the early years. NFTIC offers market research, business planning, and capital identification services. It operates a small seed fund of about a $1 million that furnishes investments of $25,000 to $50,000 to start ups. NFTIC does not have intellectual property lawyers on staff, but works closely with them, arranges referrals, and provides clients with general guidelines.

NFTIC hosts two annual meetings, one for members and one for directors and officers. Several promising companies are showcased at these meetings. In addition, NFTIC holds smaller meetings on a quarterly basis with companies and investors. Outreach occurs through the organization's quarterly newsletter distributed to leaders in the region, its Web site, referrals from members of the board of directors, and informal word of mouth.

NFTIC and Local Economic Development Organizations

NFTIC works with local economic development organizations primarily through active networking. The NFTIC president has memberships with many local organizations and serves on several of their boards. He attends their meetings and they attend his.

A recent incubator project illustrates how NFTIC interacts with local economic development organizations. The Ocala/Marion County Economic Development Council (EDC) desired to investigate the feasibility of a technology-based business incubator. The EDC wanted to contract with NFTIC to conduct the study. NFTIC did not have sufficient available staff to conduct the study, but made a special effort to hire a consultant knowledgeable about technology incubator operations. The consultant surveyed local community leaders, business executives and potential incubator tenants. The results of the study were positive, and the EDC is proceeding with development.

Outcomes

NFTIC has about six active clients in various stages of development. Its performance indicators avoid traditional economic development measures, focusing instead on capital raised and companies created. Since the mid-1990s, NFTIC has helped form about a dozen companies.

Lessons Learned

Its distinctive focus on high-technology start-ups allows NFTIC to work more easily with recruitment-oriented local economic development organizations. No other organization in the region offers the services that NFTIC provides, and NFTIC does not duplicate what local economic development organizations do in the recruitment area. As a result, the local organizations are more open to NFTIC's message about the new economy and the evolution of economic development away from stealing firms and jobs from out-of-area locals.

NFTIC has found that state and local funding helps it more effectively work with client firms. Public funding enables NFTIC to offer services to clients without requiring cash compensation. Start-up firms typically do not have that cash flow to pay for the services they receive through means other than stock.

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Web site: http://www.floridabusiness.com/

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C.14 Agri-Business Commercialization and Development Center, Richland, Washington

Background

Washington State has a significant and diverse agricultural sector. About 20 percent of the gross state product comes from agricultural production, processing, and marketing. Washington is one of the top 10 states in 35 separate commodities. It leads the nation in the production of several types of grains, fruits, and vegetables. Nevertheless, the agricultural sector faces economic challenges that can benefit from integration of technology and from value added processing. In addition, there are opportunities in the waste and waste utilization markets.

Agri-Business Commercialization and Development Center

The Agri-Business Commercialization and Development Center (ABCD) was established to help entrepreneurs and existing industry to put agricultural research technology to commercial use. The ABCD was formed in 1995 by six organizations: the Pacific Northwest National Laboratory (PNL), Battelle (which operates PNL), the U.S. Department of Energy (the owner of the laboratory), Washington State University, the Tri-City Industrial Development Council (TRIDEC), and the Port of Benton. These organizations wanted to utilize technologies that were "sitting on the shelf" more effectively to advance the local economy.

ABCD is staffed with two experienced PNL chemical engineers. ABCD operated as a unit of PNL until 1999. Currently it operates as a private nonprofit organization with a board of directors that includes agricultural producers and economic developers.

ABCD offers technology matching and consulting services. If a company seeks to diversify into a technology-based business, ABCD has access to a wide array of technologies from PNL, Washington State University, and the U.S. Department of Agriculture. Staff engineers conduct broad market and technical evaluations of technologies. They conduct feasibility studies and offer business-planning assistance. They also offer access to office and 1000-square-foot laboratory space available for client use. Staff engineers have connections to an angel network and other regional sources of capital, and have referral arrangements to address training needs.

Over the last five years, ABCD has worked with several hundred clients. One example is Bonanza Ag Exchange, Inc., a start-up business in the Tri-Cities, Washington, which teamed with Seattle-based Apple Valley International to form the Apple Valley Consortium. The Consortium's main product is an alfalfa-based treat for horses. ABCD helped initiate the partnership, fund a trial-production run of the product for test marketing, and connect with a local nutritionist, an agricultural products supplier, and a feed mill. The consortium plans to manufacture the product in the Tri-Cities region. In another example, ABCD provided business assistance to a PNL staff member forming a new company to produce an automated grape pruner.

ABCD and Local Economic Development Organizations

ABCD is involved with many local economic development organizations committees and and strategic planning initiatives. For example, ABCD is represented on the TRIDEC agriculture committee, which takes strong view of strategic planning in the technology area. ABCD is also involved in several PNL initiatives. ABCD has a cross-referral relationship with these organizations. Local economic development organizations tend to refer clients with entrepreneurial technology development needs in a hands-off mode to ABCD.

Lessons Learned

One challenge ABCD faces in working with local economic development organizations is that the center is limited in the information it can release about its clients and projects. Technology transfer often requires secrecy. Early stage clients are involved in highly competitive business areas, and marketing or informational brochures about these clients might hurt their ventures. Yet, this lack of information can hinder local economic development organization's efforts to market ABCD's capabilities or even to understand how to use the center.

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C.15 Engineering Technology Transfer Center, University of Southern California

Background

Southern California was a magnet for large aerospace and defense manufacturing firms until the 1980s. Defense cutbacks in the late 1980s and early 1990s hurt the Southern California economy. Between 1988 and 1996, Southern California's aerospace industry declined by 55 percent—from 425,000 jobs in 1988 to 189,000 jobs in 1996. Declines in defense spending were not the only reason for the downward trend in these industry segments. Southern California's high cost of doing business encouraged other lower-cost states to entice major aerospace manufacturing programs away from the region. Many influential decision-makers such as Hughes Electronics and Lockheed Martin moved their headquarters out of California. In response, the state initiated several programs to diversify the economy using technology-based businesses to replace losses in the aerospace and other defense industries.

University of Southern California Engineering Technology Transfer Center

One program that assists with this diversification is the University of Southern California (USC) Engineering Technology Transfer Center (ETTC). The ETTC has a long history. The National Aeronautics and Space Administration's (NASA) began its Industrial Application Center (NIAC) program in the 1960s, operating one of its centers at USC. The NIACs were designed to furnish technology transfer and information services to businesses. NASA replaced these centers with six NASA Regional Technology Transfer Centers (RTTCs) in 1993, and USC's School of Engineering won the contract to operate the Far West RTTC. In 1997, USC combined its NASA RTTC service with its commercial and international service under the University of Southern California Engineering Technology Transfer Center (ETTC) within the School of Engineering.

The ETTC primarily offers access to NASA technologies and technologies at other federal laboratories. The center matches technologies to client companies' needs. Once technologies are identified, the ETTC manages the entire intellectual property process including research and marketing, patent and licensee searches, and identification of funding sources. The ETTC operates an on-line catalog of commercially available technologies. In also has an on-line calendar of technology transfer-related seminars and conferences. These services are delivered by 15 professionals and seven interns.

In 1995 (the most recent publicly available data) the Far West RTTC served 1,868 companies with 777 technical and 1,057 commercialization services in its eight-state region. These activities resulted in 34 licenses and agreements. One example of a success is X-Corp, a 30-employee Los Angeles-based firm started in 1991 by former defense-industry aerospace engineers to develop and manufacture environmentally friendly automobiles using environmentally friendly manufacturing processes. X-Corp's goal was to produce cost-competitive car with fuel efficiency of 90 miles per gallon, excellent crash resistance, lightweight, and having one third fewer parts than the typical automobile. The ETTC helped identify more than 80 federal technologies that the company used in designing the automobile and production system. The ETTC also helped the company set up a consortium of component suppliers and federal laboratories to prototype the car and production system. The company signed a cooperative research and development agreement (CRADA) with the U.S. Department of Energy through the help of the ETTC.

The ETTC and Local Economic Development Organizations

The ETTC has established alliances with many state and local economic development organizations. The ETTC executive director serves on the Board of Directors of the California Association for Local Economic Development (CALED) as a way to interact with local economic development organizations in the state. He has also served as Initiative Director for the California Community Colleges, the chairman of the California Advanced Technology Center Steering Committee, a member of the steering committee for the Southern California Venture Forum, a member of the Advanced Technology Committee for the California Space Technology Alliance, and participated in the California Defense Conversion Council.

The state has adopted a strategic approach toward economic development based on regional clusters. To enhance the technology clusters in their region, local economic development organizations regularly focus on existing industry and entrepreneurial development, not just recruitment. Typically, local economic development organizations will contact the ETTC to serve as the local organization's technology transfer unit. The local organization will review its technology cluster strategy with the ETTC so that the ETTC understands which technology clusters (e.g., environmental technology, electronic commerce) are being targeted. In turn, the ETTC will narrow its focus toward five or six technologies that are especially relevant for companies in these clusters. Then the local organization will link the ETTC with local small and medium-sized companies or entrepreneurs with defense conversion or other business problems that meet the technology cluster profile. Often these companies or entrepreneurs have been "good community citizens" but need repositioning away from a mature or declining industry. The ETTC meets with the companies, matches NASA or other technologies to the companies' needs and capabilities, and assists with intellectual property issues. The local economic development organization retains management of the relationship with the company.

Lessons Learned

ETTC finds it most fruitful to work with communities that have moved away from out-of-area recruitment strategies. It is important for local economic development organizations to do the groundwork for building their technology base, including targeting technology clusters, identifying companies that would benefit from NASA technologies, and managing relationships between these companies and assistance sources such as the ETTC clients. Clients that have maintained a leadership position are especially cooperative in working with the chamber and the ETTC to reposition their business using NASA technologies.

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California Association for Local Economic Development

C.16 Technology Transfer Committee, Huntsville/Madison County Chamber of Commerce, Huntsville, Alabama

Background

Huntsville has a significant concentration of space, defense, and electronics companies. Huntsville's technology-based industries grew out of the establishment of the Redstone Arsenal during World War II, and the formation of the Cummings Research Park in the 1960s. A 1997 study by the Wharton Econometric Forecasting Associates Group ranked Huntsville second in the nation for its concentration of technology employment. The area is home to NASA's Marshall Space Flight Center, The University of Alabama in Huntsville, U.S. Army Space and Strategic Defense Command, the U.S. Army Missile Command, and the Tennessee Valley Authority. Technology-based businesses large and small, domestic and foreign also operate in the Huntsville area. More than 12,000 engineers work in Huntsville.

Technology Transfer Committee

The Huntsville/Madison County Chamber of Commerce's Technology Transfer Committee was started when NASA's Marshall Space Center approached Chamber to find ways to transfer NASA technology to local firms with which the Chamber was in contact. The Chamber's Vice President of Education and Technology established a Technology Transfer Committee in 1990 made up of designated technology transfer specialists from core technology organizations in the area—NASA's Marshall Space Flight Center, The University of Alabama in Huntsville, Alabama A&M University, U.S. Army Space and Strategic Defense Command, the U.S. Army Missile Command, and the Tennessee Valley Authority. The NASA Southern Technology Assistance Center (STAC) also participated in the Chamber program through teleconference. Representatives from private industry also volunteered their service. There were typically about 20 people at a Committee meting.

The Chamber provided the Committee with space and refreshments for monthly breakfast meetings. The Chamber also provided administrative support for meetings, including managing records of problem statements from local businesses, tracking which organization was assigned to address the problem, and following up with assistance through surveys. The Chamber also marketed the Technology Transfer Committee's service to industry.

The Committee's primary service was technology assistance rather than technology transfer. A local business's problem would be submitted to the Committee. Committee members would indicate which organization could best serve the business. The committee representatives handled technology-related needs. However, many of the problems were general business management problems rather than technology related. For general business problems, the local Small Business Development Center (SBDC) or faculty from one of the universities would be matched with the company.

The Committee met regularly over a six-year period. More than 600 companies were served during that time. Some 40 percent of the companies had less than 50 employees. Post-assistance surveys indicated that nearly 80 percent of the companies receiving assistance experienced increased revenues as a result of the assistance of the Committee, 65 percent saved or created new jobs, and more than 50 percent decreased expenses.

Aftermath

In 1996, the Committee became no longer a part of the Chamber. Several factors were responsible for this. The Chamber's Vice President of Education and Technology had retired, and technology became less critical to the chamber than did its other initiatives (business retention and expansion, business recruitment, image development, workforce development, and space and defense).

By 1996, the U.S. Department of Commerce had expanded its Manufacturing Extension Partnership Program, Alabama received an award, and the state set up a 501(c)3 with regional centers in Huntsville and other locations around the state. Dr. Bernard Schroer from the University of Alabama at Huntsville (who had volunteered time to chair the Technology Transfer Committee after the Chamber staff member's retirement) became director of the MEP Huntsville center. He decided to move the technology transfer and assistance function to the MEP center, and the Technology Transfer Committee of the Chamber was dissolved. At present, MEP agents provide the technology assistance function by linking clients with technology needs and NASA's Marshall Space Center or other technology provider.

The Chamber is no longer a major player. The SBDC, which is housed in the chamber, is accessed through the Chamber. Likewise, the Chamber's Existing Industry Committee provides access to companies. The Chamber also helped to spin off a high tech incubator about three years ago. Many of the technology transfer organizations that served on the Committee have offices at the incubator.

Lessons Learned

The key to the initiative technology transfer initiative was having the Chamber's commitment. Although the Chamber did not provide technology transfer service, it was the glue made the service work. It furnished resources and management, and lent its name to the initiative. Another important factor was the ability to access the federal laboratories. NASA assigned two to three people to serve on the Technology Transfer Committee and the other major organizations designated representatives as well. The representatives formed a core of about eight people that gave the Committee continuity.

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C.17 Industry and Technology Council of Central Ohio, Columbus, Ohio

Background

Columbus is the state capital of Ohio. Cities such as Cleveland have given Ohio the second largest manufacturing employment base in the nation. Columbus has a more diverse service industry base however. Columbus is home to The Limited, Wendy's International, Bank One, Nationwide Insurance, and the Online Computer Library Center (OCLC). This diverse economy typically has insulated Columbus from economic recessions as compared to cities in its region such as Cleveland and Pittsburgh whose local economies were dominated by mature industries undergoing restructuring.

In the early 1990s, Cleveland and Pittsburgh made changes to their economic development structures by setting up technology business councils. Columbus's technology businesses wanted to establish a similar group that could serve as a voice for technology concerns, as distinct from the typical economic development organization that is focused on new business recruitment. Equally significant, local technology-based businesses desired to become better acquainted with each other and with the capabilities of local current and potential service providers, particularly Ohio State University. They noted that technology initiatives in other cities drew heavily on the local research university, but felt that Ohio State University had not been tied into the local Columbus economy very well.

ITC Mission and Services

The Industry and Technology Council of Central Ohio (ITC) was established in 1993, as a private non-profit membership organization. Sixty percent of its budget comes from member dues, with additional funding and in-kind support furnished by Ohio State University, the Greater Columbus Chamber of Commerce, and the city and county governments. For its executive director, ITC sought an experienced senior executive with technology-based business experience rather than the typical junior staff member that runs most economic development organizations. ITC hired an executive director with over 30 years experience as a senior executive in three Columbus area technology-based companies and an executive-in-residence position at Ohio State.

ITC's mission is to strengthen the local economy through assisting Columbus's technology-based companies, and helping existing businesses better use technology. It offers four major services targeted to different audiences.

- Monthly luncheons featuring presentations from senior managers and administrators from Ohio State University, or smaller start-up firms in the information technology industry
- Specialty forums targeted to chief executive officers, chief information officers (mostly of large firms), and operating managers. Forum topics range from business plan sharing to discussions about issues in using information technology. Participating firms are not competitors.

- Technology After Hours which involves plant tours or visits to design or services firms to obtain an understanding of capabilities
- Participation in an annual trade show—Technology Exposition Technology Exchange and Student Career Expo.

ITC serves an information and referral function through facilitative networking. It uses meetings, forums, and other mechanisms to bring together the technical resources in the area by building and expanding a network of people who share mutual needs and the desire to solve problems. Discussions typically deal more with strategic business issues that are driven by technology than with specific technology-related problems. The executive director serves an information and referral function

ITC and the Greater Columbus Chamber of Commerce

ITC was originally started as part of the Greater Columbus Chamber of Commerce. The Chamber has some 70 staff serving 4200 members in 42 counties in central Ohio. Although it left the Chamber and operated from the executive director's house for nearly a year, ITC has been collocated with the Chamber and shares non-staff administrative resources. The chair of ITC's board serves on the Chamber board of directors. ITC receives referrals from the Chamber as well.

In 1996, ITC developed technology initiatives in association with the Growth Strategies Report. The initiatives involved improving information technology capabilities in the local workforce, enhancing entrepreneurial development (Ohio's rate of new business formation was only 75 percent of the national average in 1997), and establishing mechanisms for Ohio State University to become more integrated with the local economy. ITC presented these initiatives to many state and local organizations. ITC obtained endorsements from the mayor, local government, and eventually the Governor.

The Chamber Board of Directors eventually followed suit and undertook implementation of two of these initiatives. It set up a workforce development program, a portion of which promotes information technology training. It also established an entrepreneurship committee that has set up a start-up business model, conducted a study, participated in venture capital assistance, created a business resource guide, helped to establish a small business resource center, and promoted the local small business development center.

ITC and Ohio State University

Until the mid 1990s, Ohio State University had not established significant ties with local industry. The university operated a research park, but it was not fully occupied and not well-integrated with the local economy.

ITC became actively involved in the university's community outreach plans. Input from the council suggested that a more nimble approaches were needed rather than the administrative layers that governed existing university-based initiatives. The university sponsored a panel of ITC members and others to visit technology transfer programs at universities in other states. Based on what was learned from these visits, the university set up the Science and Technology Campus Corporation (STC) as a freestanding, not-for-profit entity governed by an independent board of trustees chaired by the university president. STC manages the Science and Technology Campus, a $40 million research park on Ohio State University's West Campus. The campus will include an expansion of the existing Business Technology Center incubator, the Innovation Center to incubate specialty and niche firms, a Science Village for incubator graduates, and buildings for larger companies desiring close links with Ohio State. The Science and Technology Campus will be developed in phases ending in 2014.

ITC also helped strengthen the link between the Chamber and the university. ITC found that most business people did not understand newer technology-based economic development models that emphasize the importance of universities. ITC helped communicate the connection between university research and the local economy to business and community leaders.

Lessons Learned

Several factors were responsible for ITC's success in activating the Chamber and the university. These included: (1) identifying a small core of committed technology leaders; (2) developing a short list of initiatives, (3) bringing the initiatives to various groups to widen the circle to the broader community.

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C.18 Gallatin Valley Technology Alliance, Bozeman, Montana

Background

Montana is a rural state, historically dependent on natural resources, such as mining, forestry, and tourism. Montana ranks in the bottom five in per capital income. It has lagged behind most states in industrialization. Less than 9 percent of their employees work in manufacturing companies (1997 *County Business Patterns*). The American Electronics Association's Cyberstate's report ranked Montana 49th in terms of the percentage of jobs in high technology industries.

Nevertheless, Montana is working to create an environment conducive to technology firms through workforce development. The American Electronics Association CyberEducation study found that Montana "excelled in standard math and science scores and students' access to technology in elementary and high schools." The study also noted that state had an increase in high technology degrees awarded between 1996 and 1999 while the number of degrees awarded nationwide declined.

Gallatin Development Corporation

The Gallatin Development Corporation is an economic development corporation focusing on Gallatin County, Montana and the surrounding area. Its goal is to help create high paying, high quality jobs in high technology and light manufacturing industries. In 1993, it established the Gallatin Valley Technology Alliance (GVTA) which "provides a forum for networking and the exchange of information, processes, and procedures among technology oriented businesses and institutions."

GVTA provides assistance with financing, human resources, and other business areas. It also serves as a liaison to Montana State University (MSU)'s manufacturing extension program and its technology transfer program. GVTA holds monthly meetings with speakers on various topics, including intellectual property issues, patenting, product development, and financing. Companies pay a small membership fee to be a part of GVTA.

GVTA's three full-time and one part-time employees spend most of their time working with high technology companies and the remainder of their time with light manufacturers' needs. They do not have a specific budget set aside for working with high technology companies.

University Technology Transfer Partnership

GVTA works most closely with MSU's Intellectual Property Administration and Technology Transfer (IPATNT). IPATNT offers licensing of university-owned, federal lab-owned, and NASA-owned technologies, IPATNT also sets up collaborative research agreements and manages a technology park for start up companies. IPATNT has 3.5 full time equivalent staff members dedicated to technology transfer issues. IPATNT can work statewide, but typically stays within the Gallatin Valley due to the physical size of

Montana and the presence of other state universities resources that are closer. Besides working with GVTA, IPATNT also works with the state department of commerce and, occasionally, with economic development groups in cities other than Bozeman.

The two organizations have two major initiatives. The first is a technology incubator. The notion is for GVTA to open a business incubator and provide business assistance, with MSU providing technology transfer, commercialization, and manufacturing assistance. The incubator is currently in the planning/investigation stage.

The second initiative involves scholarships and work study. The goal of this program is to provide opportunities for college juniors and seniors to work in the region while in school, with the hopes that they will be offered and will accept employment after graduation.

MSU and GVTA also engage in cross-referrals. GVTA provides business and financing assistance to companies referred by MSU. MSU provides technology transfer, commercialization, and manufacturing assistance, consulting services, and, occasionally, facilities to companies referred by GVTA.

Outcomes

GVTA and IPATNT have achieved successes in the high technology area. GVTA helped two software companies relocate to the valley, and in the last 18 months another software firm grew from a handful of people to 180 employees. GVTA has assisted numerous high technology entrepreneurs with business-related problems and financing. IPATNT has 30 licenses, 17 of which are to Montana companies.

Lessons Learned

The primary lesson GVTA has learned in trying to develop technology-based industry is the importance of supporting infrastructure. The need for a high technology workforce and high capacity telecommunications infrastructure at reasonable rates are critical needs of existing technology-based firms.

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C.19 Telecom Corridor Technology Business Council, Richardson, Texas

Background

The Telecom Corridor® is a defined geographic area primarily located in the City of Richardson, a north Dallas suburb. It includes over 600 telecommunications and technology-based companies. Some 70,000 people work in the nearly 25,000,000 square feet of high tech work space in the Telecom Corridor.

Richardson's technology industries can be traced to two companies: Collins Radio (since acquired by Rockwell International, which was then acquired by Alcatel) and Texas Instruments. These two companies spawned four generations of spin-offs The spin-offs range from multimillion-dollar companies to low-profile firms. Richardson also attracted a large Northern Telecom facility, an MCI testing facility, Fujitsu's cellular and fiber optic transmission subsidiary, and Ericsson's U.S. headquarters.

Over the last 50 years, a stable cadre of local technology executives made most of the policy and economic development decisions for the city. Executives from the city's major high tech firms held mayoral positions and most city council members either worked in technology industries or had family members who did so. Their singular focus on the technology community led to the establishment of a local engineering university, a master plan for campus-like low rise facilities, and early deployment of a traffic management system. In the late 1980s, the Richardson Chamber of Commerce developed and copyrighted a logo and the name Texas Telecom Corridor to market their community.

In the early-1990s, Chamber leadership discovered that technology business councils were being created on east and west coasts. The Chamber Board conducted an intensive nine-month analysis of councils from around the country. They particularly liked councils which had separate structures from that of the Chamber.

Structure and Services

The Telecom Corridor® Technology Business Council (TBC) was created in August 1994 by the Board of Directors of the Richardson Chamber of Commerce. Its primary objectives have been to identify common issues and programs that will enhance the technology and telecommunication growth of the Telecom Corridor®. The TBC was created as a division of the Chamber to avoid the duplicative costs of operating two organizations and to build upon the strengths that already existed within the Chamber and its partnerships with the City of Richardson, the University of Texas at Dallas, and the major technology firms in the Telecom Corridor®.

The TBC has its own mission statement, board of directors, and committee structure. Membership is restricted to two narrowly defined classifications, Technology Members (companies that own or make high tech products or processes) and Provider Members (companies that provide specialized services to technology companies through licensed engineers or other technical professionals). Participation in monthly committee meetings and some events is limited to TBC members only. Five of the Chamber's 20 staff members spend time supporting TBC activities.

The TBC's high profile event is called the "Third Friday Tech Luncheon Series." This event is open to general Chamber members as well as TBC members. About 450 people attend every month.

From a policy perspective, the TBC has focused on the passage of an R&D tax credit in Texas. The TBC established the Texas R&D Coalition as a non-profit 501(c)(6) organization in July 1998 to represent technology businesses on this issue.

In the technology transfer area, TBC established STARTech in 1996 to help the engineering community convert patents into companies. STARTech is a for-profit, wholly owned subsidiary spun-off of the Chamber. It has a separate staff and board of directors. STARTech serves as a virtual incubator, helping locate inexpensive space. It also set up a pooled venture seed fund. STARTech created a mentor network composed of retired senior-level executives from high tech firms. STARTech matches local entrepreneurs with these executives.

TBC does not do a formal evaluation of its outcomes and results. Key indicators include:

- The number of members increased from 30 in the mid-1990s to some 350 as of 2000
- STARTech has reviewed more than 400 business plans since 1997 and formally adopted 17 companies, providing them with more in-depth assistance.

Lessons Learned

Several factors account for TBC's success. TBC already had fertile soil to plow, based on Richardson's concentration of high tech industry and stable and consistent leadership from industry executives. A second factor was that TBC planners researched various models of technology business councils and found an approach that fit—a council that utilized the Chamber's resources but had a separate and narrowly defined membership and committee structure restricted to technology-savvy members. This separate structure prevents regular, non-technical chamber members from diluting issues and initiatives. The result is that the TBC can work on issues not of interest to rank and file Chamber members but very critical to technology businesses.

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C.20 Arizona Optics Industry Association, Tucson, Arizona

Background

Tucson is one of the fastest growing cities in Arizona. Surrounding Pima County grew by 2.6 percent annually in the 1990s. One main economic development challenge facing Tucson is that many of its traditional industries are in service sectors such as tourism. Although these service sectors are growing, they generally pay low wages.

Tucson is home to a notable concentration of higher-wage optics-related companies. Some 200 optics-related companies operate in the Tucson area, employing 2,000 people and doing $300+ million worth of business. These numbers led Business Week to call Tucson "Optics Valley." In addition, the University of Arizona is known for its astronomy and optical sciences research programs. It is reported that former University of Arizona students have founded some of the area's optics-related companies. (Munro 1999; Medlyn 1999)

Arizona Optics Industry Association

The Arizona Optics Industry Association (AOIA) was incorporated as a private non-profit organization in 1992. It was designed to facilitate communication among optics-related companies and institutions to promote the industry. AOIA has more than 100 members—companies and universities—and is governed by a board composed of nine chairs and two vice chairs. AOIA meets bi-monthly. Its funding comes primarily from member dues. Many of the most pressing AOIA meeting topics involve general business concerns, in part because most of the members come from a strong technical background.

AOIA and Economic Development

AOIA has participated in several major economic development initiatives. The AOIA chair Bob Breault served as cluster leader for the Greater Tucson Strategic Partnership for Economic Development (GTSPED). GTSPED is a strategic plan to promote seven clusters, one of which is optics. The plan was developed in 1996 and is currently in its implementation phase. Implementation is being managed by the Greater Tucson Economic Council (GTEC). GTEC hosts monthly breakfast meetings for GTSPED cluster chairs and others involved in the project to report on implementation activities. Many activities involve business recruitment and tax incentives creation, investment in workforce development and other infrastructure, and image marketing. One example of the latter is optics cluster's landing of a major conference in 2001 in Tucson.

AOIA also is heavily involved with GTEC directly. GTEC is the local economic development arm of Tucson. GTEC has traditionally been focused on recruitment. Although recruitment is still important, efforts of cluster chairs helped re-write GTEC's mission statement to include existing industry development. Mr. Breault has served as a past chairman of GTEC's board of directors, and GTEC staff use him as their single point of contact for optics-related requests. Two of the 11 GTEC staff members work directly with the optics cluster, mostly on recruitment activities. For example, GTEC split the cost of a optics banner for trade shows and helped design brochures In addition to recruitment, GTEC staff forwards requests to Mr. Breault that involve new business opportunities for existing AOIA companies. For example, when a manufacturer from outside Arizona contacts GTEC to find an optics company to produce a component, GTEC staff call Mr. Breault, who then links the manufacturer to the appropriate optics company. This linkage has resulted in revenue growth for local optics firms. GTEC also provides support for AOIA networking meetings.

One challenge for AOIA is to retain some of the benefits of the research done at University of Arizona in the local economy. It has been believed that other states benefit from research done at University of Arizona, either by hiring graduates or through research grants. AOIA has set up meetings with the University of Arizona's technology transfer officer to enhance awareness of the needs of local optics firms. In addition, two university researchers serve on the AOIA board.

Outcomes

A key economic development benefit of AOIA is that is serves as a focal point to highlight the optics industry in Tucson. It encourages the image that the city is a center for optics industry development. International experts studying cluster development have contacted Mr. Breault and visited Tucson to examine the cluster.

Lessons Learned

Key elements of AOIA's initiatives include: (1) focusing the research university on the needs of the local economy, (2) having heavy private sector involvement in the local economic development organization's technology-based initiatives, and (3) having strategies that involve existing businesses and start-ups (not just out-of-area business recruitment) formally in the local economic development organization's charter.

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C.21 Greater Nashua Software Entrepreneurs' Group and the Greater Nashua Center for Economic Development, Nashua, New Hampshire

Background

Nashua is the county seat of the largest county (in terms of population) in New Hampshire. It is located in southern New Hampshire and has strong ties to the metropolitan Boston economy. In the early 1990s, Greater Nashua suffered from a downtown in the computer and defense industries in the Boston economy. Companies such as Digital Equipment Corporation, Wang, and Lockheed laid off many workers. New Hampshire was left with a large available technical workforce.

The Greater Nashua Center for Economic Development

The Greater Nashua Center for Economic Development (CED) is a non-profit corporation created to expanding employment and economic opportunities within the region. The Center provides services, programs, counseling, and other forms of assistance to existing and start-up businesses within the Greater Nashua area. CED acts as a facilitator, by making available in-depth knowledge of various community contacts, including local chambers of commerce and economic development organizations. CED serves all sectors of the economy, but focuses mainly on technology industries. This case describes two major initiatives in which the CED was involved: the Greater Nashua Software Entrepreneur's Group and incubator services.

Greater Nashua Software Entrepreneurs' Group

The layoffs of the early 1990s created interest in entrepreneurship. The Greater Nashua Software Entrepreneurs' Group (GNSEG) started in 1992 to provide a vehicle for small software start-up companies to meet and discuss issues. Software entrepreneurs figured prominently in how GNSEG was organized. They indicated that software professionals were not "joiners," so GNSEG was established as a loose network rather than as a membership organization. GNSEG holds regular monthly meetings at a fixed location. GNSEG also helps organize an annual software conference in New Hampshire.

Software professionals further advised that general business issues such as intellectual property or financing were more critical than technical issues. Consequently, GNSEG is opened to lawyers, accountants, and general business consultants as well as software entrepreneurs

CED has served as an organizer and sponsor for GNSEG. CED furnished the organizational vehicle for GNSEG's creation. CED also provides administrative support for meetings. CED contributes funding to support some GNSEG activities, notably the annual software conference.

Incubator

CED operated a small business incubator from November 1994-February 1999. The incubator was collocated with the CED in the floor above. The 17,000-foot space was donated to CED under a sublease agreement, which allowed CED to offer shared executive office space at below market rates. The incubator also offered counseling and management services. Fifty-five tenants located in the incubator, including some GNSEG "members." The incubator service ended in 1999 when the sublease agreement ended and the CED could not find reasonably priced space.

Outcomes

The Greater Nashua area has benefited from the CED's initiatives. In the recession economy of the early 1990s, GNSEG provided a focus for software and technology interests. The general public was not knowledgeable about the software industry because it did not produce brand-name boxed software products. GNSEG increased local awareness, better enabling the general public to understand what New Hampshire's software professionals do. It also provided a central meeting point for both technical and general business interests, and connected the established business community to the "new technology economy."

The incubator had more easily quantifiable outcomes. Of the 55 tenants, only eight start-up firms failed. The graduating companies employ more than 400 people and occupy 180,000 square feet of commercial space. These numbers reflect a few particularly successful graduates.

In general, technology-based businesses became a more significant part of the New Hampshire economy. According to Cyberstates 3.0, New Hampshire had the highest concentration of technology workers—82 per 1,000 private sector workers. Nearly 7 percent of the state's workforce in 1999 was in the high-technology industry.

Lessons Learned

Three main lessons can be acquired from the experiences of the CED. First, industry associations targeted to technology firms should take into account the unique characteristics of those firms by involving private industry in creating the association's organizational design. The CED took software professional's advice and set up GNSEG with a loose structure and regularly meeting times and location.

Second, service providers should facilitate but not meddle in technology start-up firms. CED found that good software start-ups flourished without a significant amount of handholding.

Third, local economic development organizations should emphasize the importance of diversification. The experiences of the recession of the early 1990s enabled the CED to convince many local economic development organizations to forego their traditional emphasis on landing a single large employer and instead to diversify their local economies with smaller technology-based businesses.

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