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THE INFLUENCE OF RESEARCH UNIVERSITIES ON TECHNOLOGY-BASED REGIONAL ECONOMIC DEVELOPMENT

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IRYNA V. LENDEL

ABSTRACT

Universities are frequently assumed to be essential contributors to regional economic development although conclusive evidence that universities trigger economic growth within their region does not exist. This dissertation presents a model that characterizes the influence of university research on regional economic outcomes, changes of total regional employment and gross metropolitan product. The model controls for industry research activity and incorporates differences in regional industrial organization. The model compares the influence of university research and industry research on changes of regional employment and gross metropolitan product during the expansion (1998-2001) and contraction (2002-2004) phases of the business cycle and over the entire time period studied (1998-2004). In addition, the dissertation tests the impact of university size and reputation on regional economic outcomes in conjunction with industry research. The models are tested on the universe of metropolitan statistical areas. Lessons from the dissertation research are drawn to inform state and local technology-based development strategies.

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CHAPTER I

IMPACT OF RESEARCH UNIVERSITIES ON REGIONAL ECONOMIES: THE CONCEPT OF UNIVERSITY PRODUCTS

1.1 Introduction

Many public policies are based on a popular assumption that investment in research universities advances the technological base of a region's economy, leads to the creation of new companies and industries, and ultimately, benefits all taxpayers by increasing regional wealth. In the emerging knowledge economy universities are seen as a core element of a region's intellectual infrastructure. There are also positive externalities of university presence – land development and increased property values in adjacent neighborhoods, cultural amenities including university sport teams, and the mere fact that universities are large employers that are tied to their geography and create high multiplier-type impacts on regional economies. Politicians are embracing strategies that tie universities to regional economic development through the impacts of academic research on technological advances used by companies, recruitment of graduates into regional labor force, and the active role of universities in setting the regional economic development agenda.

Different frameworks conceptualize university impact on regional economies, ranging from scholars who see the involvement of universities in regional economic development as a third mission (Etzkowitz, 2003; Lester, 2005; Tornatzky, Waugaman, & Gray, 2002) to skeptics who do not believe that universities have adequate ability to promote economic development (Feller, 1990) and who believe that close involvement of universities with companies might compromise the integrity of the academic enterprise (Nelson, 1986; Slaughter & Leslie, 1997). This chapter introduces the concept of university products which are presented as the channels through which research universities impact regional economies. It is believed that the bundled nature of university products makes it impossible to assess the impact of each product separately. The results of models testing the impact of the presence of research universities on metropolitan employment illustrate that the impact of university products is statistically significant and causes metropolitan employment to depart from its long-term trend. Testing the impact of research university presence in metropolitan areas provides a foundation for a discussion of the influence of university products on regional growth, which is offered in the following chapters.

The evolution of the theoretical concepts underlying the role of universities in regional economic development begins with Adam Smith's (1776) theory of the market economy and advances through theories and concepts from different disciplines. Based on Young's concept of increasing return and Solow's technological residual, Paul Romer (1986) established a new growth theory – the main theoretical basis for technology-based regional strategies. Using Polanyi's concept of tacit knowledge (Polanyi, 1962, 1967) and Innis' concept of encoding personal knowledge (Innis, 1950, 1951), scholars

classified knowledge as either tacit or codified and emphasized that knowledge is neither evenly distributed nor equally accessible in every location. In different studies of knowledge spillovers from universities to companies and agglomeration effects of urbanization, universities were identified as a major component of regional innovation systems or a critical knowledge element among regional institutions (Appendix 1).[1]

Synthesizing the thoughts behind the literature on economic development theories and the knowledge spillovers suggests two major hypothesized systems linking universities with regional growth: (1) mechanisms of knowledge spillovers due to agglomeration economies and (2) specific economic environments where the knowledge spillovers occur. The environment of knowledge spillovers and deployment of the results of knowledge spillovers into regional economies can be described by characteristics that reflect the intensity of agglomeration economies and their qualitative characteristics, such as the quality of the regional labor force, level of entrepreneurship, intensity of competition in a region, structural composition of regional economic system and industries, and social characteristics of regions (such as leadership and culture).

This chapter begins by introducing the role of universities in the regional economy from the concept of learning regions to the model of university products, where universities are presented as endogenous to regional systems. The review of different models that depict the role of universities in regional economies is followed by presenting the concept of university products and a model of interactions between the university products and the factors of technology-based economic development. The

[1] The theoretical base for the role of universities in economic development and the detailed literature review of these studies is forthcoming in Lendel, I., P. Allen and M. Feldman (2009). University-Based Economic Growth. Toght, M., J. Huisman, K.-H. Mok and C. Morphew (Eds.) *International Handbook of Higher Education*. London and New York: Routledge.

statistical models in the following section test the hypothesis of the impact of a research university's presence in metropolitan statistical areas on the growth of regional employment. The models use different ways of operationalizing university presence in 14 selected scientific and technology fields and test the impact of the universities presence in a regional economy over the business cycle. Research university presence is tested in the models that include industry R&D spending among the independent variables and a number of variables describing regional industrial organization. Statistical tests are continued with the models that assess employment changes in metropolitan areas with the top nationally recognized research universities and research universities with the largest university R&D spending. The chapter ends by summarizing the system of major linkages between universities and regional economies. Results of statistical tests show that research universities presence has a significant impact on metropolitan employment growth.

1.2 Concept of University Products

1.2.1 University Roles in Regional Economies

In 1980, the United States Congress passed the Bayh-Dole Act and the intellectual property landscape in the United States changed dramatically. Universities were allowed to retain intellectual property rights and to pursue commercialization even when basic research conducted by them had been funded by the federal government. In the late 1990s, technology transfer activities of research universities began to be recognized as

important factors in regional economic growth. Scientists started to look at the different factors and mechanisms stimulating transfer of new technology from university to industry (Campbell, 1997; Cohen, Florida, & Goe, 1994; DeVol, 1999; Lowen, 1997; Slaughter & Leslie, 1997). Discussing the benefits of such technology transfer, Rogers, Yin, and Hoffmann (2000) hypothesized that "research universities seek to facilitate technological innovations to private companies in order (1) to create jobs and to contribute to local economic development, and (2) to earn additional funding for university research" (Rogers et al., 2000, p.48). They illustrated the potential impact of university research expenditures on jobs and wealth creation through the process of simple technology transfer.

Beeson and Montgomery (1993) tested the relationship between research universities and regional labor market performance. They assessed a university's impact on local labor market conditions by measuring quality in terms of R&D funding, the total number of bachelor's degrees awarded in science and engineering, and the number of science and engineering programs rated in the top 20 in the country (Beeson & Montgomery, 1993, p.755). Beeson and Montgomery identified four ways in which colleges and universities may affect local labor markets: (1) increasing skills of local workers (together with rising employment and earnings opportunities), (2) increasing ability to develop and implement new technologies, (3) affecting local demand through research funds attracted from outside the area (a standard multiplier effect), and (4) conducting basic research that can lead to technological innovations.[2]

[2] Also discussed by Nelson, R. (1986). Institutions supporting technical advance in industry. *The American Economic review*, 76(2), 186-189.

.

Link and Rees (1990) emphasized the important role of graduates to a local labor market, assuming they do not leave the region, particularly for new start-ups and the local high tech market. Gottlieb (2001) took this idea a step further in his Ohio "brain-drain" study, emphasizing that exporting graduates is a sign of long-term economic development problems for a region. In their study of 37 American cities, Acs, FitzRoy, and Smith (1995) tested university spillover effects on employment and, like Bania, Eberts and Fogarty (1993), tried to measure business start-ups from the commercialization of university basic research. These studies produced mixed results showing that university products are statistically significant in their impact in one case and insignificant in others.

Following Adams' findings about the positive effect of the geographic proximity of university research on industrial research (Adams, 2001; Adams, Chiang, & Starkey, 2000), many studies (Audretsch & Feldman, 1996; Audretsch & Stephan, 1996; Cortright & Mayer, 2002) found that for most industries, activities that lead to innovation and growth take place within only a few regions nationally or globally.

Many studies[3] focused solely on showing the impact of university presence using the multiplier effect of university expenditures. These studies confuse the impact of university products (which we identify as purposefully created outcomes according to a university's mission) and the impact of university presence in a region (which depends on university expenditure patterns). In the traditional multiplier-effect studies, the models usually take into account two factors of university impact: (1) the number of university

[3] Stokes, K. (2007) The Economic Impact of Thomas University on Southwest Georgia, http://www.thomasu.edu/pdf/2007_economic_impact.pdf; Leistritz, F. and R. Coon (2007) Economic Impact of the North Dakota University System, http://www.ndus.nodak.edu/Upload/allfile.asp?id=778&tbl=MultiUse; Humphreys, J. (2008) The Economic Impact of University System of Georgia Institutions on their Regional Economies in FY 2007, http://www.icapp.org/pubs/usg_impact_fy2007.pdf; St.Mary's University and San Antonio (2003), http://www.stmarytx.edu/impact/pdf/economic_impact.pdf; The Mizzou Impact (2008), http://www.missouri.edu/impact/.

students and employees (which is a non-linear function of university enrollment) and the impact of their income through individual spending patterns and (2) the pattern of university expenditures via a university budget. These two factors (sometimes called university products) are indirect functions of enrollment and endowments and are highly collinear with university size. While normalized on a per capita basis, they are highly correlated with university reputation and, apart from reputation, are to a high degree uniform across regions.

A similar approach is used by Porter (2002) in a report for the Initiative for a Competitive Inner City. He studied six primary university products using a multiplier-effect approach. Porter identifies the main impacts of the university on the local economy through: (1) employment, by offering employment opportunities to local residents; (2) purchases, redirecting institutional purchasing to local businesses; (3) workforce development, addressing local and regional workforce needs; (4) real estate development, using it as an anchor of local economic growth; (5) advisor/network builder, channeling university expertise to local businesses; and (6) incubator provider, to support start-up companies and advance research commercialization.

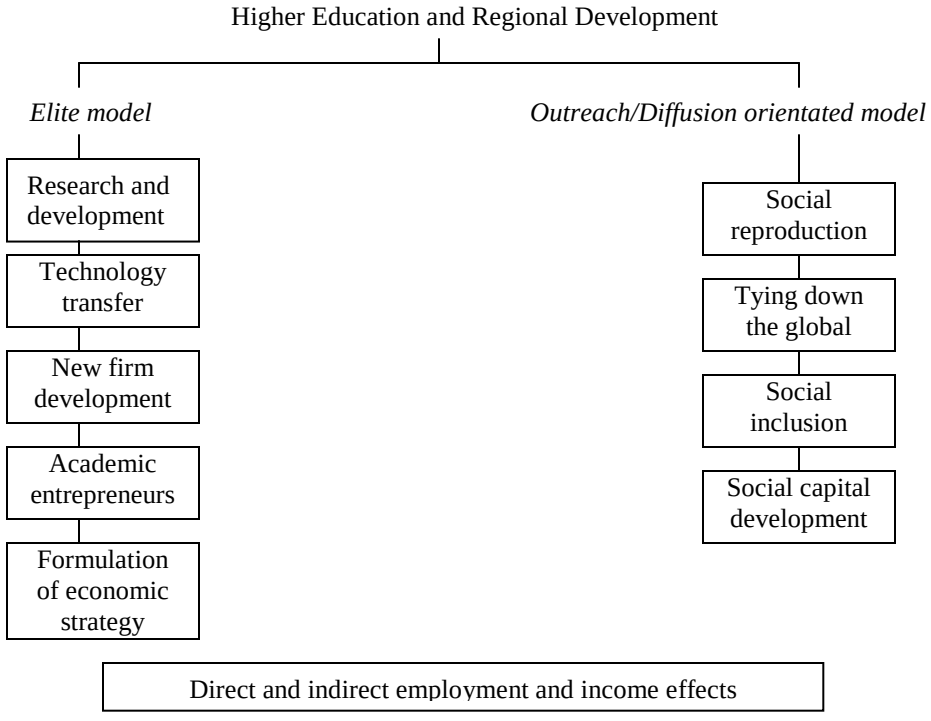
Porter's approach mixes university products – goods and services that are produced by a university according to the university mission – with university impacts, the results of university influence on surrounding environments. For example, universities influence surrounding real estate values without including this in their mission statement. Lester's study acknowledges that

> "working ties to the operating sectors of economy are not central to the internal design of the university as an institution, and as universities open themselves up to the marketplace for knowledge and ideas to a greater

degree than in the past, confusion over mission has been common" (Lester, 2005, p.9).

Morgan (2002) tries to close the gap between two concepts of university products by creating a conceptual model of the two-tier system of higher education institutions in the United Kingdom. Using Huggin's (1999) and Phelps' (1997) concept of the globalization of innovation and production in regional economies, he discusses two models of direct and indirect employment effects – the elite model and the outreach/diffusion oriented model (Figure 1).

Figure 1. Universities and Regional Development: Two Paradigms



Source: Morgan, B. (2002) "Higher Education and Regional Economic Department in Wales: An Opportunity for Demonstrating the Efficacy of Devolution in Economic Development" Regional Studies, Vol. 36.1, p.66.

Morgan emphasizes the increased role of universities in developing local social capital by acting as "catalysts for civic engagement and collective action and networking" and "widening access to cohorts from lower socio-economic backgrounds" improving local social inclusion (Morgan, 2002, pp. 66-67). Whether it was the impact of universities on the regional labor market or the impact of university R&D and technology transfer on the growth of employment or per capita income, a broader framework was needed to measure the impact of all products created in universities.

The discussion about the role of a university in the regional economy has been enriched by a model created by a group led by Louis Tornatzky and Paul Waugman (Tornatzky, Waugman, & Bauman, 1997; Tornatzky, Waugman, & Casson, 1995; Tornatzky, Waugman, & Gray, 1999, 2002). These researchers advocate the importance of research universities for regional economic development and examine whether the influence of a university on a local economy differs geographically. The authors conclude:

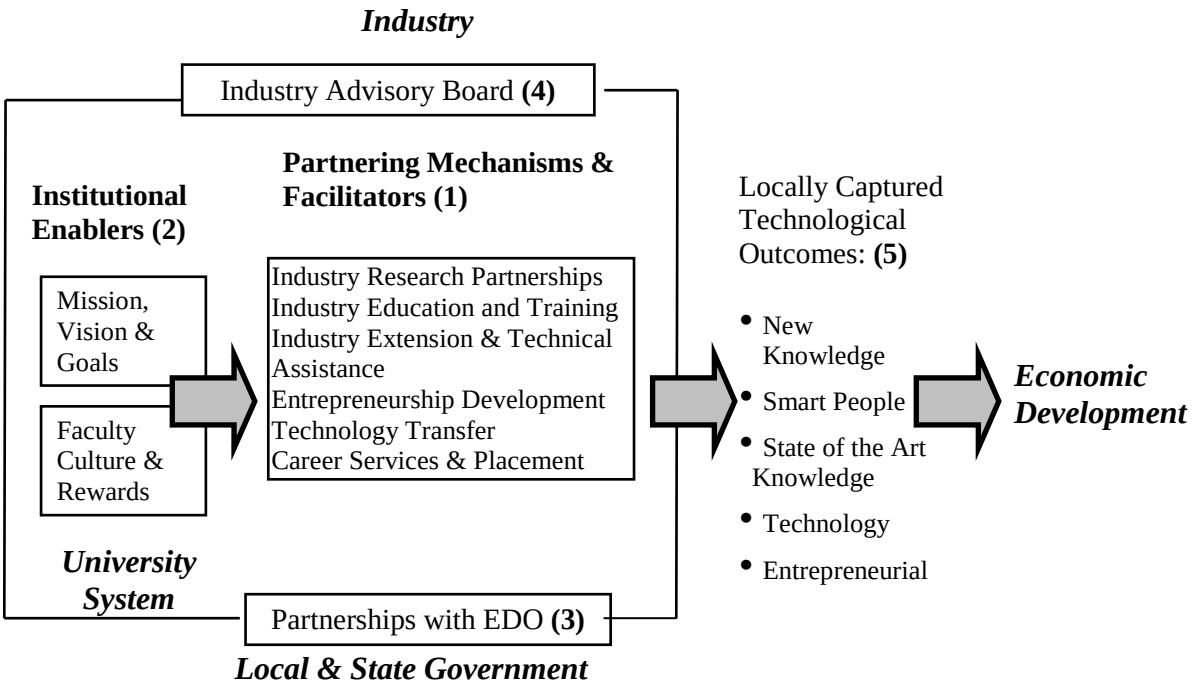
> "While we agree with skeptics who argue this [university's impact on a local economy] is not easily accomplished and that some universities and states appear to be looking for a quick fix, we believe that there is enough evidence to demonstrate that universities that are committed and thoughtful can impact their state or local economic environment in a number of ways" (Tornatzky, Waugman, & Gray, 2002, pp.15-16).

Tornatzky's hypothesis on the ways that universities can affect regional economies is presented in Figure 2. The research team identify 10 "dominants" of institutional behavior that enable the university's external interactions with industry and economic development interests and lie beneath organizational characteristics and functions that facilitate those interactions. Tornatzky, Waugman, and Gray group these

dominants, or interactions, characteristics, and functions into the three broad groups depicted in the Figure 2.

The first group, labeled (1) in Figure 2, represents partnering mechanisms and facilitators identified as "functions, people, or units that are involved in partnership activities that allegedly have an impact on economic development" (Tornatzky et al., 2002, p.16). The list of programs or activities in this component includes, but is not limited to industry research partnerships, industry education and training, and other activities listed in Figure 2.

Figure 2. New University Roles in a Knowledge Economy



Source: Tornatzky,L., P. Waugaman, D. Gray (2002). *Innovation U. New university roles in a knowledge economy.* Southern Growth Policies Board, Southern Technology Council, Raleigh, Research Triangle Park, NC, p.19, http://www.southern.org/pubs/pubs_pdfs/iu_report.pdf

The second group, labeled (2) in Figure 2, includes institutional enablers (university mission, vision, & goals and faculty culture & rewards) that enable partnering

through the "relevant behavior of faculty, students, and administrators [that] are supported by the values, norms, and reward systems of the institution" (Tornatzky et al., 2002, p.18). The third group is represented by two boundary-spanning structures and systems: formal partnerships with economic development organizations, labeled (3) in Figure 2 and industry-university advisory boards and councils, labeled (4) in Figure2. They are positioned to link the university system to the economic development intermediaries and business community. As a result of communication between all of the components, the framework captures locally generated technological outcomes, labeled (5) in Figure 2, such as new knowledge and technologies that trigger economic development.

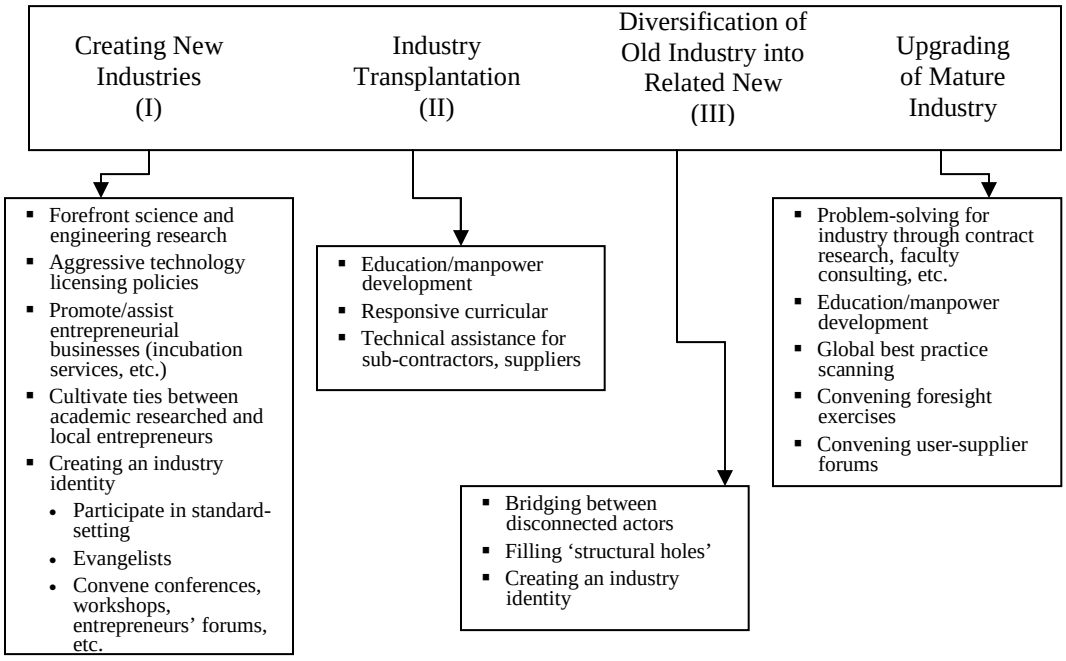
Tornatzky, Waugman and Grey acknowledge that while the local economic environment of universities is complex, only universities that are actively involved in extensive industry partnerships can successfully transfer their products into local economies. Such universities will

> "tend to adopt language in mission, vision, and goal statement that reflects that emphasis. They [universities] also tend to incorporate different versions of those statements in reports, publications, press releases, and speeches directed at the external world" (Tornatzky, Waugman, & Gray, 2002, p.19).

Bringing elements of globalization into understanding the role of universities in the local economy is widely emphasized in the MIT Industrial Performance Center's study led by Richard Lester. The report "Universities, Innovation, and the Competitiveness of Local Economies" discusses an important alignment of the university mission with the needs of the local economy, emphasizing that this alignment is affected by the globalization of knowledge and production and depends on "the ability of local

firms to take up new technologies and new knowledge more generally, and to apply this knowledge productively" (Lester, 2005). Through the different roles played by universities, Lester's study acknowledges diverse pathways of transferring knowledge from universities to local industries (Figure 3).

Figure 3. University Roles in Alternative Regional Innovation-led Growth Pathways



Source: Lester R. (2005). *Universities, innovation, and the competitiveness of local economies.* Industrial Performance Center, MIT, p.28, http://web.mit.edu/ipc/publications/pdf/05-010.pdf

Some of these pathways are common to economies with different core industries, and some are unique to the regions. For example, *education/manpower development* is as valuable for the economy as *industry transplantation* and *upgrading mature industry economy*. *Forefront science and engineering research* and *aggressive technology licensing policies* are unique and critical for *creating new industries economies*, and

bridging between disconnected actors is as distinctive for the economy as *diversifying old industry into related new*. These unique and common pathways for economies with different industrial structures imply the existence of university products that, in addition to teaching and research, include faculty consulting, publications, and collaborative research.

A large body of literature placing universities in the center of state and regional economic development strategies was developed in the public policy and political science fields. In the late 1980s and early 1990s Robert Atkinson analyzed the formation and effectiveness of state science and technology policy and continued this research later at the Progressive Policy Institute. Based on a deep analysis of six states,[4] in his earlier work Atkinson stressed:

> "Support of university scientific research, training in advanced skill occupations, and R&D support can all play a role in increasing the rate of technological innovation. Thus, it is reasonable to expect that when faced with economic distress and restructuring … states, and in particular, industrial states, will adopt science and technology policies" (Atkinson, 1989, pp.46-47).

Writing extensively on the history of American universities and state science and technology policies, [5] Roger Geiger points that, during the last two decades, the relationship between the federal government, academia, and industry has been redefined. Geiger and Sa (2005) examine state-level policies on fostering economic development by using university expertise to promote technological innovation. They conclude that the economic contribution made by universities lies not only in the production of economically relevant research, but also in the formation of human capital and a broader capacity to produce new knowledge. Describing differences in the states' science and

[4] Illinois, Indiana, Massachusetts, Michigan, New York, and Pennsylvania.
[5] Geiger (1986, 1993, 2004a, 2004b).

innovation policies, the authors emphasize that the outcomes of universities' research and commercialization activities, especially "creating and sustaining knowledge intensive industries… [are highly] relative to the quality of the university" (p.19).

Feller (2004) and Romer (2001) warn about focusing too much on just one side of higher education – promoting research capabilities of universities. They advocate for improving whole educational systems of states including schools and public universities. Feller advises, "States that are either unable or unwilling to provide that financial support necessary to maintain competitive higher education systems are likely to fall behind in longer-term efforts to develop nationally competitive knowledge-based production (Feller, 2004, p. 141). Romer (2001) points out that federal and state governments are too focused on increasing demand through developing and commercializing innovation and should consider the availability of supply of the scientists and engineers to respond to that demand.

Several national policy organizations strongly support the redefined roles of American universities in creating wealth and strengthening the competitiveness of regional, state, and national economies. The Council on Competitiveness fostered the initiative on Clusters of Innovation led by Michael Porter (Porter, 2005). In a series of publications,[6] the Council emphasizes the strong input of universities in creating innovative capacities, which results in increased competitiveness of regional economies and the prosperity of their citizens. Studying the regional innovation environments (Innovate America, 2004), the organization promotes the active role of academia in technology-based economic development and strong connections between universities

[6] Innovate America, 2005; Regional innovation national prosperity, 2005; Governor's guide to cluster-based strategies for growing state economies, 2007; Cooperate: A practitioner's guide for effective alignment of regional development and higher education, 2008.

and all elements of innovative ecologies. This organization is rejoined in their effort by the National Governors Association and the National Association of State Universities and Land-Grant Colleges.

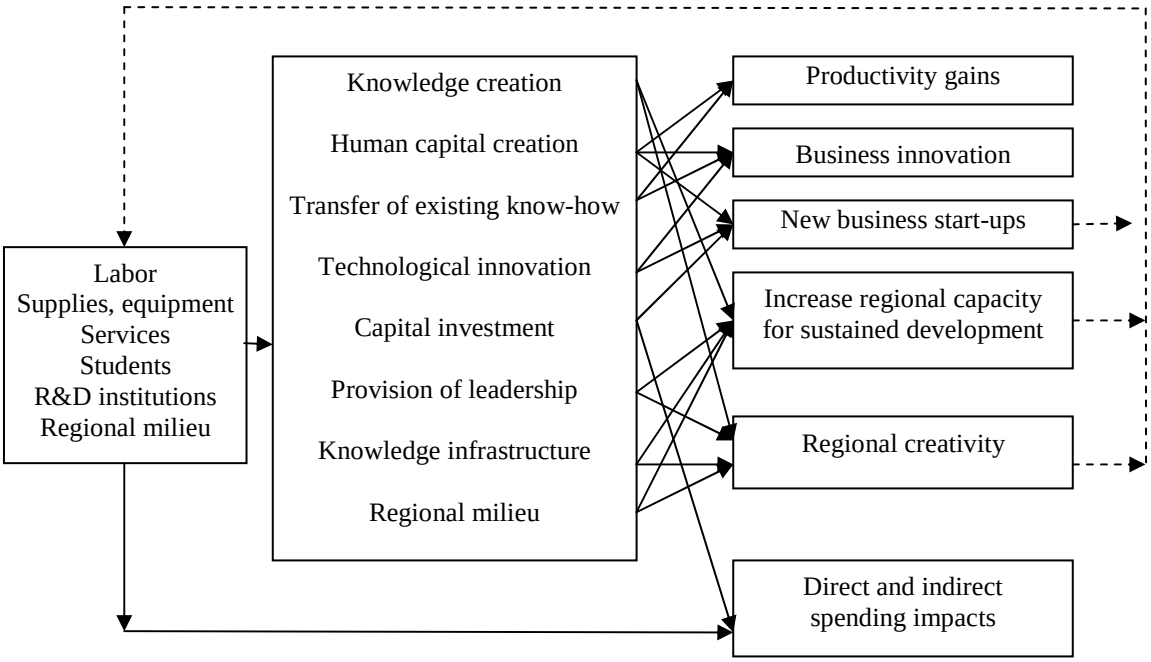
1.2.2 The Concept of University Products

Paytas and Gradeck (2004) examine the scope of universities' economic engagement in local economies in their case studies of eight universities. They assess the breadth of involvement of universities with their regions and local communities and conclude that for a university to play an important role in the development of industry clusters, it "must be aligned with regional interests and industry clusters across a broad spectrum, not just in terms of technical knowledge. The characteristics of the clusters are as important, if not more important than the characteristics of university" (p.34).

Goldstein, Maier, and Luger (1995) develop a set of university outputs that is also broader than the traditional understanding of university products, which includes only *skilled labor* and *new knowledge* (Figure 4). Their framework distinguishes between knowledge creation and co-production of knowledge infrastructure, human capital creation, and technological innovation and technology transfer.

This model adds a new and very important understanding of leadership value and regional milieu. This framework was operationalized by Goldstein and Renault (2004) and tested with the modified Griliches-Jaffe production function. Goldstein and Renault find statistically significant impact of multiple university products on regional economic development outcomes.

Figure 4. University Outputs and Expected Economic Impacts



Source: Goldstein H., Maier G., Luger M. (1995) *The university as an instrument for economic and business development: U.S. and European comparison,* In D. Dill & B. Sporn (Eds.) *Emerging Patterns of Social Demand and University Reform: Through a Glass Darkly. Issues in Higher Education.* Tarrytown, NY: Elsevier Science Inc.

According to Hill and Lendel (2007), higher education is a multi-product industry with seven distinct products: (1) education, (2) contract research, (3) cultural products, (4) trained labor, (5) technology diffusion, (6) new knowledge creation, and (7) new products and industries. These products become marketable commodities that are sold regionally and nationally or they became part of a region's economic development capital base. Growth in the scale, quality, and variety of these products increases the reputation and status of a university. An improved, or superior, reputation allows a university to receive more grants and endowments, attract better students, increase tuition, conduct more R&D, and develop and market more products. This reinforcing mechanism

between a university's reputation and university products transforms universities into complex multi-product organizations with a complicated management structure and multiple missions. A university manages its portfolio of products as defined in the university's mission statement and expressed through the university functions and policies.

Each university interacts with the regional economy as represented by local businesses, government agencies, and the region's social and business infrastructure. The actual interaction is based on its set of products and their value to the region. The university can create sources of regional competitive advantage and can significantly strengthen what Berglund and Clarke (2000) identified as the seven elements of a technology-based economy: (1) regional, university-based intellectual infrastructure – a base that generates new ideas, (2) spillovers of knowledge – commercialization of university-developed technology, (3) competitive physical infrastructure, including the highest quality and technologically advanced telecommunication services, (4) technically skilled workforce – an adequate number of highly skilled technical workers, (5) capital creating adequate information flows around sources of investments, (6) entrepreneurial culture – where people view starting a company as a routine rather than an unusual occurrence, and (7) the quality of life that comes from residential amenities that make a region competitive with others.

The impact of the university products on these factors of economic development is hypothesized as a framework for this dissertation and illustrated in Figure 5. The underlying assumptions are that each university product can be an asset used by a regional economy or can be sold outside the region, generating regional income. Each

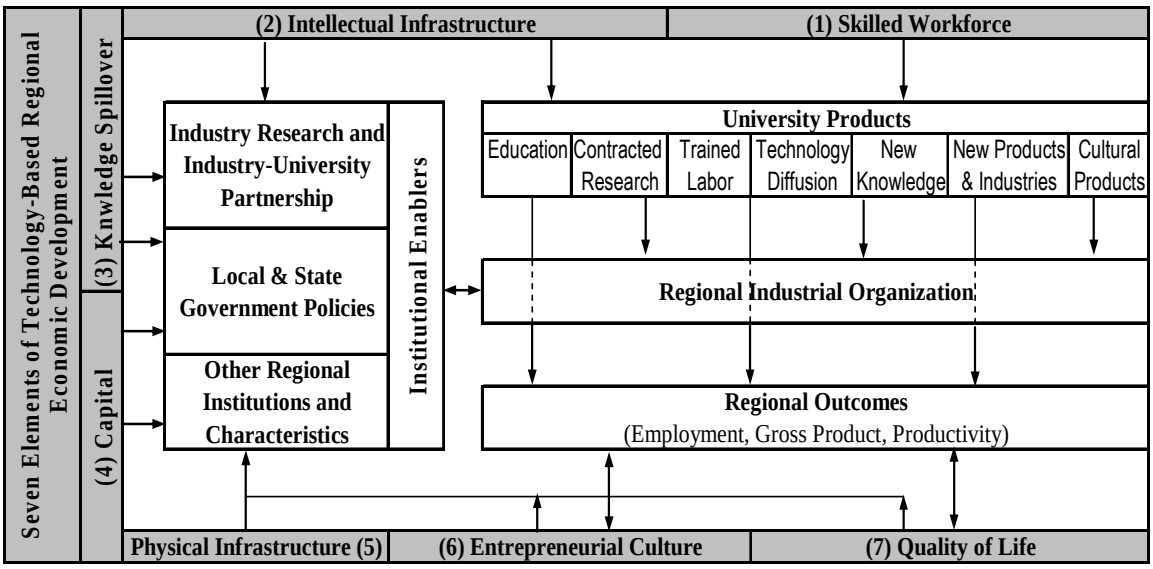
university makes a choice about what product will be a priority to produce and sell. These priorities are expressed through the university mission, budget resources assigned to development of each product, and leadership that creates policies to implement university goals.

It is frequently asserted that the greatest contribution to economic growth and the largest stream of benefits to the region can come from developing and commercializing new products. The completion of this task, however, requires immense and consistent expenditures over a significant period of time. The investments need to be made while acknowledging the risk that the results of the scientific research will be deployed outside the regional economy. Higher education can have an alternative impact on a region through the labor market, by creating a deep pool of highly skilled specialized labor that attracts new employers and revives the existing economic base. Whether a region invests primarily in developing and commercializing new products or strengthens the region's workforce and physical infrastructure is determined by complex interactions among regional players, including the research university.

Figure 5 shows how the constructs discussed in this section are inter-related in a comprehensive framework of regional economic development. To provide an understanding of the economic performance of a region, university research should be considered in conjunction with all university products as well as industry research and knowledge transfer mechanisms. The regional *intellectual infrastructure (2)* and *skilled workforce (1)* provide a sufficient level of special knowledge to become recipients of knowledge spillover and new technology diffusion. Overall, the *knowledge spillover*

culture (3) of the region becomes an environmental part of *university-industry partnerships* through research and development. Together with *local and state*

Figure 5. Interaction of University Products and the Elements of Technology-Based Economy



government policies promoting investment in innovative activities and supporting the flow of venture and angel *capital (4), other regional institutions and unique regional characteristics* (including but not limited to *physical infrastructure (5),* telecommunications, and *regional amenities [quality of life (7)]*) are the elements of *institutional enablers* that all together create a regional *entrepreneurial culture (6)* towards innovation. This culture is very difficult to assess. It can be operationalized through the acceptance of diversity and tolerance of failure – two concepts that are also difficult to measure.

The *institutional enablers* and *regional industrial organization* constitute the environment of regional demand for university products. Only if this demand exists and

is supported by *institutional enablers* and appropriate *industrial organization* (competitive business environment, anchor companies, entrepreneurship, industrial specialized clusters and diversified economy), can university products be deployed regionally. The final consumers of university products vary from regional companies and institutions (for *trained labor*, *contracted research*, *new products* and *new technologies*) to population (*cultural products*) and regions as a whole (*new industries* and *new knowledge*). Not all university products can be deployed regionally. Depending on the market niche of each university, some university products compete on the national and global markets. However, regions benefit from the presence of research universities because at least a part of university products will always be consumed locally.

Although the interactions of the university products and the factors of regional technology-based economic development are conceptually clear and plausible, the statistical assessment of the impact of each separat university product on regional development outcomes is almost impossible. Strong inter-relations of university products and the bundled nature of their effect on regional economies leads to over estimation of the outcome variables, such as change of employment or change of output. For example, participation of students in *contracted research* is part of their *education* and a part of *knowledge* created in the university. In a similar way, *education* affects several factors of the regional environment; at the very least it affects regional characteristics such as *skilled workforce* and *knowledge spillover*. The following section addresses the dilemma of the bundled nature of the impact of research universities on corresponding regional economies. It presents the variables that reflect the presence of research universities and

analyzes the results on the impact of a research university's presence on change of metropolitan employment.

1.3 Model of Research University Presence in Regional Economy

There are a number of challenges in measuring the individual impact of each university product on the regional economy. Several university products are inter-related and are bundled in their nature. It is difficult to separately assess the impact of these products on the regional economy. The products that closely correlate in their impact on regional economic outcomes are university research, new knowledge, and technology diffusion. Conceptually these three products could be on the same continuum (if developed across a common technology field) from creating knowledge to the transfer of knowledge to the regional economy. The products can be identified by their positions along that continuum and by the function of a university regarding the product (conducting research, obtaining intellectual property rights of an invention, or consulting a company on transferring new technology and creating a product prototype or improving a production process). However, all three could be stand alone products and can differentiate universities by specialization in different technologies and different functions.

A large portion of academic research in the United States is conducted by a small number of top research universities that have excellent reputations not only for their Ph.D. programs, but for all university products – creation of new knowledge, development of new products and industries, fast technology transfer, highly trained

graduates, contracted R&D, and even, at times, prominent sports teams. A majority of these universities (97 of the NSF's top 100, ranked by university R&D expenditures) are located in metropolitan areas with large economies. The positive effects of agglomeration economies of scale on the process of knowledge-transfer from universities to companies reinforce the impact of top research universities on regional economic outcomes. Large-scale economies with a high concentration of companies and industries create more demand for university products, have technological diversity, and provide better infrastructure for developing innovation. Universities, in turn, can respond with better university products because of more opportunities to cooperate with local companies, conduct joint research, consult, train students through internships, and communicate ideas among academics and practitioners.

According to the conceptual framework of this dissertation, the top research universities affect regional economies by offering their products, which include: (1) education, (2) contract research, (3) trained labor, (4) technology diffusion, (5) new knowledge, (6) new products and new industries, and (7) cultural products. Regional economies absorb the university products and improve the elements of a technology-based economy: (1) skilled workforce, (2) intellectual infrastructure, (3) knowledge spillovers, (4) capital, (5) physical infrastructure, (6) entrepreneurial culture, and (7) quality of life (Figure 5, p.18). The interactions between the universities' products and the elements of a technology-based economy occur within the economic environment described by a specific regional industrial organization reflecting the level of specialization and diversification of the regional economy, presence of large companies, local competition, and entrepreneurial culture. Improved elements of a technology-based

economy provide better input resources for companies which enable them to increase their productivity and, as a result, positively affect the aggregate regional economic indicators. While the university products are bundled in their impact on the factors of a technology-based economy, the mere presence of a research university in a metropolitan area should indicate that the region is taking an advanced path in economic development. Anecdotal evidence suggests this is the case for some regions with prominent research universities. However, the question of whether it is true for any metropolitan area that is a home to a research university or whether it is dependent on the scale of research activity or any other university products, remains unanswered.

The following section presents the research questions and hypothesis about the significance of the mere presence of research universities in metropolitan areas, explains a research model and specific variables, and concludes with a discussion about the impact of research university presence on regional economic outcomes.

1.3.1 Research Question and Hypotheses

A number of studies[7] ranked research universities and graduate programs using a variety of indicators and assumed that a higher research quality rank approximates greater university impact on the regional or state economy. A majority of studies that assess the impact of university products on regional economies acknowledge the bundled nature of university products and the difficulty in disentangling their effect and separately attributing it to each product (Goldstein & Drucker, 2006; Goldstein & Renault, 2004).

[7] Coupe (2003); Macri, J., & Sinha, D. (2006); Miller, Tien, & Peebler (1996); Webster (2001).

Despite this realization, each product is frequently entered separately in impact models and then the effect of each product is summed to assess the total impact. These types of assessments result in the overestimation of the overall impact of universities on regional economies (Hoffman, 2007).

Prominent universities that belong to top 20 or top 50 as ranked by Carnegie Foundation for the Advancement of Teaching or *U.S. News & World Report* classification of research institutions are often selected by scholars for their studies. Leef and Sanders (2000) used in their study the number of prestigious universities counted based on the *U.S. News & World Report's* four-tier ranking. The authors questioned whether spending on higher education really correlated to economic growth. They compared states to the national average using measures of economic growth and the state per capita spending on higher education. Leef and Sanders also counted the number of "top-tier" and "national universities" within cohorts of "High-Growth" and "Slow-Growth" states and concluded that the presence of "prestigious" universities is not a necessary condition for fast economic growth, nor it is a sufficient condition to prevent states from poor economic performance.

Beeson and Montgomery (1993) used the number of top-rated science and engineering programs in *An Assessment of Research-Doctorate Programs in the United States*.[8] Surprisingly, the authors found that among 218 Standard Metropolitan Statistical Areas (SMSAs), incomes increase with university R&D funding and decrease with the number of science and engineering programs rated in the top 20 in the country. Although

[8] Unfortunately, authors did not specify a citation for this publication, but most likely they refer to the study of the Conference Board of Associated Research Councils (CBARS) sponsored by the American Council of Learned Societies, the American Council of Education, the National Research Council, and the Social Science Research Council (CBARC, 1982).

the model indicated statistically significant relationships between the incomes and university characteristics variables, after tests on the standard error estimates, the authors noted that the OLS estimates may overstate the significance of these relationships, especially because none of the university characteristics were statistically significant when included in the equations individually (Beeson & Montgomery, 1993, pp.755-756). There could be another reason for the insignificance of the individually included university variables. The real effect of the university products is difficult to assess when they are including only one is used in a statistical model. The common input or output measure of multiple products might be necessary to statistically estimate the impact of universities on regional economies. There are anecdotes and case studies describing the effect of prominent research universities on their regional economies. However, there is no statistical assessment showing the effect of the presence of research universities on the regional economic outcomes across a large sample or the universe of metropolitan statistical areas.

Research Question

The main research question addressed in the following section asks whether the presence of a top research university (or universities) has a meaningful economic impact on a metropolitan region. Due to the bundled nature of the university products and their cumulative effect on the regional economy, the mere presence of a research university should cause a departure of the regional economic outcomes from the national trend and should show regional performance above cyclical economic changes. A complementary

question asks whether the presence of any research university has an impact on the regional economy. Does any research university that accounts for products associated with R&D spending (new knowledge, contracted research, and technology diffusion) have an impact on regional economic outcomes, or is a specific scale of university products (reflected, for example, in the level of R&D spending) needed to make the regional economy vary from its long-term development trend? What is the level of university R&D expenditures needed to create a positive effect on regional economic outcomes?

The answers to these questions should be of interest to government officials who create public policies tying university research to technology-based economic development and promoting state and federal spending on university research. These answers should also be of interest to the general public who pay taxes and expect economic returns from this expenditure.

Hypotheses

The set of hypotheses in this chapter discusses the impact of the presence of a research university (or research universities) on change in metropolitan employment.

- (Ho) The presence of a research university (or research universities) within a region has no positive effect on change of total employment.
- (H1) The presence of a research university (or research universities) within a region has a positive effect on change of total employment.

It is expected that not only the mere presence of research universities, but also a certain scale of R&D expenditures that approximates a minimal level of university products related to R&D, creates a meaningful economic impact on regional employment.

1.3.2 Research Model and Policy Variables

The main policy variable, the presence of a research university (or research universities) in a metropolitan area, is operationalized in the research model by two types of variables: dummy variables and categorical variables. The dummy variables *Research University Presence* (RUP) reflect the presence of at least one research university in a metropolitan area. There are several pairs of dummy variables that were tested in the research model:

- RUP: this variable equals 1 if at least one research university from the sample of 742 research universities participating in the National Science Foundation survey of research universities between 1987 and 1997 was in a metropolitan area; otherwise, this variable equals 0.
- RUP150: this variable equals 1 if at least one research university from the sample of the top 150 research universities ranked by the average of their total R&D expenditures during the period of time from 1987 to 1997 was in a metropolitan area; otherwise, this variable equals 0.
- RUP100: this variable equals 1 if at least one research university from the sample of the top 100 research universities ranked by the average of their total R&D expenditures during the period of time from 1987 to 1997 was in a metropolitan area; otherwise, this variable equals 0.

- RUP50: this variable equals 1 if at least one research university from the sample of the top 50 research universities ranked by the average of their total R&D expenditures during the period of time from 1987 to 1997 was in a metropolitan area; otherwise, this variable equals 0.

The policy variable constructed to answer the research question about the scale of R&D expenditures that can approximate a cumulative impact of the university products on the regional economy is operationalized by categorical variables. The second group includes policy variables constructed from a subset of the top 150 research universities identified by their average annual R&D expenditures from 1987 to 1997. The R&D expenditures of the 150 research universities were summed across metropolitan areas where these universities are situated. Then the continuum of the 361 metropolitan areas ranked by the total R&D expenditures of the 150 research universities was divided into six groups (variables ONE through SIX) established by the natural breaks of data. Metropolitan statistical areas within each group had a certain level of total university R&D expenditures because of either one or several research universities across the MSA. For example, metropolitan areas in group FIVE had average annual university R&D expenditures of more than $502.5 million across all universities located in each of these MSAs. Metropolitan areas in group FOUR had a level of average annual university R&D expenditures between $250.4 and $209.1 million from 1987 to 1997. Metropolitan areas that had at least one research university from the subset of the selected top 150 universities or had annual average university R&D expenditures below $87.5 million

belong to group FIVE. According to this division, the following variables were tested in the research model:

- FIVE: MSAs with more than $502.5 million in average annual R&D spending from 1987 to 1997;
- FOUR: MSAs with between $250.4 and $209.1 million;
- THREE: MSAs with between $187.2 and $156.3 million
- TWO: MSAs with between $119.2 and $87.5 million
- ONE: MSAs with less than $87.5 million.

The research model to test the impact of university presence on regional employment change included university and industry R&D expenditures and the path-dependency variables describing the previous performance of a region (1):

$$\underbrace{RO_j}_{\text{Regional employment}} = \alpha_0 + \underbrace{\alpha_1 RUP_j}_{\text{Policy variable}} + \underbrace{\alpha_2 PR_j + \alpha_3 H_j}_{\text{Path dependency}} + e_{ij} \qquad (1)$$

where:

- RO_j is a percentage change in employment in region j.
- RUP_j is a dummy variable of research university presence in region j.
- PR_j is the size of industrial R&D in region j.
- H_j is path dependency represented by variables that reflect the previous performance of region j.

The presence of research universities is also assessed by the model constructed over the different phases of the latest business cycle. The dependent variables in this model are

the percentage change of employment over the expansion phase of the business cycle (from 1998 to 2001), the contraction phase of the business cycle (from 2002 to 2004), and over the entire time period (from 1998 to 2004) (2):

$$\underbrace{RO_j}_{\text{Regional employment}} = \alpha_0 + \underbrace{\alpha_1 RUP_j}_{\text{Policy variable}} + \underbrace{\alpha_2 PR_j + \alpha_3 E_j + \alpha_4 RCM_j + \alpha_5 RS_j + \alpha_6 RD_j + \alpha_7 RL_j}_{\text{Regional Industrial Organization}} + \underbrace{\alpha_8 H_j}_{\text{Path dependency}} + e_{ij} \quad (2)$$

where:

- RO_j is a percentage change in employment in region j over business cycle segment.
- RUP_j is a dummy variable of the research university presence in a region j from the subset of the top 100, 87, and top 50 research universities.
- PR_j is the size of industrial R&D in region j.
- E_j is a variable characterizing level of entrepreneurship in region j.
- RCM_j is the level of competition in region j.
- RS_j is the specialization of the regional industries.
- RD_j is the diversification of the regional industries.
- RL_j reflects the presence of establishments with more than 1,000 employees (approximates a presence of large companies) in region j.
- H_j is path dependency represented by variables that reflect the previous performance of region j.

The source of data for calculating the policy variables is the National Science Foundation (NSF) Survey of Research and Development Expenditures at Universities and Colleges, which is conducted annually by the NSF Division of Science Resources Statistics (SRS). The averages of the annual R&D expenditures were calculated across the 14 selected scientific and technology fields most often affiliated with technology-based economic development. These fields are:

1. Aeronautical and Astronautical Science
2. Bioengineering/Biomedical Engineering
3. Chemical Engineering
4. Electrical Engineering
5. Mechanical Engineering
6. Metallurgical and Materials Engineering
7. Materials Engineering
8. Chemistry
9. Physics
10. Other Physical Sciences
11. Computer Sciences
12. Biological Sciences
13. Medical Sciences
14. Other Life Sciences.

The universe of the NSF survey of R&D expenditures at universities and colleges[9] in 14 science and technology-related fields includes about 550 universities annually. Although the list of universities responding to this survey changes every year, the population of universities that responded to this survey at least once between 1987 and 1997[10] is greater than any number of universities that responded to this survey for any given year. Removing from the population those universities that had annual R&D expenditures below $100,000[11] in any year between 1987 and 1997 brought the count of research universities included in the database for the calculation of university R&D expenditures to 742.

More methodology details on operationalization and calculating the variables are presented in Appendix B. The hypotheses are tested by running cross-sectional multiple regression models on a universe of 361 metropolitan statistical areas using the December 2003 boundary definition.[12]

1.3.3 The Impact of University Presence over the Business Cycle

The research university presence variables show a statistically significant effect on the percentage change in total regional employment during the expansion phases of the business cycle, from 1998 to 2001 (Table I). The first equation tested the presence of at least one research university in a metropolitan statistical area from the universe of 742

[9] Collected from the Integrated Science and Engineering Resource Data System maintained by the National Science Foundation (NSF) at the Library of Congress WebCASPAR, http://webcaspar.nsf.gov
[10] The methodology of collecting university R&D data by NSF's university survey changed in 1998, which makes it impossible to compare 1998 data to previous years.
[11] Measured in nominal dollars of the assessment year.
[12] OMB Bulletin No. 03-04. Statistical and Science Policy Branch, Office of Information and Regulatory Affairs, Office of Management and Budget.

Table I. Influence of Research Universities Presence on Regional Employment, 1998-2001

Variable	Variable name		1998-2001 Employment percentage change							
			RUP	**RUP150**	**ONEFIVE**	**FIVE**	**FOUR**	**THREE**	**TWO**	**ONE**
Constant		Coefficient		-0.606	3.338	-0.328	-0.382	-0.472	-.0366	-0.476
POLICY VARIABLES										
Presence of research universities	RUP	Coefficient	0.556							
		t-statistic	1.987**							
Presence of 150 research universities	RUP150	Coefficient		0.767						
		t-statistic		2.193**						
University presence by R&D expenditures	ONEFIVE	Coefficient			0.647					
		t-statistic			3.943***					
University presence by R&D expenditures: group five	FIVE	Coefficient				2.805				
		t-statistic				2.172**				
University presence by R&D expenditures: group four	FOUR	Coefficient					2.884			
		t-statistic					3.182***			
University presence by R&D expenditures: group three	THREE	Coefficient						2.491		
		t-statistic						3.747***		
University presence by R&D expenditures: group two	TWO	Coefficient							1.547	
		t-statistic							2.694***	
University presence by R&D expenditures: group one	ONE	Coefficient								1.91
		t-statistic								0.234
Industry R&D spending, percentage change 1987-1997	IRD8797	Coefficient	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
		t-statistic	3.778***	3.614***	3.780***	3.436***	3.518***	3.671***	3.561***	3.637***
PATH-DEPENDENCY VARIABLES										
Employment growth rate 1982-86	E8286	Coefficient	0.122	0.147	0.141	0.150	0.151	0.145	0.147	0.147
		t-statistic	7.115***	7.419***	7.191***	7.573***	7.690***	7.398***	7.416***	7.427***
Employment growth rate 1987-91	E8791	Coefficient	0.055	0.132	0.139	0.143	0.138	0.137	0.138	0.137
		t-statistic	4.266***	5.231***	50575***	5.611***	5.505***	5.495***	5.470***	5.411***
Employment growth rate 1992-97	E9297	Coefficient	0.124	0.092	0.98	0.095	0.097	0.099	0.095	0.10
		t-statistic	3.027***	3.386***	3.677***	3.510***	3.599***	3.697***	3.510***	3.717***
Employment growth rate 1998-01	E9801	Coefficient								
		t-statistic								
		R Square	0.311	0.366	0.384	0.366	0.375	0.382	0.370	0.384
		Adjusted R square	0.299	0.357	0.376	0.357	0.366	0.373	0.361	0.370

* significant at the .10 confidence level ** significant at the .05 confidence level *** significant at the .01 confidence level

Number of observations metro group = 361

research universities that have more than $100,000 of R&D spending in at least one of 14 science and technology-related fields most often associated with technology-based economic development in any year between 1987 and 1997. The dummy variable of university presence is statistically significant above the 95% critical value and positively associated with the percentage change of total employment across the universe of the metropolitan areas in the United States.

The percentage change of industry R&D spending over the same period of time, from 1987 to 1997 is strong and statistically significant above the 99% critical value. It is also positively associated with the growth of total regional employment over the expansion phase of the business cycle. The positive relationships of the R&D spending variables with the dependent variable suggest that the presence of research universities in regional economies creates a positive impact on the growth of regional employment. Accounting for industry R&D expenditures suggests that university R&D activity and its related university products have a role in developing innovation and deploying its results within the regional economy independent from private industry.

The path dependencies in employment growth (lagged dependent variables constructed over the previous phases of the business cycle) are statistically significant and positive during the expansion phase of the business cycle (the critical value of the lagged values of employment growth rate exceeds 99%). The statistical significance of the path-dependency variables representing historical performance of the regional economy assures that the performance of the regional economy over the expansion phase of the business cycle, from 1998 to 2001, is due to the policy R&D expenditures variables. It confirms that the effect of university presence on employment growth is a

departure from the long-term regional trend of growth and verifies that the departure from the regional trend is not simply due to cyclical economic fluctuations.

Similar results are shown from the model that includes the presence of the top 150 research universities as a policy variable. The university presence and the industry R&D spending variables are statistically significant at the 95% and 99% critical value, respectively, and they are positively associated with employment growth across the universe of the metropolitan statistical areas. These two models do not allow to disprove the null hypothesis that assumes no impact of research university presence on metropolitan employment growth during the expansion phase of the business cycle. On the contrary, the model results suggest the positive association between the university products operationalized by research university presence and regional economic growth.

Columns two to six in Table I (named ONEFIVE, FIVE, FOUR, THREE, TWO, and ONE) show the results of testing university presence described by the categorical variables indicating the place of metropolitan areas within the groups categorized by a university R&D expenditures scale. The columns FIVE to TWO include a corresponding categorical variable as a dummy variable on the universe of metropolitan statistical variables. For example, the model FIVE tests the policy variable of research university presence that is equal to 1 if a metropolitan area has more than $502.5 million in average annual R&D spending from 1987 to 1997 and is equal to zero for all other metropolitan areas. Similarly, each model, from the model in column FOUR to the model in column ONE use the dummy policy variables of the research university presence that equal 1 if a metropolitan area belongs to corresponding interval in average annual R&D spending from 1987 to 1997 (see the description of the policy variables on pp. 26-27) and is equal

to zero for all other metropolitan areas. The model presented in a column ONEFIVE includes university presence as a categorical variable with five categories describing five intervals of university R&D expenditures scale.

Four models with the dummy policy variables (columns FIVE through TWO) and the model with the categorical policy variable (column ONEFIVE) show positive and statistically significant relationships between the university presence variables and employment change during the expansion phase of the business cycle. All policy variables are statistically significant at the 95% and 99% critical value. The model ONEFIVE shows that it is impossible to disprove the null hypothesis stating that there is no impact of research university presence on regional employment. It strengthens the argument that, on the universe of the U.S. statistical metropolitan areas, research university presence makes an impact on regional employment growth during the expansion phase of the business cycle.

The models FIVE through TWO show strong and statistically significant impact of university products associated with the cumulative annual average university R&D spending above $87.5 million (for the metropolitan areas that belong to groups FIVE, FOUR, THREE, and TWO). Below that level of R&D expenditures, the university products did not generate a meaningful economic impact on regional employment.

Industry R&D spending was positive and statistically significant through all of the models at the 99% critical value. All path dependencies in employment growth were statistically significant and positive during the expansion phase of the business cycle as well. The statistical significance of the path-dependency variables confirms that the departure from the regional trend is due to the university and industry R&D spending and

not simply due to cyclical economic fluctuations. All statistical models presented in Table I explained from 30% to 37% of variation in dependent variables.

The results of university presence operationalized with policy variables RUP, RUP150, and ONEFIVE (Table II) demonstrate the mixed results of the statistical significance of the policy variables on employment change over the contraction phase of the business cycle (from 2002 to 2004) and for the entire time period (from 1998 to 2004). The results of the model with the presence of at least one of the top 150 research universities in a metro area (column RUP150) and the university presence as the categorical variable (column ONEFIVE) indicate that the top research universities and universities in metropolitan areas with significant R&D expenditures had statistically significant and positive impact on regional employment even during the recession. Having merely any research university in a region (operationalized by the research university presence variable) did not create an economically meaningful impact on regional economy from 2002 to 2004 as this variable was not statistically significant even at the 90% critical value.

Neither of the policy variables was statistically significant over the entire time period. Similar to the results of other models in this dissertation, the lack of statistical significance illustrates that research universities have a different type of the impact on regional economies over the different phases of the business cycle. The impact of research universities on regional economic outcomes is very strong in the expansion phase of the business cycle. During the contraction phase of the business cycle, only prominent research universities had strong and statistically significant impact on regional economies; there are no statistically significant relationships between the presence of

Table II. Influence of Research University Presence on Regional Employment, 2002-2004 and 1998-2004

Variable	Dependent variable: percentage change of employment		2002-2004			1998-2004		
			RUP	RUP150	ONEFIVE	RUP	RUP150	ONEFIVE
Constant		Coefficient	-0.997	0.548	4.109	-1.443	-2.061	-2.839
POLICY VARIABLES								
Presence of research universities	RUP	Coefficient	-0.243			-0.339		
		t-statistic	1.045			-1.43		
Presence of 150 research universities	RUP150	Coefficient		0.941			-0.502	
		t-statistic		3.022***			-0.755	
University presence by R&D expenditures	ONEFIVE	Coefficient			0.564			0.095
		t-statistic			3.923***			0.312
Industry R&D spending, percentage change 1987-1997	IRD8797	Coefficient	0.001	0.001	0.001	0.003	0.004	0.004
		t-statistic	0.588	0.807	0.911	3.299***	2.258**	2.318**
PATH-DEPENDENCY VARIABLES								
Employment growth rate 1982-86	E8286	Coefficient	-2.059	-0.059	-0.06	0.271	0.27	0.269
		t-statistic	-4.997***	-2.024**	-3.344**	7.338***	7.405***	7.342***
Employment growth rate 1987-91	E8791	Coefficient	-0.475	-0.045	-0.036	0.28	0.285	0.282
		t-statistic	-3.746***	-3.502***	-1.607	5.759***	6.150***	6.099***
Employment growth rate 1992-97	E9297	Coefficient	-0.061	-0.082	-0.074	0.19	0.195	0.193
		t-statistic	-3.998***	-4.188***	-3.174***	3.666***	3.926***	3.887***
Employment growth rate 1998-01	E9801	Coefficient	-0.447	-0.189	-0.21			
		t-statistic	-5.338***	-4.188***	-4.618***			
		R Square	0.326	0.266	0.278	0.372	0.373	0.372
		Adjusted R square	0.312	0.253	0.266	0.364	0.364	0.363

* significant at the .10 confidence level ** significant at the .05 confidence level *** significant at the .01 confidence level

Number of observations metro group = 361

research universities that do not belong to the cohort of the top 100 research universities identified by the amount of R&D expenditures and economic outcomes. It is possible that the effects of research universities on regional economies over the expansion and contraction phases of the business cycle cancel out each other when assessed over the longer period of time that captures both phases.

The pattern of signs and statistical significance of industry R&D spending over the different phases of the business cycle and the entire time period is also consistent with other models in this dissertation and suggests that private R&D spending is more sensitive to economic downturns than university R&D spending. The industry R&D spending variable was not statistically significant in either of the models describing the contraction phase of the business cycle. This variable was very strong and positively associated with employment change over the entire time period.

The employment growth rates were statistically significant both in the models capturing the contraction phase of the business cycle and over the entire time period. The negative regression coefficient of the path-dependency variables in the contraction phase suggest that regions with declining employment in the periods of time prior to economic downturns declined even more during the 2002-2004 time period.

Testing research university presence in the model that includes characteristics of regional industrial organization provides an additional argument for the positive impact of university presence on metropolitan employment (Table III). The policy variables tested within this research framework attempted to determine the threshold of the number of prominent research universities that have an economically meaningful impact on regional employment. The results of the models suggest that even smaller groups of the

Table III. Impact of Top Research Universities on Regional Employment over the Business Cycle

Variable	Variable name		Dependent variable: percentage change of employment:								
			1998-2001			2002-2004			1998-2004		
POLICY VARIABLES		Coefficient	-0.639	-0.625	-0.771	-0.475	-0.471	-0.436	-1.217	-1.315	-1.424
Top 100 research universities	RUP100	Coefficient	1.215			1.301			-0.432		
		t-statistic	1.931*			2.171**			-0.340		
87 research universities	TOP87	Coefficient		1.114			2.563			-1.526	
(R&D groups ONE through FOUR)		t-statistic		1.891*			3.567***			-0.459	
Top 50 research universities	RUP50	Coefficient			1.161			2.211			-1.766
		t-statistic			1.240			2.880**			-1.090
Industry R&D spending, percentage	IRD8797	Coefficient	0.003	0.003	0.003	0.0004	0.0004	0.0004	0.003	0.003	0.003
change 1987-1997		t-statistic	2.170**	2.060**	1.98*	0.13	0.135	-0.050	1.350	1.356	1.400
REGIONAL INDUSTRIAL ORGANIZATION VARIABLES											
Ratio of regional bus est to U.S. bus est,	COMP8897	Coefficient	0.119	0.126	0.121	-0.081	-0.081	-0.081	0.228	0.236	0.230
percentage change 1988-1997		t-statistic	3.748***	3.828***	3.570***	-3.001**	-3.091**	-3.030***	4.130***	4.139***	4.175***
Number of large establishments, 1988	LRG88	Coefficient	-0.254	-0.254	-0.252	0.248	0.277	0.255	-0.806	-0.826	-0.813
		t-statistic	-3.245***	-3.235***	-3.180***	3.470***	3.970***	3.880***	-5.920***	-4.960***	-5.961***
Single-establishment start-ups normalized by	ENT90	Coefficient	0.004	0.004	0.004	-0.001	-0.001	-0.001	0.008	0.008	0.008
population, 1990		t-statistic	3.321***	3.521***	3.410***	-0.580	-0.580	-0.630	3.490***	3.490***	3.590***
Industrial specialization, 1987	SP87	Coefficient	-0.026	-0.026	-0.021	0.026	0.026	0.022	-0.039	-0.042	-0.028
		t-statistic	-0.970	-0.965	-0.780	1.164	1.164	1.023	-0.820	-0.620	-0.593
Industrial diversification, 1987	DV87	Coefficient	0.031	0.031	0.030	0.025	0.025	0.022	0.009	0.006	0.012
		t-statistic	0.531	0.531	0.520	0.523	0.523	0.473	0.090	0.090	0.120
PATH-DEPENDENCY VARIABLES											
Employment growth rate 1982-86	E8286	Coefficient	0.089	0.096	0.091	-0.058	-0.061	-0.055	0.192	0.216	0.191
		t-statistic	3.581***	5.581***	3.681***	-2.761**	-2.881**	-2.631**	4.481***	4.651***	4.461***
Employment growth rate 1987-91	E8791	Coefficient	0.140	0.149	0.139	-0.010	-0.010	-0.009	0.214	0.264	0.212
		t-statistic	4.751***	4.791***	4.711***	-0.410	-0.410	-0.380	4.222***	4.252***	4.172***
Employment growth rate 1992-97	E9297	Coefficient	0.118	0.138	0.123	-0.144	-0.144	-0.141	0.309	0.415	0.310
		t-statistic	3.507***	3.827***	3.641***	-5.071***	-5.061***	-5.000***	5.310***	5.622***	5.350***
Employment growth rate 1998-01	E9801	Coefficient				-0.155	-0.155	-0.155			
		t-statistic				-3.045***	-3.055***	-3.060***			
		R Square	0.381	0.394	0.378	0.361	0.372	0.369	0.460	0.465	0.462
		Adjusted R square	0.357	0.357	0.356	0.333	0.333	0.324	0.439	0.441	0.443

* significant at the .10 confidence level ** significant at the .05 confidence level *** significant at the .01 confidence level

Number of observations metro group = 361

prominent research universities (top 100 research universities identified by the average annual R&D expenditures during 1987-1997, RUP100) and 87 research universities whose cumulative R&D expenditures placed their metropolitan areas within the categorical groups FIVE to TWO (Top87) have a statistically significant (at the 90% critical value) and positive impact on regional employment during the expansion phase of the business cycle. This impact of the prominent research universities is even stronger during the contraction phase of the business cycle (2002-2004), but it is cancelled out in the models describing the entire time period (1998-2004).

The impact of the top 50 research universities (identified by the average annual R&D expenditures during 1987-1997, RUP50) show no statistically meaningful impact in the expansion phase of the business cycle, but show statistically significant results over the contraction phase of the business cycle (at the 95% critical value). This pattern of statistical significance suggests that the most prominent research universities (top 50) help their regional economies perform better during periods of economic decline because the high salaries of professors and research staff, continued R&D spending, and stable flow of students allows them to be a stable business regardless of economic fluctuations.

The variables characterizing regional industrial organization (described in detail in Appendix B) show mixed results in their statistical significance and the signs of their regression coefficients. The *percentage change in the ratio of regional business establishments to U.S. business establishments* (approximating regional business competition) is statistically strong in both phases of the business cycle and over the entire time period. Showing positive regression coefficients in the expansion phase of the business cycle and over the entire time period and negative regression coefficients during

the contraction phase of the business cycle, suggests that local business competition might help the regional economy to prosper during times of economic growth, but during economic downturns employment declines are more severe in regional economies with stronger competition.

The *number of large establishments* (approximating the presence of large companies in a region) is statistically significant in all models at the 99% critical value. The signs of the regression coefficients of this variable are positive for all models that were run for the contraction phase of the business cycle and negative in all models describing the dynamic of regional employment in the expansion phase of the business cycle and the entire time period. This pattern of signs suggests that the presence of large companies operationalized as the *number of large establishments* captures large labor-intensive units of production in metropolitan areas and estimates a negative impact of the presence of such labor-intensive companies on regional outcomes. These companies are perhaps less related to innovation created in universities and are more associated with large businesses that are loosing employment and going through restructuring. Examples of those business establishments could be large auto manufacturing assembly plants. In this case, the presence of large labor-intensive production units create a negative effect on regional economies, especially during the times of economic restructuring.

The *single-establishment start-ups normalized by population* (approximating entrepreneurial culture in a region) is another independent variable that is positive and statistically significant during the expansion phase of the business cycle and over the entire time period. Regional economies that generate a relatively greater number of new businesses are healthier and their population is more entrepreneurial in comparison to

regional economies with less entrepreneurial population and fewer new business establishments. Both qualities might support commercializing university innovation and, therefore, in addition to their own positive impact on regional employment, might strengthen the impact of research university presence during economic growth periods. This variable has no statistical association with the dependent variable during the contraction phase of the business cycle. Specialization and diversification of regional industrial organization had no statistically meaningful relationships with employment change in any of the statistical models.

The statistical significance of the path-dependency variables proves the true effect of the policy variable – research university presence produces employment changes over different phases of the business cycle and over the entire time period. The results of the model that capture the regional industrial organization variables suggest that the null hypothesis cannot be disproved. This suggests that the presence of research universities in a metropolitan area creates a positive impact on regional employment.

The tested statistical models cannot estimate very specific quantitative results due to the categorical nature of the policy variables. They rather suggest that these models can be tested with better specified policy variables representing one or several university products. Later chapters of the dissertation operationalize the university product concept through the reputation of research universities and cumulative R&D expenditures.

1.4 Conclusions

The new growth theory and the concepts of increasing returns to scale, knowledge spillovers and knowledge externalities form a basis for creating a framework for technology-based regional economic development. They enable an understanding of the factors that influence regional knowledge creation and implementation of innovation into regional economic systems.

The studies of knowledge spillovers and agglomeration effects apply a variety of approaches and methodologies to study the impact of knowledge. Even as they lead to a better understanding of the impact of universities, the results are often fragmented into specific industries and geographies, primarily because of constraints on data availability. However, even with this fragmentation, the empirical results prove the significance of the influence of university-based research on directions of industry R&D. This impact was tested using intermediate results of innovation, including patents, start-up companies, and growing employment and wages. The positive role of the university in regional economic performance is evident.

However, the effect of university products on regional economic outcomes is hard to assess. New knowledge lead to inventions and the inventions can be commercialized and assessed by patents counts, a number of licenses, and a number of spin off companies. Other university products include graduates; new products and technologies; and new economic, social, and cultural regional environments. Deployed within regional economies, these products create local competitive advantage and help regional companies increase productivity.

The mechanism that explains how universities affect regional economies can be conceptualized through the set of university products. These products are outputs purposefully created by university and strategically identified within the university mission. The conceptual framework of this dissertation identifies seven university products that interact with the elements necessary for creating technology-based economy: education, research, trained labor, technology diffusion, new knowledge, new products and industries, and cultural products. Because of the bundled nature of university products, the impact of universities on regional economies was tested by assessing the impact of research university presence variables on regional employment during the expansion phase of the business cycle (1998-2001). Using the results of these models and the results of the models that assessed the impact of university presence over the different phases of the business cycle and over the entire time period (1998-2004), the null hypothesis could not be disproved.

The pattern of the statistical significance of policy variables and the signs of their regression coefficients suggests that the presence of research universities has a positive and economically meaningful effect on metropolitan economies. This effect seems to differ depending on the scale of university R&D expenditures and suggests that the most prominent research universities have a stronger impact on their regional economies when compared to the universe of research universities that conduct R&D activities in technology-related fields with the scale of annual expenditures at least of $100,000 annually.

The statistical results of this research emphasize the strategic importance of universities for technology-based economic development. Engaged in producing new

knowledge, creating human capital, and conducting industry-relevant research, universities influence economic growth through their products deployed within regional economies. The bundled nature of university products does not allow disentangling the impact of each product separately. Nevertheless, the influence of the research universities presence on metropolitan economies is inarguable. Regional leadership and public policy officials need to analyze and improve the innovative climate by creating ecologies favorable for the involvement of research universities in creating a regional competitive advantage.

CHAPTER II

UNIVERSITY REPUTATION AND REGIONAL GROWTH

2.1 Introduction

It is especially beneficial for a region if a highly reputable research university is at the core of the region's intellectual infrastructure. The university can affect regional economic development through the impact of different university products on economic and cultural aspects of regional life. The research-related university products are identified in the literature as the creation of new knowledge, the performance of contracted research, technology diffusion, and the invention of new products and industries. These products are tightly bundled and their impact is very hard to disentangle. This chapter will assess the influence of the university research products on the outcomes of regional economies. The full set of university research products are operationalized by the reputation of Ph.D. programs in the fields associated with technology-based economic development.

Although the reputation of research-oriented academic departments is usually created by successful research and educated graduates, highly reputable research

universities are strongly associated with heavy funding of R&D, large endowments, prominent scholars, beautiful physical infrastructures, and appealing cultural amenities (such as prominent sport teams, home for international summits, and the heart of art and music masterpieces). Prominent universities are also typified as places of synergy of high intellects and world-class performances created by years of strong, purposeful leadership and accumulated investments.

Reputational policy variables reflect the impact of the whole set of university products on regional economies; they are measured as the summation of the reputational scores in Ph.D. programs across technology-related fields of science and across all universities that belong to the regional economy. A unique dataset of reputational scores of doctoral programs was produced from the National Research Council's 1994 survey on university reputation. Faculties' assessments on the reputation of Ph.D. programs in their fields of specialization were transformed into ratio scores that represent continuous variables that are adequate for comparing Ph.D. programs within their fields and across regions.

Using the statistical results of the cross-sectional multiple regression tests, this chapter argues that, across the universe of U.S. metropolitan areas, there are positive and statistically significant relationships between the high reputation of university Ph.D. programs in technology-related fields and regional growth.

The chapter begins with a literature review, a statement of the research question and main hypotheses, and detailed explanations of constructed policy variables that transform reputational scores of individual doctoral programs into the measurements of regional academic excellence. A correlation between the university fields of excellence

is presented in the second section. It is followed by the interpretation of the regression results in models that use two different dependent variables — the percentage change in total employment and the percentage change in gross metropolitan product (GMP). The chapter continues with a description of different results across the expansion and contraction phases of the business cycle and compares them to the results of the model that captures the entire time period. The analysis of the models includes explanations of independent variables that describe regional industrial organization. The conclusion to this chapter includes a comparison of the results across all models analyzed in this chapter and compares them to the models that are using R&D expenditures as a policy variable and the models of previous research on reputational scores of Ph.D. programs.

2.2 Theoretical Background and Relevant Studies

Since the development of new growth theory, many studies have been conducted aiming to understand the role of universities in technology-based economic development. There are a few economic development theories that underlie technology-based economic development (TBED) and the role of knowledge and innovation in TBED. The most important among them are: the Schumpeter's (1934) theory of creative destruction; the endogenous growth theory of Romer (1990), which is based on agglomeration economies of scale and reflects Young's (1928) study[13] on increasing returns to scale; the product cycle theory of Vernon (1966) and Markusen's (1985) profit cycle concept with its accompanying spatial occupation distributions and firm strategies; Veblen's (1935) description of evolutionary science and economic progress as the product of

[13] Published in Young (1969).

technological advances and Solow's (1957) technology residual, which is addressed in the Griliches (1963)-Jaffe (1989) knowledge production function. Warsh (2006) summarized the evolution of all these preceding theories[14] and summarized endogenous growth theory and the properties of knowledge:

> "The question Romer had framed as a graduate student had an answer now. … How could economics be right about so much and fundamentally wrong about growth? The answer was that a basic economic principle was missing – the principle of the nonrivalry of knowledge as the fundamental source of increasing returns." (Warsh, 2006, p. 298)

None of these theories, however, on its own, provides the comprehensive foundation for science and technology-based development policies. Instead, taken together, they create a composite sketch for the way knowledge is transformed into regional economic outcomes. Policy prescriptions have been developed from a raw amalgam of these theories, which have received strong popular support. Together they are known as technology-based economic development.

The core theoretical background of the positive effect of universities on technology-based economic development is composed of two sets of concepts. The first set includes a concept of increasing returns to economic scale, the effects of agglomeration economies, and the non-rival nature of knowledge consumption that together with two types of knowledge (tacit and codified) enables increasing returns to scale. The concept of increasing returns due to technology advances implies the existence of knowledge spillovers that can be spread from one institution to another and therefore can benefit companies and institutions that co-locate within the same economic market (Grossman & Helpman, 1992; Lucas 1988, 1993; Romer, 1986). The specific characteristic of knowledge as a merit good and the different types of knowledge, tacit

[14] Also acknowledging Veblen (1898) and Hayek (1937, 1948).

and codified, (Doring & Schnellenbach, 2006; Polyanyi, 1958, 1966; Popper, 1972[15]) allow researchers to hypothesize the existence of the transfer of knowledge created in universities to companies within regional economies and outside of regions. Two types of agglomeration — specialization economies within the same industry [economies of scale] and urbanization economies due to a co-location of different industries within a region [economies of scope] — are based on two different forms of knowledge externalities that are theorized to exist in the nature of spillover flows (Griliches, 1979; Jaffe, 1986, 1989).

The second set of concepts includes the framework of university-industry interactions and models of the role of research universities in regional economies. The framework of industry-university interactions states that knowledge produced in universities finds the market of industries that not only utilize that knowledge, but follow the direction of university R&D with their own R&D spending, developing new products and starting new companies and industries. The models of university interactions with regional economies complement the framework of the university-industry interactions by looking at the regional markets of factors of production, the role of governments and other institutions, and the public policies that support these interactions and compensate for market failures.

[15] The simplicity of diffusion of tacit knowledge is based on Polyanyi's (1958) concept of *explicit* and *tacit* knowledge, which describes explicit knowledge as knowledge that is codified in formal documents (articles, conference papers, memos) and tacit knowledge is knowledge that is primarily transformed though personal contacts. There are two major obstacles described in the literature that relate to the division of knowledge into explicit and tacit categories: proprietary rights for codified knowledge and the cognitive ability of individuals to absorb tacit knowledge (Doring & Schnellenbach, 2006). Another method distinguishes types of knowledge as *objective* [written down and ready to be used immediately] or *subjective* [one that is carried by individuals and might effect their decision-making process] (Popper, 1972).

In the mid-nineties the Griliches-Jaffe knowledge production function became a major framework for modeling the impact of universities on separate industries and whole regions (Acs, 2002; Acs, Audretsch, & Feldman, 1991; Acs, Audretsch, & Feldman, 1994a; Acs, Audretsch, & Feldman, 1994b; Acs, FitzRoy, & Smith, 1995; Almedia & Kogut, 1994; Audretsch & Feldman, 1996; Audretsch & Stephan, 1996). In 1994, Acs, Audretsch, and Feldman differentiated the production function for large and small firms, finding that geographic proximity to universities is more beneficiary for the small firms as university R&D may play a substitution role for firms' internal R&D, which is too costly for small firms. Feldman and Florida (1994) used the knowledge production function to study 13 three-digit SIC industries on a state level and reach conclusions regarding the influence of agglomeration through the network effect:

> "Concentration of agglomeration of firms in related industries provide a pool of technical knowledge and expertise and a potential base of suppliers and users of information. These networks play an especially important role when technological knowledge is informal or tacit nature…" (Feldman & Florida, 1994, p.220).

Using less aggregated industrial classification (four-digit SIC sectors), Audretsch and Feldman (1996) found that the geographical concentration of innovation output is positively related to industrial R&D, which proves the existence of knowledge spillovers within the industrial cluster. Using a similar framework at the MSA level, Anselin et al. (1997) uncovered a significant effect of technology transfers between university research and high technology innovative activity via private research and development.

This literature, however, often looks at the single link that channels knowledge created in a university to a specific industry, but never assesses the comprehensive impact

of all university products on a regional economy. Jaffe (1989) is very careful in interpreting his research results noting:

> "It is important to emphasize that spillover mechanisms have not been modeled. Despite the attempt to control for unobserved 'quality' of universities, one cannot really interpret these results structurally, in the sense of predicting the resulting change in patents if research spending were exogenously increased" (Jaffe, 1989, p.968).

Varga (1997) confirmed this position in his literature survey "Regional Economic Effects of University Research: A Survey." He synthesized the literature on the impact of university research in four areas: (1) the location choice of high tech facilities, (2) the spatial distribution of high tech production, (3) the spatial pattern of industrial research and development activities, and (4) the modeling of knowledge transfers emanating from academic institutions. Varga found:

> "regarding the effect of technology transfer on local economic development, the evidence is still vague. Its main reason is that no appropriate model of local university knowledge effects has been developed in the literature. Studies either test for a direct university effect on economic conditions or focus on academic technology transfer, but none of them provides an integrated approach" (Varga, 1997, p.28).

Audretsch (1998) also expressed his caution regarding the interpretation of knowledge spillovers in several empirical studies:

> "While a new literature has emerged identifying the important role that knowledge spillovers within a given geographical location plays in stimulating innovative activity, there is little consensus as to how and why this occurs. The contribution of the new wave of studies … was simply to shift the unit of observation away from firms to a geographic region" (Audretsch, 1998, p. 24).

In the late 1990s, major contributions that studied knowledge spillovers and differentiation of two types of knowledge came from Glaeser, Kallal, Schenkman, and Shleifer (1992), followed by Black and Henderson (1999), Ellison and Glaeser (1997),

Ellison, Glaeser, and Kerr (2007), and Henderson (1999). Using the concept of tacit and codified knowledge, Audretsch and Feldman (1996), Caniels (2000), and Lucas (1988) emphasized that knowledge is neither evenly distributed nor equally accessible in every location. The accumulation of tacit knowledge has regional boundaries while the utilization of codified knowledge depends more on the susceptibility of the recipient to accumulate and employ it. Researchers who contributed to the stream of research initiated by Adams and Jaffe (Adams, 2001, 2002, 2004; Adams, Chiang, & Starkey, 2001; Adams & Jaffe, 1996; Feldman, 1994), focus on the localization of university spillovers and find significant evidence that knowledge flows travel a certain geographical distance within regions, even though, the exact distance differed from study to study.

Another relevant stream of economic development studies looks at the direct effect of universities and especially of university research on regional economies and acknowledges the great impact of the Bayh-Dole Act passed by the U.S. Congress in 1980 as an event that dramatically changed the intellectual property landscape in the United States. Universities were allowed to retain intellectual property rights and to pursue commercialization even though the basic research had been funded by the federal government. In the late 1990s, technology transfer activities of research universities began to be recognized as important factors in regional economic growth. Scientists started to look at the different factors and mechanisms stimulating the transfer of new technologies from university to industry (Campbell, 1997; Cohen, Florida, Goe, 1994; DeVol, 1999; Lowen, 1997; Slaughter & Leslie, 1997).

Acknowledging the impact of universities on regional economies via research and technology development, a number of scholars emphasized that the primary effect of universities results from their core mission – to prepare an educated workforce. Beeson and Montgomery (1993) tested the relationship between research universities and regional labor market performance. They assessed a university's impact on local labor market conditions by measuring quality in terms of R&D funding, the total number of bachelor's degrees awarded in science and engineering, and the number of science and engineering programs rated in the top 20 in the country (Beeson & Montgomery, 1993, p.755). Link and Rees (1990) emphasized the importance of the role of graduates to a local labor market, particularly for new start-ups and the local high tech market, assuming they do not leave the region. Gottlieb (2001) took this idea further in his Ohio "brain-drain" study, emphasizing that exporting graduates is a sign of long-run economic development problems for a region. In their study of 37 American cities, Acs, FitzRoy and Smith (1995) tested university spillover effects on employment, and like Bania, Eberts, and Fogarty (1993), tried to measure business start-ups from the commercialization of university basic research. These studies produced mixed results showing that university products are statistically significant in their impacts in some cases and insignificant in others.

Also in the 1980s and early 1990s, regional scientists started to put some elements traditionally studied separately into some type of regional arrangements. For example, Antonelly (1986, 1989) and Cooke (1985) studied *regional innovation policies*; Aydalot (1988), Keeble (1988), Maillat (1991, 1995), and Maillat and Lecoq (1992) analyzed '*innovative milieux'*; Camagni (1991) talks about *innovation networks* and *high*

technology complexes, Saxenian (1994) describes a *regionalized technology complex*. These elements of systematic approach to studying regional economies resulted in the Cooke's (1992) model of a Regional Innovation System, which is similar to Tornatzky's and his group (Tornatzky et al. 1995, 1997, 1999, 2002) model of regional elements and Porter's (1990) cluster concept. [16] Cooke looked at regional institutions as enablers of regional innovation and identified an important role to universities as agents of institutionalized learning and innovative culture.

Each university interacts with the regional economy as represented by local businesses, government agencies, and the region's social and business infrastructure.[17] The actual interaction is based on its set of products and their value to the region. The university can create sources of regional competitive advantage and can significantly strengthen what Berglund and Clarke (2000) identify as the seven elements of a technology-based economy: (1) regional, university-based intellectual infrastructure – a base that generates new ideas, (2) spillovers of knowledge – commercialization of university-developed technology, (3) competitive physical infrastructure, including the highest quality and technologically advanced telecommunication services, (4) technically skilled workforce – an adequate number of highly skilled technical workers, (5) capital creating adequate information flows around sources of investments, (6) entrepreneurial culture – where people view starting a company as a routine rather than an unusual

[16] The elements of the regional innovation systems were also studied by Asheim and Gertler (2006), Asheim and Isaksen (1997, 2002), Braczyk et al. (1998), Cooke (2001, 2002), Cooke and Morgan (1994, 1998), Doloreux and Parto (2005), Gunasekara (2004, 2006), Mazzoleni and Nelson (2007).

[17] Many studies are focused solely on showing the impact of university presence using the multiplier effect of university expenditures (Adebayo, 2006; Bleaney et al., 1992; Egan et al., 2005; Jafri et al., 2000). These studies substitute the impact of university products (which we identify as purposefully created outcomes according to a university mission) with the impact of university presence in a region (which depends on university expenditure patterns).

occurrence, and (7) the quality of life that comes from residential amenities that make a region competitive with others.

Bringing elements of globalization into understanding the role of universities for the local economy is widely emphasized in the MIT Industrial Performance Center's study led by Richard Lester. The report "Universities, Innovation, and the Competitiveness of Local Economies" discusses an important alignment of the university mission with the needs of the local economy, emphasizing that this alignment is affected by the globalization of knowledge and production and depends on "the ability of local firms to take up new technologies, and new knowledge more generally, and to apply this knowledge productively" (Lester, 2005). Through the different roles played by universities, this study acknowledges diverse pathways of transferring knowledge from universities to local industries. Some of these pathways are common to economies with different core industries, and some are unique to the regions. For example, *education/manpower development* is as valuable for the economy as is *industry transplantation* and *upgrading mature industry economy*. *Forefront science and engineering research* and *aggressive technology licensing policies* are unique and critical for *creating new industries economies,* and *bridging between disconnected actors* is as distinctive for the economy as *diversify old industry into related new*.

The discussion about the role of a university in the regional economy has been enriched by a model created by Louis Tornatzky, Paul Waugman, and Denis Gray (Tornatzky, Waugman, & Bauman, 1997; Tornatzky, Waugman, & Casson, 1995; Tornatzky, Waugman, & Gray, 1999, 2002). These researchers advocate the importance of research universities for regional economic development and examine whether the

influence of a university on a local economy differs geographically. The authors conclude:

> "While we agree with skeptics who argue this [university's impact on a local economy] is not easily accomplished and that some universities and states appear to be looking for a quick fix, we believe that there is enough evidence to demonstrate that universities that are committed and thoughtful can impact their state or local economic environment in a number of ways" (Tornatzky, Waugman, & Gray, 2002, pp.15-16).

Paytas and Gradeck (2004) tested this hypothesis in their case studies of eight universities by examining the scope of universities' economic engagement in local economies. Goldstein, Maier, and Luger (1995) developed a set of university outputs that is also broader than the traditional understanding of university products, which includes only *skilled labor* and *new knowledge*. A similar approach is used by Porter (2002) in a report for the Initiative for a Competitive Inner City. He studied six primary university products using a multiplier-effect approach.

According to Hill and Lendel (2007), higher education is a multi-product industry with seven distinct products: (1) education, (2) contract research, (3) cultural products, (4) trained labor, (5) technology diffusion, (6) new knowledge creation, and (7) new products and industries. These products become marketable commodities that are sold regionally and nationally or they became part of a region's economic development capital base. Growth in the scale, quality, and variety of these products increases the reputation and status of a university. An improved, or superior, reputation allows universities to receive more grants and endowments, attract better students, increase tuition, conduct more R&D, and develop and market more products. This reinforcing mechanism between a university's reputation and university products transforms universities into complex multi-product organizations with a complicated management structure and

multiple missions. A university manages its portfolio of products as defined in the university's mission statement and expressed through the university's functions and policies.

These studies vary by unit of geography, type of industry under study, and method. However, despite their differences, there are consistent findings that show that academic research when placed in dense metropolitan economies generates a number of desirable externalities that re-shape the industrial structure of their surrounding economies.

2.3 Research Question and Hypotheses

A very limited number of studies that assess the impact of universities on regional economies use university reputation or university ranking as a factor in their framework or as a variable in their research model (Austin & Solomon, 1981; Davis & Papanek, 1984; Dill & Soo, 2005; Dusansky & Vernon, 1998; Fairweather, 1988; Fairweather & Brown, 1991; Guarino et al., 2005; Lowry & Silver, 1996; Scott & Mitias, 1996; Volkwein, 1986; Webster, 1992). Typically, the influence of universities on regional economies is operationalized by the number of university graduates, university R&D, university patents, or university spin off companies (Bozeman, 2000; Cohen et al., 2002; David et al., 2000; Grandi & Grimaldi, 2005; Hall et al., 2003; Lee, 1996; Martin & Scott, 2000; Powers & McDougall, 2005).[18] Those studies that consider university reputation most often operationalize it with the rank given by the Carnegie Foundation,

[18] The active participation of university in spillover and commercialization of knowledge is also considered by many scholars as university entrepreneurship (Agrawal & Henderson, 2002; Audretsch & Lehmann, 2005; Bell, 1993; Jacob et al., 2003; Rothaermel, et al. 2007)

which uses university R&D funding to measure university research excellence or faculty publications (Clemens et al., 1995; Webster, 2001; Porter & Toutkoushian, 2006). Sine et al. (2003) used three measures of university prestige to assess the internal process of university technology licensing: U.S. News and World Report graduate school ranking, Gourman Report scores,[19] and 1992 National Research Council graduate department ranking.

The majority of studies that assess the impact of university products on regional economies acknowledge the bundled nature of university products and the difficulty of disentangling their effect and attribute it to each product separately (Goldstein & Drucker, 2006; Goldstein & Renault, 2004). Instead, they often use each product separately in their impact models and sum the effect of the multiple university products while acknowledging overestimating the cumulative overall impact of universities on regional economies (Hoffman, 2007).

The uniqueness of this chapter is in resolving the conflict about the bundled nature of the university products and the resulting overestimating of the impact on regional economies by different university products. Reputational scores of academic Ph.D. programs, an underlying variable of the research policy variables in this chapter, reflects the simultaneous effect of all university products on regional economies. The reputational scores were created by the National Research Council (NRC), which spun off many studies in higher educational policy and sociology on ranking university departments and evaluating their quality and effectiveness (Katz & Eagles, 1996;

[19] Gourman Report scores are a commonly used measure of overall intellectual prestige of the university's graduate programs based of faculty survey. Gourman survey is conducted every three years and provides a score calculated from an assessment of 10 dimensions of a graduate program on a 1 to 5 scale. (Sine at al. 2003: 484).

Jackman & Siverson, 1996; Lowry & Silver, 1996; Miller, Tien, & Peebler, 1996; Garand & Graddy, 1999).[20]

Research Question

The primary research question in the dissertation examines the influence of research universities on regional economic outcomes. The policy variables used in this chapter represent research universities by the reputational scores of Ph.D. programs in technology-related fields of study. The impact of reputational research excellence on regional economic outcomes is measured across the universe of the U.S. metropolitan statistical areas. Three research questions are addressed in this chapter:

- Do both the scale and the scope of metropolitan research excellence, based on the reputational scores of university Ph.D. programs in technology-related fields, have an impact on regional economic outcomes?
- How do the scale and the scope of metropolitan research excellence, based on the reputational scores of university Ph.D. programs, impact regional outcomes controlling for industry R&D spending?
- How does regional industrial organization influence the transformation of the scale and scope of the metropolitan research excellence based on the reputational scores of university Ph.D. programs into regional growth?

[20] The early studies of academic reputation were based on measuring reputation of individual faculty and reputation of academic departments measuring characteristics such as the level of scholarship generated by individual faculty (Hagstrom, 1971; Morgan et al., 1976; Zuckerman, 1988); student retention, post-graduate employment (Dolan 1976, Merton 1968, Webster 1992); different characteristics of individual scholars as a unit of analysis (Long et al., 1979; Long & McGinnis, 1981; Reskin, 1978); and departmental characteristics, departmental resources, and rewards necessary to support scientific work (Hagstrom, 1971; Zuckerman, 1977; Ehrenberg & Hurst, 1996).

Hypotheses

The first set of hypotheses in this chapter discusses the impact of the scale of research excellence on regional outcomes. The scale of research excellence based on the reputational scores of university Ph.D. programs in a metropolitan area is represented by a variable created from the reputational scores of individual Ph.D. programs in technology-related fields. The scale of research excellence at the MSA level variable is created as a selection of the highest sum of all reputational scores of individual Ph.D. programs in a single technology-related field across all research universities in that metro area. In the entire chapter this policy variable is called the *high score (HS)*. For example, if a metropolitan area has two research universities, both having Ph.D. programs in Computer Science and Chemistry, two sums in research excellence will be computed – one for Computer Science (by adding the two reputational scores of individual Computer Science programs in the two universities) and one for Chemistry (by adding the reputational scores of the two individual Chemistry Ph.D. programs in each university). The higher of these two sums will be selected to represent the highest cumulative reputational research excellence of that metropolitan area.

The highest cumulative reputational excellence captures the economies of scale phenomenon, and examines the cumulative effect of university products across all regional universities within a single science and technology field of research. The corresponding set of hypotheses describes the effect of excellence within a single technology-generating Ph.D. discipline across a region on economic development outcomes:

- (H_{1o}) The concentration of excellence within a single technology-generating Ph.D. discipline across a region has no positive effect on economic development outcomes.
- (H_{11}) The concentration of excellence within a single technology-generating Ph.D. discipline across a region has a positive effect on economic development outcomes.

The second set of hypotheses looks at the scope of academic excellence across all technology-based fields and examines the effect of the cumulative excellence of doctoral programs across all fields and all universities in a metropolitan area on regional economic outcomes:

- (H_{2o}) The concentration of university excellence across an array of technology-generating Ph.D. disciplines across a region has no positive effect on economic development outcomes.
- (H_{21}) The concentration of university excellence across an array of technology-generating Ph.D. disciplines across a region has a positive effect on economic development outcomes.

The scope of the region's research excellence, based on the reputational scores of the Ph.D. programs of the region's universities, is represented by a variable also created from the individual reputational scores of Ph.D. programs in technology-related fields. Similar to the sum score average — the average of cumulative university R&D spending across all high programs and all universities in a region over the period of time from 1987 to 1997, the scope of research excellence on the MSA level is created as a cumulative sum of all of the reputational scores of individual Ph.D. programs, across all technology-

related fields, across all research universities in that metropolitan area. In the entire chapter, this policy variable is called the *sum score (SS)*. Continuing the example of two research universities in a metropolitan area, each with Ph.D. programs in Computer Science and Chemistry, the scope of the reputational research excellence variable for this metropolitan area will be the sum of all four reputational scores of the individual Ph.D. programs: two in Computer Science and two in Chemistry.

The third set of hypotheses discusses the influence of the factors of regional industrial organization on the process of transformation of metropolitan research excellence into economic outcomes:

- (H_{30}) The characteristics of regional industrial organization have no positive effect on the process of transforming metropolitan research excellence into economic development outcomes.
- (H_{31}) The characteristics of regional industrial organization have a positive effect on the process of transforming metropolitan research excellence into economic development outcomes.

These three sets of hypotheses are tested within the models structured following the Jaffe-Griliches knowledge production function framework. The two dependent variables in these models are the percentage change in gross regional product or the percentage change in total regional employment. The changes in the dependent variables measure the departure from the long-term trend of these variables specified by the lagged dependent variables. The departure from the trend is associated with the impact of university excellence, changes in industry R&D spending, and changes and structural characteristics of regional economy.

2.4 Research Model and Data

The model for testing these three sets of hypotheses is structured according to equation:

$$\underbrace{RO_j}_{\text{Regional outcomes}} = \alpha_0 + \underbrace{\alpha_1 UR_j + \alpha_2 PR_j}_{\text{Policy variables}} + \underbrace{\alpha_3 E_j + \alpha_4 RCM_j + \alpha_5 RS_j + \alpha_6 RD_j + \alpha_7 RL_j}_{\text{Regional Industrial Organization}} + \underbrace{\alpha_8 H_j}_{\text{Path dependency}} + e_{ij} \quad (3)$$

where:

- RO_j — a percentage change in employment or gross product in a region j.
- UR_j is a reputational scores reflecting the set of university products in a region j.
- PR_j is the size (scope) of industrial R&D in a region j.
- E_j is a variable characterizing level of entrepreneurship in a region j.
- RCM_j is the level of competition in a region j.
- RS_j is the industrial specialization of the regional economy.
- RD_j is the industrial diversification of the regional economy.
- RL_j reflects the presence of establishments with more than 1,000 employees (approximates a presence of large companies) in a region j.
- H_j is path dependency represented by variables that reflect the previous performance of a region j.

To assess the impact of the scale and scope of academic excellence on regional outcomes, two policy variables are specified: the scale of reputation of research university Ph.D. programs in a single field of excellence, which is represented by a variable called *high score* (HS) and the scope of reputation of research university Ph.D. programs across all fields of excellence, which is represented by a variable called *sum score* (SS).

These variables are calculated across 14 selected scientific and technology fields most often affiliated with technology-based economic development. These fields are slightly different from the fields of research included in the previous chapter due to differences in specification in the two surveys that provide the data for both variables. The technology-affiliated areas of research from the National Research Council's survey include 14 fields (among which 7 fields of Biological and Life-Sciences [1-7], 6 fields of Engineering [8-13], and Chemistry as a stand-alone field):

15. Biochemistry and Molecular Biology
16. Biomedical Engineering
17. Cell and Developmental Biology
18. Molecular and General Genetics
19. Neurosciences
20. Pharmacology
21. Physiology
22. Computer Science
23. Electrical Engineering
24. Materials Sciences

25. Industrial Engineering

26. Mechanical Engineering

27. Chemical Engineering

28. Chemistry.

In 1993, the National Research Council conducted a survey of the reputation of 3,634 doctoral programs in 247 universities. The 14 fields of research affiliated with technology-based economic development are among total of 41 fields surveyed. Respondents to the survey were asked to assess the scholarly quality of program faculties and the effectiveness of the programs in educating scientists. The measures of the highest cumulative quality among fields and the total cumulative quality in the region utilize the scholarly quality of program faculties since this measure is also the basis for a university to effectively train new scholars. The reviewers rated programs within one of seven categories (including "don't know" as one of the seven choices) where each category corresponded to a particular interval of numerical values:

- Distinguished – from 4.01 to 5.00
- Strong – from 3.01 to 4.00
- Good – from 2.51 to 3.00
- Adequate – from 2.00 to 2.50
- Marginal – from 1.00 to 1.99
- The interval from 0.00 to 0.99 was considered as not sufficient for doctoral education.[21]

[21] The National Research Council's study provides a detailed explanation of the transformation of qualitative estimates drawn from the survey into the quantitative ratio measurement.

After the doctoral programs were matched to corresponding metropolitan statistical areas, the cumulative scores by each of the 14 fields were calculated and then either summed to construct the *sum score* data for each metropolitan area or the highest score in a single field to define a *high score* for each metropolitan area. The formulae to calculate the quality scores were used from a previous study on quality of research universities.[22] The *high score* (*q*) was calculated as:

$$HS_r = Max\sum_{p=0}^{P} q_{fp}\ , \qquad (4)$$

where *r* – metropolitan statistical area, *r*=1, …, 361; *f* – field of doctoral program, *f*=1, … 14; and *p* – individual doctoral program in a metropolitan area, *p*=1, …, P.

The *sum score* was calculated as:

$$SS_r = \sum_{f=1}^{14}\sum_{p=0}^{P} q_{fp}\ . \qquad (5)$$

The third policy variable, *level of excellence*, reflects the level of academic excellence of a region and helps to distinguish between the regions with a number of research universities of mid-level excellence and the regions with research universities of the highest excellence. The variable was calculated as the number of universities that are among the top 50 or top 100 research universities at the beginning of the treatment period – 1987 (formula (10), p.91).[23]

[22] Hill and Lendel (2007).

[23] In a previous research, the level of excellence variable was calculated as a number of "distinguished" or a number of "distinguished" and "strong" Ph.D. programs in a metropolitan area. However, the variable was highly correlated with both other policy variables and could not be used as an independent in regressions. I also created interactive variables between the level of excellence and sum score variables or level of excellence and highest scores variables, but this did not improve the explanatory power of regressions either.

After constructing the policy variables, the research hypotheses are tested using cross-sectional multiple regression models on the universe of 361 metropolitan statistical areas using the December 2003 boundary definition.

2.5 Correlation Among University Research Fields of Excellence

There is a large variation in the cumulative university excellence across the universe of metropolitan areas. There are a few distinct categories of metropolitan areas: those that have one average research university (for example, Clemson University in the Greenville MSA, SC or the University of Southern Mississippi in the Hattiesburg, MS), those that have several middle-quality universities (like Medical School of Wisconsin and University of Wisconsin Milwaukee in the Milwaukee-Waukesha-West Allis MSA, WI), some metropolitan areas that have one or a few outstanding research universities (University of Washington in the Seattle-Tacoma-Bellevue MSA, WA; or Carnegie Mellon, University of Pittsburgh, University of Pittsburgh School of Public Health and other schools in the Pittsburgh MSA, PA), and a handful of metropolitan areas that have a number of highly ranked doctoral programs within a group of outstanding research universities (like New York, Boston, Chicago, Philadelphia, Washington D.C., and the Los Angeles metropolitan areas).

The process of constructing a variable that reflects the cumulative excellence of Ph.D. programs in a metro area by summing the quality scores across all technology-related Ph.D. programs in a metro area (*sum score*) or selecting the single Ph.D. program with the highest cumulative quality score (*high score*) introduces the possibility of bias.

Summing two "good" or "adequate" programs might equate to a score of one "distinguished" program. At the same time, the impact of the presence of two (or even a greater number) of moderate programs on the regional economy may not be equivalent to the impact of the presence of even a single outstanding Ph.D. program.[24]

The face validity of the created scores of excellence[25] (*sum score* and *high score*), however, was surprisingly good for an intriguing reason. The metropolitan areas with a number of highly reputable research universities were distinct from the rest of the metro areas in forms of the high correlation among their doctoral programs' scores and by the distinctively high figures of their *high score* and *sum score*. In other words, strong research universities that were more likely to have research programs with high values, i.e., "distinguished" programs, are more likely to be found in universities with other "distinguished" or "strong" programs. A single field was rarely ranked "strong" or "distinguished" if there were no other technology-related Ph.D. programs in that university. This observation, made in the process of constructing the policy variables, suggests that both cumulative and highest research excellence in metropolitan areas reflect outstanding excellence of doctoral programs and capture their distinct effect on regional growth.

Only one-third of U.S. metropolitan areas (130 of 361) have research universities with doctoral programs in the 14 fields identified as being of direct interest to

[24] During the exploratory stage of this research a separate categorical variable describing the level of excellence of the doctoral programs was created. A number of tests were preformed with interactive variables created by combining the categorical variable of the excellence of Ph.D. programs and the variables of cumulative scores (*high score* and *sum score*). As a result of exploratory tests, the conclusion was drawn that neither the combined variables nor the categorical variable alone have enough variation on the universe of metropolitan areas, and therefore these variables did not capture the desired selective excellence of distinguished Ph.D. programs.

[25] Face validity reflects the extent to which the contents of newly created variables seem to be adequately measuring the phenomena they are supposed to measure.

technology-based economic development. The descriptive statistics on the policy variables illustrate the greatest and the lowest values, mean, and a standard deviation of the variables on the universe of 361 U.S. metropolitan areas (Table IV).

Table IV. Descriptive Statistics of the Research Scores of Excellence, Industry R&D, and the Regional Output Variables

Policy Variables		Max	Min	Mean	St Dev
Research Scores of Excellence (n=361)	SS	247.54	0*	10.93	27.80
	HS	28.69	0*	1.83	3.59
Industry R&D Spending Change, %	1987-1997	1,261.8	-84.2	93.7	200.2
Employment Change, %	1998-2004	43.5	-10.9	5.6	7.7
	1998-2001	19.5	-8.9	4.0	4.2
	2002-2004	5.9	-15.1	-1.6	3.3
Gross Regional Product Change, %	1998-2004	51.6	-7.1	17.1	10.4
	1998-2001	30.2	-14.1	6.0	6.2
	2002-2004	21.9	-3.9	7.3	3.9

* Metropolitan areas that do not have doctoral programs in the 14 technology-related fields.

The cumulative research excellence variable, which accrues quality scores of all of the doctoral programs in a metropolitan area (*sum score, SS*), has a large variance — from a minimum of 0 in a region that does not have a research university to the greatest number of 247.5, the research excellence cumulative score of all technology-related Ph.D. programs in metropolitan New York. The mean of 10.9 reflects the average of *sum score* across all metropolitan areas in the United States with a standard deviation of 27.8. The highest cumulative quality score (*high score, HS*) has a range of values from 0 to 28.7 with a mean of 1.8 in the universe of MSAs.

The distribution of the policy variables is affected by the seven metropolitan areas with a sum score exceeding 100.0 and 12 more metropolitan areas that have a sum score between 100.0 and 62.0. Both policy variables have a very high standard deviation

across the universe of 361 U.S. metropolitan areas. The distribution of policy variables is not normal and is skewed to the right with a few metropolitan areas with a very high *sum score* values and a long flat "tail," indicating many metropolitan areas with low quality scores. The distribution of the *sum score* across the subset of 130 metropolitan areas that have at least one doctoral program of interest is shown in Figure B-1 (Appendix B). This distribution is skewed due to the seven metropolitan areas with the *sum score* exceeding 100.0: New York-Northern New Jersey-Long Island, NY-NJ-PA; Chicago-Naperville-Joliet, IL-IN-WI; Boston-Cambridge-Quincy, MA-NH; Philadelphia-Camden-Wilmington, PA-NJ-DE-MD; New Orleans-Metairie-Kenner, LA; Blacksburg-Christiansburg-Radford, VA; and Pittsburgh, PA.

Both measures of research excellence on the metropolitan level (*SS* and *HS*) are highly correlated (94.9%), which indicates that highly reputable research universities have excellent Ph.D. programs. The greatest *high score (HS)* in a single field of research belongs to New York's Cell and Developmental Biology field (28.69) with highly rated Ph.D. programs at Columbia University ("distinguished" - 4.10), New York University ("strong" - 3.85), New York Medical School ("good" - 2.93), and the agglomeration of the score across other universities that have Ph.D. programs in Cell and Developmental Biology in the New York metropolitan area (programs rated "good" in Seton Hall University (2.77), State University of New York Stony Brook (2.72), Fordham University (2.68), Albert Einstein School of Medicine (2.60); programs rated "adequate" in Polytechnic University (2.48), Stevens Institute of Technology (2.00); and a "marginal" program in University of Medicine and Dentistry of New Jersey (1.63).

Such a high cumulative score in a single field comes hand-in-hand with very high scores in several related areas of research. For example, Biochemistry and Molecular Biology in New York has a cumulative score of 27.45 with a number of doctoral programs rated as "distinguished" at New Jersey Institute of Technology (4.26); "strong" at Columbia University (3.89), Albert Einstein School of Medicine (3.33), and State University of New York Science Center Brooklyn (3.03); and four other universities in the New York metropolitan area with doctoral programs in Biochemistry and Molecular Biology rated as "good" (with quality scores rated from 2.78 to 2.90). Another three related fields of research in the New York MSA, Chemistry, Molecular & General Genetics, and Pharmacology, have sums of cumulative quality scores of 27.91, 24.87 and 25.51, respectively. These high scores are composed of "distinguished" Chemistry and Molecular & General Genetics Ph.D. programs at Columbia University (4.46 and 4.17, respectively); "strong" programs at New Jersey Institute of Technology, Seton Hall University, and State University of New York Health Science Center Brooklyn; and also "strong" programs in Pharmacology at Columbia and Fordham Universities and at Rutgers University New Brunswick. In addition, the New York metropolitan area, in these three fields alone, has nine more programs rated "good" and three rated "adequate."

In a single field of excellence, the New York metropolitan area is followed by Chicago (24.16 in Biochemistry and Molecular Biology), Philadelphia (23.17 in Pharmacology), Boston (17.94 in Biochemistry and Molecular Biology), and Los Angeles (14.44 also in Biochemistry and Molecular Biology). Instead of being distinguished in a single field, all these and many other metropolitan areas have similarities in the pattern of correlation between high quality scores of their doctoral

programs. This pattern of excellence is confirmed by the correlation among reputational scores in metropolitan statistical areas (Table V).

The correlation between research fields of Ph.D. excellence suggests a high probability of knowledge spillover and cross-fertilization among technology-related fields of science. Table V shows Pierson's correlation statistics between pairs of doctoral programs among the 14 technology-related Ph.D. programs summed to the level of metropolitan areas. Analyzing the correlation, two levels of coefficients were identified: "high" if the coefficient of correlation exceeded 0.8 and "strong" if the coefficient of correlation ranged from 0.65 to 0.79. The high coefficient of correlation may indicate that the presence of certain sets of Ph.D. programs is a necessary condition for achieving a distinguished score for research excellence.

The two fields of Information Technology, Computer Science and Electrical Engineering, are the most commonly affiliated with other areas of academic excellence. Both have high Pearson's correlations with 10 other doctoral programs. Thus, Computer Science has a correlation higher than 0.80 with Electrical and Mechanical Engineering, Chemical Engineering and Chemistry, and three bio-life sciences programs: Biochemistry and Molecular Biology, Cell and Developmental Biology, and Molecular and General Genetics. Electrical Engineering correlates highly (more than 0.80) with four other programs: Computer Science, Chemistry, Biochemistry and Molecular Biology, and Cell and Developmental Biology, and moderate-to-high correlation (between 0.65 and 0.79) with six other programs. In regional economic development, such a high correlation between Information Technology and other science fields can be interpreted as a necessary condition for technological progress for all other areas of university research

Table V. Correlation among Reputational Scores in Metropolitan Statistical Areas

	Bio-Life Sciences							Information Technology		Process Innovation		Advanced Materials	Chemistry	
	Biochemistry & Molecular Biology	Biomedical Engineering	Cell and Developmental Biology	Molecular and General Genetics	Neurosciences	Pharmacology	Physiology	Computer Science	Electrical Engineering	Industrial Engineering	Mechanical Engineering	Materials Sciences	Chemical Engineering	Chemistry
Bio-Life Sciences														
Biochemistry & Molecular Biology	1.000													
Biomedical Engineering	0.505	1.000												
Cell and Developmental Biology	0.967	0.571	1.000											
Molecular and General Genetics	0.900	0.705	0.899	1.000										
Neurosciences	0.935	0.605	0.932	0.964	1.000									
Pharmacology	0.617	0.325	0.518	0.507	0.462	1.000								
Physiology	0.847	0.523	0.861	0.646	0.685	0.694	1.000							
Information Technology														
Computer Science	0.815	0.677	0.860	0.800	0.764	0.304	0.753	1.000						
Electrical Engineering	0.861	0.399	0.846	0.794	0.795	0.300	0.653	0.915	1.000					
Process Innovation														
Industrial Engineering	-0.189	0.244	-0.172	-0.080	-0.068	-0.572	-0.231	0.179	0.074	1.000				
Mechanical Engineering	0.750	0.544	0.765	0.601	0.637	0.327	0.819	0.877	0.783	0.324	1.000			
Advanced Materials														
Materials Sciences	0.302	0.395	0.401	0.328	0.318	-0.288	0.290	0.743	0.658	0.515	0.622	1.000		
Chemistry														
Chemical Engineering	0.795	0.526	0.823	0.647	0.749	0.263	0.810	0.832	0.767	0.280	0.937	0.614	1.000	
Chemistry	0.856	0.447	0.882	0.805	0.779	0.330	0.700	0.936	0.972	-0.028	0.771	0.634	0.730	1.000

affiliated with high tech. In other words, a region must evaluate the level of excellence in its Computer Science program as a necessary condition for the development of the other fields of research.

Four Bio-Life Science doctoral fields have the second-highest inter-correlation with other cumulative Ph.D. programs' excellence on the level of metropolitan area. These programs are each associated with nine to ten other fields at either a high (more than 0.80) or strong level of correlation (between 0.65 and 0.79): Physiology (4/6 – the numerator indicates the number of programs with which this doctoral field is very highly correlated – more than 0.80; the denominator indicates the number of programs with which this doctoral field is moderately-to-highly associated – between 0.65 and 0.79), Biochemistry and Molecular Biology (8/1), Cell and Developmental Biology (8/1), and Molecular and General Genetics (5/4). The peculiarity of these inter-correlations is the high inter-relationship of excellence between the Bio-Life Sciences' doctoral programs. Four of the eight programs that are highly correlated with Biochemistry and Molecular Biology are in Bio-Life Sciences, and three of these four programs have correlation statistics with Biochemistry and Molecular Biology that are higher than 0.90. For Cell and Developmental Biology, this ratio is four of eight. For Physiology, of the 10 programs that are inter-correlated at high or strong levels, five programs are in Bio-Life Sciences, and two of the five are correlated at higher than 0.8 level.

The high inter-correlation among the research areas of Bio-Life Sciences indicates that a metropolitan region should develop a cluster of strong research fields if it wants to build competitive research advantage in bio-life sciences. For example, excellence in Biochemistry and Molecular Biology goes hand-in-hand with high quality research in

Cell and Developmental Biology, Neurosciences, and Molecular and General Genetics. In addition, very strong university research in Chemistry and Information Technology is a must. Chemistry is correlated with three areas in Bio-Life Sciences at higher than 0.8 level and with two more programs at higher than 0.7 level. Across all technology-related programs, Chemistry is correlated with five programs at higher than 0.8 and with four additional programs at higher than 0.7 level.

This finding cannot be generalized to the level of a research university. It is impossible to split the effect of cumulative metropolitan excellence among separate doctoral programs. The task of building a bridge from the findings at the regional level to the level of a research university, however, is so appealing that it becomes the subject for the third essay in this dissertation. The third essay tries to assess the impact of the presence of prominent research universities on regional economic outcomes.

2.6 Impact of University Reputation on Regional Employment Over the Business Cycle

The cumulative excellence of doctoral programs' reputation in the 14 fields affiliated with technology-based economic development significantly impacted regional employment during the different phases of the business cycle. The pattern of statistical significance of the two policy variables in the cross-sectional multiple regression models is similar to the pattern of the impact of cumulative university R&D expenditures on regional employment, as described in chapter 3. Both policy variables, the sum of cumulative quality scores (*sum score, SS*) that reflects cumulative excellence of all technology-related Ph.D. programs in a metropolitan area, and the highest cumulative

quality scores (*high score, HS*), which reflects the highest score in any single area of doctoral programs' excellence in a metropolitan area, are statistically significant during both the expansion and contraction phases of the business cycle (Table VI). The policy variables are statistically significant at the 0.01 level during the period of economic expansion (1998-2001) and both have positive regression coefficients (*sum score* 0.052, *high score* 0.233), indicating that increases in the cumulative quality of doctoral programs at research universities (both *sum score* and *high score*) are strongly associated with growth in total regional employment.

During the contraction phase of the business cycle and the following recovery (2002-2004), the policy variables are significant at the 0.05 level and still have positive regression coefficients, although with lower values (*sum score* 0.033, *high score* 0.128). Whether the economy is declining or recovering or restructuring, university reputation helps to increase regional employment (relative to the mean of the distribution) even if other factors have the opposite effect and are more powerful and are associated with a decline in total employment.

During the contraction phase of economic changes only the path-dependency *variables* and a few regional industrial organization variables are statistically significant. Besides *sum score* and the *high score*, only the variable approximating the change of the level of competition was statistically significant indicating that tougher competition forced businesses to release more employees.

The unexpected absence of statistically meaningful relationships between academic reputation and metropolitan employment growth over the period of time

Table VI. Influence of Reputational Scores on Regional Employment

Variable	Dependent Variable: percentage change of employment:		1998-2001		2002-2004		1998-2004	
Constant		Coefficient	-0.078	-0.120	0.753	0.729	-2.012	-2.032
POLICY VARIABLES								
Sum of cumulative quality scores, *sum score*	SS	Coefficient	0.052		0.033.		0.020	
		t-statistic	4.196***		2.887**		0.841	
Highest cumulative quality scores, *high score*	HS	Coefficient		0.233		0.128		0.119
		t-statistic		3.976***		2.405**		1.077
Industry R&D Spending, percent change 1987-1997	IRD8797	Coefficient	0.004	0.004	0.001	0.001	0.004	0.004
		t-statistic	4.166***	4.156***	0.713	0.659	2.625**	2.647**
REGIONAL INDUSTRIAL ORGANIZATION VARIABLES								
Ratio of regional business establishments to U.S. business establishments, percent change 1988-1997	COMP8897	Coefficient	0.103	0.104	-0.065	-0.065	0.180	0.179
		t-statistic	3.769***	3.777***	-2.630**	-2.621**	3.479***	3.472***
Number of large establishments, 1988	LRG88	Coefficient	-0.067	-0.072	0.003	0.003	-0.101	-0.107
		t-statistic	-3.945***	-4.045***	0.186	0.173	-3.168***	-3.234***
Single-establishment start-ups normalized by population, 1990	ENT90	Coefficient	0.001	0.001	0.0001	-0.000818	0.001	0.001
		t-statistic	2.798**	3.255***	-0.785	-1.497	2.748***	2.860***
Industrial Specialization, 1987	SP87	Coefficient	-0.040	-0.036	0.016	0.020	-0.052	-0.051
		t-statistic	-1.952*	-1.727	0.887	1.097	-1.332	-1.323
Industrial Diversification, 1987	DV87	Coefficient	0.025	0.020	-0.033	-0.035	0.076	0.074
		t-statistic	0.525	0.433	-0.789	-0.852	0.862	0.844
PATH-DEPENDENCY VARIABLES								
Employment growth rate, 1982-1986	E8286	Coefficient	0.113	0.113	-0.046	-0.046	0.213	0.212
		t-statistic	5.662***	5.646***	-2.493**	-2.507**	5.669***	5.657***
Employment growth rate, 1987-1991	E8791	Coefficient	0.156	0.154	-0.046	-0.048	0.297	0.297
		t-statistic	6.182***	6.110***	-1.960**	-2.033**	6.286***	6.275***
Employment growth rate, 1992-1997	E9297	Coefficient	0.120	0.120	-0.094	-0.095	0.234	0.235
		t-statistic	4.422***	4.427***	-3.824***	-3.833***	4.611***	4.620***
Employment growth rate, 1998-2001	E9801	Coefficient			-0.182	-0.176		
		t-statistic			-3.856***	-3.720***		
		R Square	0.435	0.432	0.296	0.291	0.411	0.412
		Adjusted R square	0.419	0.416	0.274	0.269	0.395	0.395

* significant at the .10 confidence level ** significant at the .05 confidence level *** significant at the .01 confidence level
Number of observations metro group = 361

from 1998 to 2004[26] can be explained by the different structure of employment growth during the two phases of the business cycle. This finding is also supported by the statistical significance of the policy variables and the other independent variables in equations describing the expansion and contraction phases of the business cycle. Both equations describing the expansion phase (1998-2001) show that employment growth was associated with the policy variables, industry R&D spending, and the variables of regional industrial structure, while both equations describing the contraction phase of the business cycle and slow recovery (2002-2004) show that employment changes were primarily related to the lagged dependent variables and statistically weaker reputational scores.

Private businesses are more responsive to cyclical changes. They increased their employment during the economic expansion and when the economy turns down or restructures they are more likely to decrease their employment. *Industry R&D spending* is statistically significant during the expansion phase of the business cycle and over the entire time period. In the equations describing the expansion and contraction phases of the business cycle, this variable has positive regression coefficients (0.004 and 0.001, respectively), indicating that larger investment in private research is positively associated with metropolitan employment growth. During the period of economic recession and recovery from 2002 to 2004, *industry R&D spending* was not associated with changes of regional employment. *Industry R&D spending* was statistically associated with

[26] Over the entire time period from 1998 to 2004, there are no statistically meaningful relationships between the two policy variables (sum score and high score) and the percentage increase in metropolitan area employment. This is similar to the findings in the previous chapter on the impact of university R&D spending on regional employment and supports previous research on the impact of academic reputation on regional economic outcomes in Hill and Lendel "The Impact of the Reputation of Bio-Life Science and Engineering Doctoral Programs on Regional Economic Development." Economic Development Quarterly, Vol. 21 No. 3, August 2007 223-243.

employment changes in the equation describing the expansion phase and had no statistical association with percentage change of metropolitan employment in the equation describing the contraction phase of the business cycle. *Private R&D spending* is also positively associated with metropolitan employment growth over the entire time period (1998-2004) with the statistical significance at the 0.05 level in both equations.

The variables of regional industrial organization are closely associated with employment changes during the expansion phase of the business cycle, and, together with the policy and path-dependency variables, explain 42% of variation in the change of metropolitan employment. Variables measuring the *change in the ratio of regional business establishments to U.S. business establishments*, the *number of large establishments*, and the *single-establishment start-ups normalized by population* are statistically significant at the 0.01 level. The variables of the *change in the ratio of regional business establishments to U.S. business establishments* and the *single-establishment start-ups normalized by population* have positive regression coefficients (0.10 and 0.001, respectively) indicating that an increase in their values is associated with employment growth. The *number of large establishments* has a negative regression coefficient (-0.07) with both policy variables demonstrating that an increase in their values is associated with negative changes in metropolitan employment.

The variable approximating regional *industrial specialization* is negatively associated (-0.04) with metropolitan employment change, and it is statistically significant at the 0.10 level only in the model that uses *high score* as a policy variable. The negative sign of this variable's regression coefficient suggests that the higher percentage of

employment in the five top export[27] industries is associated with the negative changes in metropolitan employment over the expansion phase of the business cycle. The regional *industrial diversification* variable was not statistically significant in any employment model.

In the models describing the contraction phase of the business cycle, only the variable approximating regional competition among business establishments is statistically significant (at the 0.05 level). The *change in the ratio of regional business establishments to U.S. business establishments* is negatively associated (-0.065) with metropolitan employment changes during economic recession and recovery. The independent variables in the models describing the contraction phase of the business cycle explain only 29-30% of the variation in the percentage of metropolitan employment change.

The models describing the entire period of time, from 1998 to 2004, have a specific pattern of statistical significance. This pattern is similar to that of the models exploring the expansion phase of the business cycle. The variables measuring the *change in the ratio of regional business establishments to U.S. business establishments*, the *number of large establishments*, and *single-establishment start-ups normalized by population* are all statistically significant at the 0.01 level. The variables of the *change in the ratio of regional business establishments to U.S. business establishments* and the *single-establishment start-ups normalized by population* have positive regression coefficients (0.18 and 0.001, respectively) indicating that an increase in their values is positively associated with employment growth. The *number of large establishments* has a negative regressions coefficient (-0.1) with both policy variables demonstrating that an

[27] The export industries are approximated by the location quotient of their gross product.

increase in their values is associated with the negative changes of metropolitan employment. The variables of regional *industrial specialization* and *industrial diversification* are not statistically significant. All the independent variables explain 41% of the variation in metropolitan employment in the models for the entire time period.

All the employment path-dependency variables in the models describing the entire time period are statistically significant at the 0.01 level. The coefficients of all of the path-dependency variables of employment change are positive in both equations, which indicates that high reputation of research and high regional private R&D spending captured in these path-dependency variables also support an increase in total regional employment. The consistent statistical significance of the path-dependency variables in all models indicates that economic momentum captured by these variables is associated with the increase in total employment in the expansion phase and over the entire time period (having positive signs of regression coefficients in these equations), and the decline in employment during business downturns and economic restructuring (having negative coefficients of path-dependency variables).

2.7 Impact of University Reputation on Gross Metropolitan Product Over the Business Cycle

In the models of employment growth, the policy variables (*sum score* and *high score*) were consistently statistically significant and positively related to changes in employment over the expansion and contraction phases of the business cycle. In the models of gross regional product changes, the policy variables have positive regression

coefficients and are consistently statistically significant only for the expansion phase of the business cycle. During the contraction phase of the business cycle, only the *sum score* is statistically significant and both policy variables have negative association with employment change (Table VII).

The policy variables have a positive effect on the growth of the gross metropolitan product (*sum score* 0.082, *high score* 0.342) and are statistically significant at the 0.01 level during the expansion phase of the business cycle. Both policy variables have a similar pattern in all three sets of regressions (Table VII) and their signs and statistical significance change in the same way. Only the *sum score* is statistically associated with the changes in gross regional product during the contraction phase of the business cycle, but the regression coefficient of this policy variable is negative (-0.034) indicating that increase of the *sum score*s is associated with decrease of the percentage change of gross metropolitan product. Both policy variables become statistically insignificant in the model that covers the complete time period.

The economic significance of the quality score variables on gross regional product, however, is quite different. During the contraction phase of the business cycle, the *sum score* and *high score* not only lose their statistical significance, but the signs of the regression coefficients of the policy variables are reversed. When the economy declined, higher values of the cumulative metropolitan excellence in doctoral research are associated with negative changes in the total gross regional product. In the model that examines the entire time period, the policy variables' regression coefficients were again positive, but not statistically significant.

Table VII. Influence of Reputational Scores on Gross Metropolitan Product

Variable	Dependent Variable: percentage change of GMP:		1998-2001		2002-2004		1998-2004	
Constant		Coefficient	2.637	2.558	5.664	5.705	10.253	0.010
POLICY VARIABLES								
Sum of cumulative quality scores, *sum score*	SS	Coefficient	0.082		-0.034		0.047	
		t-statistic	3.668***		-2.230**		1.265	
Highest cumulative quality scores, *high score*	HS	Coefficient		0.342		-0.115		0.168
		t-statistic		3.260***		-1.628		1.407
Industry R&D Spending, percent change 1987-1997	IRD8797	Coefficient	0.006	0.006	-0.00045	0.000034	0.008	0.006
		t-statistic	3.835***	3.791***	-0.039	0.033	3.065***	3.488***
REGIONAL INDUSTRIAL ORGANIZATION VARIABLES								
Ratio of regional business establishments to U.S. business establishments, percent change 1988-1997	COMP8897	Coefficient	0.029	0.032	0.011	0.010	0.107	0.176
		t-statistic	0.640	0.692	0.372	0.322	1.399	3.368***
Number of large establishments, 1988	LRG88	Coefficient	-0.160	-0.164	-0.011	-0.013	-.0249	-0.172
		t-statistic	-5.403***	-5.295***	-0.519	-0.628	-5.028***	-4.881***
Single-establishment start-ups normalized by population, 1990	ENT90	Coefficient	0.001	0.002	0.0001	0.0001	0.003	0.002
		t-statistic	4.574***	4.941***	1.084	0.900	4.766***	4.561***
Industrial Specialization, 1987	SP87	Coefficient	-0.025	-0.018	-0.002	-0.006	0.008	-0.056
		t-statistic	-0.676	-0.476	-0.072	-0.237	0.125	-1.329
Industrial Diversification, 1987	DV87	Coefficient	0.059	0.052	0.027	0.030	0.117	0.092
		t-statistic	0.708	0.621	0.483	0.535	0.841	0.969
PATH-DEPENDENCY VARIABLES								
GMP growth rate, 1998-2001	GP9801	Coefficient			0.162	0.157		
		t-statistic			4.587***	4.440***		
GMP growth rate, 1987-1997	GP8797	Coefficient	0.068	0.069	0.024	0.024	0.153	0.173
		t-statistic	4.237***	4.287***	2.255**	2.240**	5.715***	9.499***
		R Square	0.181	0.175	0.122	0.116	0.190	0.302
		Adjusted R square	0.162	0.156	0.100	0.094	0.172	0.286

* significant at the .10 confidence level ** significant at the .05 confidence level *** significant at the .01 confidence level

Number of observations metro group = 361

The pattern of statistical significance and signs of regression coefficients for the *private R&D spending* variable in some cases is similar to the pattern of this variable in the metropolitan employment models, but not in all cases. The *private R&D* variable is statistically significant at the 0.01 level during the expansion phase of the business cycle and in the model that describes the entire time period. The regression coefficient for this variable stays at the level of 0.006 for the models with *sum score* and the *high score* as the policy variables during the expansion phase and for the model with the *high score* for the entire time period; the coefficient of *private R&D spending* increases to 0.008 for the model for the entire time period with the *sum score* as a policy variable. During the contraction phase of the business cycle, *industry R&D spending* variable is not statistically significant in both equations, with the *sum score* and with the *high score* as the policy variables.

Two of the variables describing the regional industrial organization, the *number of large establishments* and *single-establishment start-ups normalized by population*, had the most consistent pattern of statistical significance and signs of the regression coefficients across all models describing a change of gross metropolitan product.

The *number of large establishments* (specified as the number of establishments with more than 1,000 employees) is negatively related to the gross regional product and is statistically significant at the 0.01 level only in the models that capture the expansion phase of the business cycle and the entire time period. In contrast, the variable of *single-establishment start-ups normalized by population* is statistically significant at the 0.01 level and is positively related to changes in gross metropolitan product during the expansion phase of the business cycle and over the entire time period (with coefficients

of correlation from 0.001 to 0.003). During the contraction phase of the business cycle, neither variable is statistically significant.

The pattern of statistical significance and the signs of the regression coefficients of these two variables suggest that regions with smaller *numbers of large establishments* and higher rates of increase in *single-establishment start-ups normalized by population* had a larger increase in gross regional product. This was only true, however, when the overall economy was growing, as the first set of models (first and second equations in Table VII) describes economic expansion and the third set of models (fifth and sixth equations) describes the whole economic cycle that, overall, resulted in economic growth.

The impact of the research quality of university doctoral programs on regional performance is not cyclical. In all six models, with regional gross product as a dependent variable and the research quality scores as the main policy variables, all path-dependency variables were statistically significant at the 0.01 or 0.05 level. Similar to the models of regional employment growth, these history variables of lagged gross product represent lag effects and path dependencies. The consistency of statistical significance of these variables suggests that the structure of the models is correct. The lagged variables account for the effects of long-term consistent investment in research excellence, the changes in dependent variables that relate to the past growth of the regional gross product due to existing labor markets and economic structure of regional economies, and path dependencies related to the bundled nature of the university products reflected in our policy variables, reputational excellence.

The explanatory power of all models was lower than for the models of regional employment growth, ranging from 16% to 29% during economic growth periods to 9%

to10% during the economic decline and recovery period. Such a low explanatory power suggests that the models might reflect only partial recovery after the last recession and do not capture the entire effect of the cumulative excellence of university research.

Overall, all six models analyzed in this section suggest that the null hypotheses – that the concentration of excellence within a single technology-generating Ph.D. discipline across a region and the concentration of excellence across an array of technology-generating Ph.D. disciplines across a region – cannot be rejected. The research reputation of university doctoral programs has a statistically significant impact on regional outcomes during a period of economic expansion. The results about the impact of reputational excellence on regional outcomes for the contraction phase of the business cycle and over the complete time period were not conclusive because the policy variables were statistically meaningful only in selective models and because the signs of their regression coefficients were different across the models with change of employment and change of gross product as dependent variables.

The pattern of statistical significance and the signs of the regression coefficients of the variables describing regional industrial organization suggest that the null hypothesis that the characteristics of regional industrial structure have no positive effect on the process of transforming metropolitan excellence into economic development outcomes cannot be rejected for the *change in the ratio of regional business establishments to U.S. business establishments* and the number of *single-establishment start-ups normalized by population*. These two regional characteristics had statistically meaningful and positive effect on gross regional product changes in the models for the expansion phase of the business cycle and over the entire time period. The *number of*

large establishments in the regional economy was statistically significant but negatively associated with gross product changes in the models for the expansion phase of the business cycle and over the entire time period.

There was no statistical evidence to disprove this null hypothesis on the role of the variables of regional industrial organization for the contraction phase of the business cycle and for two other variables of regional industrial organization. Neither *industrial specialization* nor *industrial diversification* – variables that describe the employment structure of basic industries in the regional economy – were statistically significant in any model.

2.8 Consistency of the Results in the Reputational Score Impact Models

The consistency of the statistical significance of policy variables (*sum score* and *high score*) and other independent variables across all models of this chapter is examined in this section (Table VIII). The models for different output variables (employment growth and gross metropolitan product growth) and for the different time periods (the expansion and contraction phases of the business cycle and over the entire time period of 1998-2004) are also studied for signs of their regression coefficients (Table IX).

Overall, the policy variables were statistically significant in the expansion and contraction phases of the business cycle, but not over the entire time period. The *industry R&D* variable was statistically significant in the models that examine the expansion phase of the business cycle and over the entire time period. This variable had no statistically meaningful relationship with regional output variables in the contraction phase of the

Table VIII. Statistical Significance of the Independent Variables in the Reputational Scores Impact Models

Variable	Variable Name	Dependent Var: % 1998-2001				Dependent Var.: 2002-2004				Dependent Var.: 1998-2004			
		Empl	GMP	Empl	GMP	Empl	GMP	Empl	GMP	Empl	GMP	Empl	GMP
POLICY VARIABLES													
Sum of cumulative quality scores, *sum score*	SS	***	***			**	**						
Highest cumulative quality scores, *high score*	HS			***	***			**					
Industry R&D, percent change 1987-1997	IRD8797	***	***	***	***					**	***	**	***
REGIONAL INDUSTRIAL ORGANIZATION VARIABLES													
Ratio of business establishments, pct chng 1988-97	COMP8897	***		***		**		**		***		***	***
Number of large establishments, 1988	LRG88	***	***	***	***					***	***	***	***
Single-est start-ups normalized by population, 1990	ENT90	**	***	***	***					***	***	***	***
Industrial Specialization, 1987	SP87	*											
Industrial Diversification, 1987	DV87												
PATH-DEPENDENCY VARIABLES		***	***	***	***	***	***	***	***	***	***	***	***
R Square		0.435	0.181	0.432	0.175	0.296	0.122	0.291	0.116	0.411	0.190	0.412	0.302
Adjusted R square		0.419	0.162	0.416	0.156	0.274	0.100	0.269	0.094	0.395	0.172	0.395	0.286

* significant at the .10 confidence level ** significant at the .05 confidence level *** significant at the .01 confidence level
Number of observations metro group = 361

Table IX. Signs of the Regression Coefficients of the Independent Variables in the Reputational Scores Impact Models

Variable	Variable Name	Dependent Var.: % 1998-2001				Dependent Var.: % 2002-2004				Dependent Var.: % 1998-2004			
		Empl	GMP	Empl	GMP	Empl	GMP	Empl	GMP	Empl	GMP	Empl	GMP
POLICY VARIABLES													
Sum of cumulative quality scores, *sum score*	SS	+	+			+	–			+	+		
Highest cumulative quality scores, *high score*	HS			+	+			+	–			+	+
Industry R&D, percent change 1987-1997	IRD8797	+	+	+	+	+	–	+	+	+	+	+	+
REGIONAL INDUSTRIAL ORGANIZATION VARIABLES													
Ratio of business establishments, pct chng 1988-97	COMP8897	+	+	+	+	–	+	–	+	+	+	+	+
Number of large establishments, 1988	LRG88	–	–	–	–	+	–	+	–	–	–	–	–
Single-est start-ups normalized by population, 1990	ENT90	+	+	+	+	+	+	–	+	+	+	+	+
Industrial Specialization, 1987	SP87	–	–	–	–	+	–	+	–	–	+	–	–
Industrial Diversification, 1987	DV87	+	+	+	+	–	+	–	+	+	+	+	+
PATH-DEPENDENCY VARIABLES		+	+	+	+	–	+	–	+	+	+	+	+
R Square		0.435	0.181	0.432	0.175	0.296	0.122	0.291	0.116	0.411	0.190	0.412	0.302
Adjusted R square		0.419	0.162	0.416	0.156	0.274	0.100	0.269	0.094	0.395	0.172	0.395	0.286

Note: There is no statistically meaningful relationships between the regional outcomes and independent variables in the shaded cells
Number of observations metro group = 361

business cycle. The variables describing regional industrial organization had a mixed pattern of statistical relationships with changes in regional employment and gross product.

In the expansion phase of the business cycle, the policy variables were statistically significant at the 0.01 level in all four models (Table VIII). The coefficients of regression of the *sum score* and *high score* were positive across all four models (Table IX). The consistency of the statistical significance of policy variables during the expansion phase of the business cycle in both sets of regressions confirms the positive impact of research universities on the regional economic outcomes. This consistency does not answer the question of how many "good" or "excellent" doctoral programs in technology-related fields generate the positive changes in employment and output. These patterns of regression coefficient signs and statistical significance, however, suggest that the growth of the regional economy at the metropolitan level is strongly associated with the research excellence of Ph.D. programs in technology-related fields of science.

During the economic recession, the high accumulation of the research excellence helps metropolitan areas to retain employment, but it does not help to sustain or increase gross metropolitan product. In three out of four models examining the contraction phase of the business cycle, the weaker statistical significance (at the 0.05 level) was observed in conjunction with the inconsistency of the regression coefficient signs of policy variables. Employment changes during the contraction phase of the business cycle were positively associated with an increase of *sum score* and *high score*, however, the change of gross metropolitan product was negatively associated with an increase in research excellence across all programs in a metropolitan area (the only statistically significant

policy variable in GMP models examining economic decline). Over the entire time period, neither of two policy variables was statistically meaningful for changes of regional outcomes, even though the signs of their regression coefficients were all positive.

Private R&D helps grow regional economies during economic expansions and over times of the entire business cycles. This variable is statistically associated with changes of the regional outcome variables in the models examining the expansion phase of the business cycle (at the 0.01 level) and in the models for the entire time period (at the 0.01 level in GMP equations and at the 0.05 level in employment change models). In all eight models the higher amount of *industry R&D* is associated with increases in employment and GMP changes. *Private R&D* is not statistically significant in any models exploring the contraction phase of the business cycle, even though in three of them the variable keeps a positive sign of the regression coefficient.

Among the variables describing regional industrial organization, the variables approximating competitive regional markets and entrepreneurship (the *change in the ratio of regional business establishments to U.S. business establishments* and the *single-establishment start-ups normalized by population*, respectively) have positive and statistically meaningful relationships with the outcome variables; the *number of large establishments* approximating the presence of large companies (specified as the number of establishments with more than 1,000 employees) has a statistically meaningful and negative effect on changes of employment and gross regional product.

The change in the *ratio of regional business establishments to U.S. business establishments* is statistically significant in the employment models at the 0.01 level for

the expansion phase of the business cycle and over the entire time period and the increase of the relative number of business establishments helps to grow regional employment. During the period of economic decline, higher rates of change in the relative number of business establishments is associated with declining rates of the regional employment at the 0.05 level of statistical significance.

The *number of large establishments* is statistically significant at the 0.01 level in the models for the expansion phase of the business cycle and over the entire time period. It has no statistically meaningful relationships with the output variables during the economic recession. In all statistically significant relationships, the *number of large establishments* (with more than 1,000 employees) is negatively associated with employment and GMP growth emphasizing that the presence of large companies might have a negative impact of regional growth.

The number of *single-establishment start-ups normalized by population* (that approximates entrepreneurship in all industries) is statistically significant at the 0.01 level[28] and has positive relationships with employment and GMP growth at the expansion phase of the business cycle and the entire time period. This variable has no statistically meaningful relationships to the outcome variables during the contraction phase of the business cycle, even though its regression coefficient remains positive for three of the four models. The results of statistical significance and the signs of the regression coefficients for this variable suggest that a higher level of entrepreneurship in a metropolitan area helps to grow employment and GMP when the economy is growing overall and for the long-term regional growth over the entire business cycle.

[28] With the exception of one model with the statistical significance at the 0.05 level – employment growth over the expansion phase of the business cycle with the sum score as the policy variable.

2.9 Summary and Conclusions

During the last 20 years, regional economies were prospering in metropolitan areas with prominent research universities. Overall, these economies secured a departure from the national growth trend of rising employment and gross product in metropolitan areas with highly ranked academic Ph.D. programs. Research universities with highly ranked Ph.D. programs in technology-related fields successfully responded to growing demand for innovation, creating new knowledge, new products and industries, commercializing inventions, conducting contracted research, preparing highly educated graduates and training labor, and enriching urban life with cultural amenities.

The reputational quality of research universities is statistically associated with fluctuations of total metropolitan employment and gross metropolitan product during the economic expansions and contractions of the most recent business cycle. This reflects the growing demand for high quality research in the 1990s and early 2000s when the economy had resources to purchase it. The reputation reflected in academic Ph.D. programs promised high quality research and the economy was willing to take the risk.

The statistically significant association of the high reputation of academic Ph.D. programs with regional economic outcomes also explains why, during the economic contraction, employment gains held in economies that continued to grow and decreased where economies declined. The gross metropolitan product gains did not hold during the contraction phase. The drop in the volume of GMP was even greater in regions with high concentrations of all types of technology-related programs. The quality of university

research was not statistically associated with the changes in GMP in places with a high specialization of research in a single technology area. This dynamic shows that, during the economic downturn, universities try to save their assets – talented researchers – and the regional economy is supported by their comparably high salaries even in the time of scrutiny. The gross metropolitan product responds faster to cyclical changes. It contracts quickly during economic downturns cutting out the risky products first. Using the results of the models showing the impact of university reputation over the different phases of the business cycle and over the entire time period (1998-2004), the null hypothesis could not be disproved.

The economic returns for university excellence are almost reversed during the expansion and contraction phases of the business cycle. Economic expansion stimulates demand for products with the highest marginal growth, these products include the results of academic research in technology-related areas guaranteed by the reputation of prominent American universities. The attractiveness of these products guarantees a high rate of funding for academic research and, as a result, growth of employment and the GMP due to the deployment of innovation and multiplier effects in respective regional economies. Growing businesses and high salaries of professor and scientists trigger spending for real estate and business and personal services, which guarantee regional economies' steady growth. During economic downturns, regional economies with a large presence of prominent research universities hold their employment better than the average metro area; however, these regions do not hold their GMP following the logic of survival during recessions. The promises of university research are a good short-term commodity. Due to such opposite directions in economic returns during the phases of the

business cycle, neither excellence in specialized research nor cumulative excellence across technology-related Ph.D. fields makes significant difference for the regional outcomes over the entire time period. The longer period of time summarizes these two dynamics that statistically cancel each other.

Moreover, the positive association between university research excellence and regional economic outcomes is supported by the high correlation between the reputational scores of different Ph.D. programs. It suggests that the research specialization in technology-related areas comes in combinations of fields. Almost all fields had a high quality research score if their Chemistry and Computer Science programs ratings were at the highest level. The bundled nature of research excellence among multiple technology areas strengthens the cumulative reputation of universities and therefore helps to sell their promise of research products during economic expansion and hold their employment during economic declines.

The industry R&D expressed in terms of total expenditures reflected typical behavior for industrial clusters in its responses to the phases of the business cycle. The expenditures for industry R&D increased and strongly supported the regional economic growth when the economy was expanding and declined in the period of economic contraction, showing no statistically significant relationships with the regional employment and GMP. Over the entire time period, however, it shows statistical significance to both growth of total employment and gross metropolitan product. Such a dynamic over the long run reflects the overall scale of industry R&D funding that

overwhelmingly exceeds university R&D expenditures and absorbs downturns of economic recessions resulting in a positive sum effect.[29]

Regions differ in their industrial structure, which partially defines the readiness of their economies to absorb innovation. More entrepreneurial economies with larger numbers of small establishments are better able to transform academic research excellence in regional economic outcomes, especially during the economic expansion and over the long period of time. The metropolitan areas with the history of the presence of large-employment companies are likely to diminish these results, probably due to a low demand for research products, glum entrepreneurial culture, and social problems in such regions that withdraw resources from the economy.

Statistical research on the influence of research reputation on regional growth inarguably emphasized the importance of strong research universities to technology-based economic development. Producing new knowledge, creating a highly skilled labor force, and conducting industry-relevant research, universities influence economic growth through products deployed within regional economies. They strengthen the competitiveness of their regions by developing new knowledge via contracted research, creating new products and industries, and by improving cultural amenities and creating regional synergies through dialogs among important regional players.

University products that are highly dependant on university quality include technology diffusion, new market products and new industries, contracted research, and the creation of new basic knowledge. The capacity of universities to create these

[29] The regression coefficients of industry R&D variable in the models were significantly smaller in the equations describing the contraction phase of the business cycle compared to the expansion phase. The differences were especially remarkable for the growth in metropolitan product (Tables VI and VII in this chapter).

products should be the focal point of regional leadership and public policy officials. Public policy should create an environment highly favorable for regional innovation. Involvement of research universities in creating a regional competitive advantage must be central to that environment. State and local officials should consider making public investments in research capacities of universities, creating innovation and generating local demand. They should also provide continuous base-funding to universities that will help to meet that demand by producing highly skilled labor and enhancing human capital.

CHAPTER III

INFLUENCE OF UNIVERSITY AND INDUSTRY R&D ON REGIONAL GROWTH

3.1. Introduction

Many public economic development policies are based on the popular assumption that investment in university research and infrastructure benefits regional economies. Universities are seen as a core element of a region's intellectual infrastructure and an essential factor in building successful technology-based firms and industrial clusters. Support for building technology clusters is justified by the desire to create engines of economic growth and at the same time develop competitive advantage.

This argument is attractive to many politicians who are promoting technology-based economic development and has become a third mission of universities (Etzkowitz, 2003a) or one of the university's functions (Goldstein et al., 1995). The supporters of the

traditional roles of universities, with the main emphases on knowledge creation and a university's "social function" (Feller, 1990), doubt the ability of universities to promote economic development. These views are consistent with those of scholars who do not see a research university as a required element for a strong regional technological intellectual base and assign the role of "surrogate university" to large companies (Saxenian, 1994, 1996; Baumol, 2002; Cortright & Mayer, 2002; Mayer, 2005) that perform the core functions of an "entrepreneurial university" (Etzkowitz, 2003b, 2004): to create new knowledge, commercialize innovation, and spin off firms.

A body of empirical work examining knowledge spillovers from universities to industries and regional economies concludes that the presence of universities is a necessary, but not sufficient, condition for positive regional growth. Studies identify multiple university products such as university graduates, new knowledge, contracted research and cultural amenities, and assess their impact on regions. The question addressed here is which university products contribute to technology-based economic development and create an impact on regional economic outcomes.

Using the results of statistical models, this chapter presents the argument that, across the universe of U.S. metropolitan areas, there are positive and statistically significant relationships between university R&D expenditures in technology-related fields and regional growth. This chapter begins with a literature review that presents the concept of university products, the conceptual framework of this study. The chapter continues with a deliberation on R&D expenditures in technology-related fields as a variable that approximates the role of research universities in technology-based economic development and looks at studies that used university R&D expenditures as a policy

variable in their models. The next section provides an interpretation of the regression results in models that use two dependent variables – the percentage change in total employment and the percentage change in regional metropolitan product. In addition to the policy variable – university R&D expenditures – each model in this chapter includes industry R&D spending and a set of variables describing regional industrial organization. The models are analyzed across the expansion and contraction phases of the business cycle and their results are compared to a model that captures the entire time period. The chapter concludes with an assessment of the impact of the marginal increase in academic R&D expenditures on the regional economic outcome variables.

3.2. Theoretical Background and Relevant Studies

Since the development of new growth theory, many studies have been conducted on the role of universities in technology-based economic development. There are a few economic development theories that underlie technology-based economic development (TBED) and the role of knowledge and innovation in TBED. The most important among them are: Schumpeter's (1934) theory of creative destruction; the endogenous growth theory of Romer (1990), which is based on agglomeration economies of scale and reflects Young's (1928) study of increasing returns to scale; the product cycle theory of Vernon (1966) and Markusen's (1985) profit cycle concept with its accompanying spatial occupation distributions and firm strategies; Veblen's (1935) description of evolutionary science and economic progress as the product of technological advances; and Solow's (1957) technology residual, which is addressed in the Griliches (1979)-Jaffe (1989)

knowledge production function. Warsh (2006) reviewed the evolution of all these preceding theories[30] and summarized the endogenous growth theory and the properties of knowledge. He pointed out that the question Romer had framed as a graduate student had finally been answered and concluded that economists were fundamentally wrong about growth overlooking a basic economic principle – the nonrivalry of knowledge as the source of increasing returns.

None of these preceding theories on its own, however, provides the comprehensive foundation for science and technology-based development policies. Instead, taken together they create a composite sketch for the way knowledge is transformed into regional economic outcomes, known as technology-based economic development.

Each university interacts with the regional economy as represented by local businesses, government agencies, and the region's social and business infrastructure.[31] The actual interaction is based on a university's set of products and its value to the region. The university can create sources of regional competitive advantage and can significantly strengthen what Berglund and Clarke (2000) identify as the seven elements of a technology-based economy: (1) regional, university-based intellectual infrastructure – a base that generates new ideas, (2) spillovers of knowledge – commercialization of university-developed technology, (3) competitive physical infrastructure, including the highest quality and technologically advanced telecommunication services, (4) technically

[30] Also acknowledging Veblen (1898) and Hayek (1937, 1948).
[31] Many studies are focused solely on showing the impact of university presence using the multiplier effect of university expenditures (Jafri et al., 2000; Egan et al., 2005; Adebayo, 2006). These studies substitute the impact of university products (which we identify as purposefully created outcomes according to a university mission) with the impact of university presence in a region (which depends on university expenditure patterns).

skilled workforce – an adequate number of highly skilled technical workers, (5) capital creating information flows around sources of investments, (6) entrepreneurial culture – where people view starting a company as a routine rather than an unusual occurrence, and (7) the quality of life that comes from residential amenities that make a region competitive.

Bringing elements of globalization into understanding the role of universities in local economies is emphasized in the MIT Industrial Performance Center study led by Richard Lester. The report "Universities, Innovation, and the Competitiveness of Local Economies" discusses an important alignment of the university mission with the needs of the local economy, emphasizing that this alignment is affected by the globalization of knowledge and production and depends on "the ability of local firms to take up new technologies, and new knowledge more generally, and to apply this knowledge productively" (Lester, 2005). This study acknowledges the diverse roles played by universities for transferring knowledge from universities to local industries (Chapter I, Figure 3, p. 12). Some of these paths are common to economies with certain core industries, and some are unique to certain regions. For example, *education/manpower development* is as valuable for the economy as *industry transplantation* and *upgrading mature industry economies*. *Forefront science and engineering research* and *aggressive technology licensing policies* are unique and critical for *creating new industries economies*, and *bridging between disconnected actors* is as important for the economy as *diversify old industry into related new industry.*

The discussion about the role of the university in the regional economy has been enriched by a model created by Louis Tornatzky, Paul Waugman, and Denis Gray

(Tornatzky et al., 1995; Tornatzky et al., 1997, 1999, 2002). These researchers advocate the importance of research universities for regional economic development and examine whether the influence of a university on a local economy differs geographically. The authors conclude:

> "While we agree with skeptics who argue this [university's impact on a local economy] is not easily accomplished and that some universities and states appear to be looking for a quick fix, we believe that there is enough evidence to demonstrate that universities that are committed and thoughtful can impact their state or local economic environment in a number of ways" (Tornatzky et al., 2002, pp.15-16).

Paytas and Gradeck (2004) tested this hypothesis in their case studies of eight universities by examining the scope of universities' economic engagement in local economies and arrived at similar conclusions. Goldstein et al. (1995) developed a set of university outputs that is broader than the traditional understanding of university products, which includes only *skilled labor* and *new knowledge*. A similar approach is used by Porter (2002) in a report for the Initiative for a Competitive Inner City. He studied six primary university products using a multiplier-effect approach.

According to Hill and Lendel (2007), higher education is a multi-product industry with seven distinct products: (1) education, (2) contract research, (3) cultural products, (4) trained labor, (5) technology diffusion, (6) new knowledge creation, and (7) new products and industries. These products become marketable commodities that are deployed regionally, nationally, or globally according to the market niche of each product. If deployed regionally, they became a part of a region's economic development capital base. Three of these products, contract research, new knowledge, and new

products and industries are directly related to R&D expenditures, a popular input measure of university impact.

The conduit of the major impact of research universities on regional economies is university-industry interaction. The literature discusses many types of interactions emphasizing that the interaction pattern is not homogeneous across different technological fields (Geisler & Rubenstein, 1989; Louis & Anderson, 1998; Lee, 1996; 1999, Etzkowitz & Leydesdorff, 2000; Scibany et al., 2000). According to Meyer-Krahmer and Schmoch (1998), industry has a role as a simple observer of science-based university R&D fields that are focused primarily on basic research, and industry is most likely to interact with universities in less science-based fields focused on solving technical problems. Etzkowitz and Leydesdorff (2000) analyzed the organizational structure of university-industry interactions, recognizing that new technologies induce reorganization of industrial sectors. Using examples of biotechnology and information and computer technologies, they emphasized that "university research may function increasingly as a locus in the 'laboratory' of such knowledge-intensive network transitions." Looking beyond an increasing role of universities in technology transfer, Lee (1999) and Scibany et al. (2000) rank university products by their importance to large companies (from the most to the least important) as: (1) educated and highly skilled personnel, (2) the provision of up-to-date research and new ideas, (3) the provision of general and useful information, and (4) direct support in the product development process.

Universities create new knowledge by conducting basic and applied research, which is usually measured by the input variable of total university R&D expenditures.

Many scholars have tested the relationships between public and private R&D investments, trying to explain whether these relationships have a complementary or substitutional character. Many studies found a statistically significant and positive spillover effect of public research on industry R&D spending. This has been confirmed not only by empirical models (Jaffe, 1989; Adams, 1990; Acs et al., 1991; Cohen et al., 2002; Toole, 1999a, 1999b) but also in historical case studies (Link & Scott, 1989; National Research Council, 1999).

The framework of university-industry interactions dictates that knowledge produced in universities finds a market in industries that not only utilize that knowledge, but also follow the direction of university R&D with their own R&D spending, developing new products and starting new companies and industries. In addition to university-industry relationships, these models of technology-based economic development look at the regional factors of production, the role of governments and other institutions, and the public policies that support these interactions and counterweigh market failures.

The Griliches-Jaffe knowledge production function has become a major framework for modeling the impact of universities on separate industries and whole regions (Acs, 2002; Acs et al., 1991; Acs et al., 1994; Acs et al., 1995; Almedia & Kogut, 1994; Audretsch & Feldman, 1996; Audretsch & Stephan, 1996; Jaffe, 1989). Modeling spillovers from university research in several high technology industries on a state level, Jaffe (1989) found a significant effect of university research on corporate patents and an indirect effect on local innovation by inducing industrial R&D spending. In 1994, Acs, Audretsch, and Feldman differentiated the production function for large and small firms,

finding that geographic proximity to universities is more beneficial for small firms because the university's R&D may substitute for a firms' internal R&D, which may be too costly for small firms. Feldman and Florida (1994) used the knowledge production function to study 13 three-digit SIC industries on a state level and reached conclusions regarding the influence of agglomeration through the network effect:

> "Concentration of agglomeration of firms in related industries provide a pool of technical knowledge and expertise and a potential base of suppliers and users of information. These networks play an especially important role when technological knowledge is informal or tacit nature…" (Feldman & Florida, 1994, p.220).

Using a less aggregated industrial classification (four-digit SIC sectors), Audretsch and Feldman (1996) found that the geographic concentration of the innovation output is positively related to industrial R&D, which proves the existence of knowledge spillovers within the industrial cluster. Using a similar framework at the MSA level, Anselin et al. (1997) uncovered a significant effect of technology transfers between university research and high technology innovative activities via private research and development. Goldstein and Drucker (2006) built upon the Goldstein and Renault (2004) model of the impact of university entrepreneurial functions on regional wage growth and examined the impact of 4-year colleges and universities on earning gains in metropolitan areas. They found substantial positive effects of different university functions, including the total amount of research expenditures on regional outcomes.

Another area of literature suggests that universities contribute to innovation and TBED through "open" and "public" sources of knowledge transfer – publications,

conferences, faculty consulting, and informal exchanges of tacit knowledge[32] (Agrawal & Henderson, 2002; Cohen, Nelson, & Walsh, 2002; Feller, 1997; Roessner, Carr, Feller, McGeary, & Newman 1998). Moreover, accounting for the direct effect of university R&D expenditures or accepting the wider framework of university contributions through open-source knowledge transfer, the number of research universities which impact economic development has significantly grown over the past 40 years (Graham & Dimond, 1997). Further evidence of public belief in the impact of research universities is the increase in the number of public Research I and Research II Carnegie-ranked institutions from 57 to 125 between 1970 and 1994 (Feller, 2004).

The literature provides evidence that university R&D activities and derived products affect the development of companies and industries, and as a result, regional economic outcomes. The mixed results of these studies reflect multiple limitations in their design. Some studies look only at selected industries (primarily high technology industries) or selected regions. The regional definition is particularly important as studies often fail to look at metropolitan areas, ignoring the fact that they are the primary units of regional economies. Because they are defined by labor markets, this is the level of the economy where the market forces act. Some studies fail to control for the path dependency of regional trends and path dependencies and assign all regional gains (or losses) to the universities' impact on regional economies. The design of the research models in this chapter addresses these limitations and assesses the impact of academic R&D expenditures on regional outcomes using the model that accounts for industrial

[32] In his earlier publication Feller (1990) referred to the creation of scientific and technological knowledge of universities as the "supply of a collective good"which constitutes universities' "social roles." He claimed that participation in commercialization of faculty research leads to institutional change.

R&D expenditures, regional industrial structure and path dependencies across U.S. metropolitan areas.

3.3. Research Design

A number of studies have used university R&D expenditures as the policy variable or as one of the several policy variables describing university impact on regional economies or university-industry relations (Agrawal & Cockburn, 2003; Anselin et al., 1997; Audretsch, 1991; Audretsch & Fendman, 1996; Bania et al., 1993; David et al., 2000; David & Hall, 2000; Feldman & Florida, 1994; Jaffe, 1989; Kirchhoff et al., 2002; Mansfield & Lee, 1996; Markusen et al., 1986; Martin, 1998; Sivitanidou & Sivitanides, 1995; Stankiewicz, 1986; Tornquist & Hoenack, 1996).[33] Many of these studies documented positive and statistically significant spillover effects of university R&D expenditures by stimulating private R&D spending (Acs et al., 1991; Adams, 1990; Jaffe, 1989; Toole, 1999a, 1999b). Some studies were able to record no effect or only marginal effects of R&D expenditures on private companies, industries, or regional economies.

Research Question

Preceding studies tested the impact of university R&D expenditures on regional economies using a variety of research designs. Some looked at the impact of a single-area research and development on regional outcomes, and others assessed a group of

[33] There is also a stream of literature that assesses the effect of R&D public subsidies or government R&D funding performed by firms (Mamuneas & Nadiri, 1996; Busom, 2000; Guellec & de la Potterie, 2003)

research fields as the causal effect factor. Often the selection of the research field(s) was determined by the availability of data or the specialization of the region of interest.

This chapter attempts to assess the impact of the *scale* and *scope* of university R&D expenditures in technology-oriented fields on regional economic outcomes using a framework of the university products. Concentrating R&D activities in a single research field emphasizes the specialization of research. The specialization of research creates positive externalities of the *economies of scale* that benefit from having specialized suppliers (or, specifically in a case of research activities, state of the art research equipment), a specialized pool of labor (a nationally thin but regionally thick pool of scientists and specialists with specific knowledge and skills), specialized finance (angels and venture capital) and specialized marketing of the unique area of research expertise. All these factors increase efficiencies on the supply side of research and also increase the probability of successful research outcomes from deep specialization of knowledge in one area.

University R&D expenditures that span a broad array of technology-related research fields creates benefits from the positive externalities of *economies of scope*. Synergies among different research products and fields create a fruitful ground for creative solutions and cross-field applications, reinforced by efficiencies in the way research is supported at the university-level and the way knowledge and intellectual property is marketed and distributed.

The research framework identifies seven distinct products of research universities: (1) education, (2) contract research, (3) cultural products, (4) trained labor, (5) technology diffusion, (6) new knowledge creation, and (7) new products and industries.

The policy variable used in this chapter, total university R&D expenditures in technology-related fields, represents the resource (input) that generates three major university products (outputs): new knowledge, new products and industries, and contracted research. The policy variable is operationalized across research fields and across universities within an MSA.

The operationalization of the policy variable as the accumulation of R&D expenditures in a single research field aims to test the hypothesis on the specialization of research within a single area of research expertise. This variable is designated to capture economies of scale. Summing research expenditures across all research fields in a region is designed to capture, and is best suited for economies of scope.

There are three research questions addressed in this chapter:

- Do both the scale and the scope of university R&D expenditures in technology-related fields in a metropolitan area have an impact on regional economic outcomes?
- How do the scale and the scope of university R&D expenditures in technology-related fields impact regional outcomes in comparison with industry R&D spending?
- How does regional industrial organization influence the transformation of university R&D expenditures in technology-related fields into regional growth?

Hypotheses

The first set of hypotheses in this chapter tests for economies of scale of university R&D expenditures. That is, it tests for the existence of positive economic spillovers from

expenditures in a single technology-oriented field of research across all universities in a metropolitan area.

- (H_{1o}) The concentration of university R&D expenditures within a single technology-generating field within a region (scale of R&D) has no positive effect on change of regional employment and gross metropolitan product.
- (H_{11}) The concentration of university R&D expenditures within a single technology-generating field within a region (scale of R&D) has a positive effect on change of regional employment and gross metropolitan product.

The second hypothesis tests for the hypothesized impact of economies of scope of academic research. It tests for existence of positive economic spillovers produced by the sum of university R&D expenditures across of technology fields in all universities in a metropolitan region.

- (H_{2o}) The scope of university R&D expenditures across an array of technology-generating fields within a region has no positive effect on change of regional employment and gross metropolitan product.
- (H_{21}) The scope of university R&D expenditures across an array of technology-generating fields within a region has a positive effect on change of regional employment and gross metropolitan product.

The third hypothesis addresses the influence of regional industrial organization on the process of transforming university and industry R&D expenditures into regional economic outcomes:

- (H_{30}) The characteristics of regional industrial organization have no effect on the way university and industry R&D expenditures influence the change of regional employment and gross metropolitan product.
- (H_{31}) The characteristics of regional industrial organization affect the way university and industry R&D expenditures influence the change of regional employment and gross metropolitan product.

These three sets of hypotheses are tested with cross-sectional regression models that include university R&D expenditures as policy variables. The percentage change in total employment and gross metropolitan product (GMP) are the dependent variables. The other independent variables include industry R&D expenditures, variables describing regional industrial organization, and path-dependency variables that reflect the long-term trend of regional development. The path-dependency variables absorb the effect of path dependencies.

Research Model

The general form of the model is:

$$\underbrace{RO_j}_{\text{Regional outcomes}} = \alpha_0 + \underbrace{\alpha_1 UR_j + \alpha_2 PR_j}_{\text{Policy variables}} + \underbrace{\alpha_3 E_j + \alpha_4 RCM_j + \alpha_5 RS_j + \alpha_6 RD_j + \alpha_7 RL_j}_{\text{Regional Industrial Organization}} + \underbrace{\alpha_8 H_j}_{\text{Path dependency}} + e_{ij} \quad (1)$$

where:

- RO_j is percentage change in employment or gross product in region j.

- UR_j is university R&D expenditures in region j.
- PR_j is industrial R&D expenditures in region j.
- E_j is a variable characterizing the level of entrepreneurship in region j.
- RCM_j is the level of competition in region j.
- RS_j is the industrial specialization of the regional economy.
- RD_j is the industrial diversification of the regional economy.
- RL_j reflects the presence of establishments with more than 1,000 employees (approximates a presence of large companies) in region j.
- H_j is lagged dependent variables that are referred to as path dependency represented by variables that reflect the previous performance of region j.

The policy variable UR_j is total university R&D expenditures that approximate an input resource that creates university products, such as contract research, technology diffusion, new knowledge creation, and new products and industries. This policy variable is operationalized by two R&D variables, high score average (HSA) and sum score average (SSA).

The high score variable reflects the scale of university R&D expenditures within a single technology-related research field and is calculated as a summation of all R&D expenditures in that field across all universities within a metropolitan area that have this

field of research. Due to a high volatility of R&D expenditures over time, this variable is calculated as an annual average during the period of time from 1987 to 1997:[34]

$$HSA_j = Max_f \left(\frac{\sum_{t=1}^{11} \left(\sum_{p=1}^{P} ur_{pf} \right)}{11} \right)_{\forall f}, \qquad (2)$$

where j – metropolitan statistical area, j=1, …, 361; f – field of university research programs, f=1, …, 14; p – individual research program in a metropolitan area, p=1, …, P; and t – period of time during which the average of university R&D expenditures was calculated, from 1987 to 1997, t=1, … 11.

The sum score variable reflects the scope of university R&D expenditures across all 14 technology-related fields and is calculated as a summation of all R&D expenditures across all 14 fields and across all universities within a metropolitan area. This variable is also calculated as an annual average during the period of time from 1987 to 1997.

The sum score was calculated as:

$$SSA_j = \sum_{f=1}^{14} \left(\frac{\sum_{t=1}^{11} \sum_{p=1}^{P} ur_{pt}}{11} \right). \qquad (3)$$

These variables are calculated across 14 selected scientific and technology fields most often affiliated with technology-based economic development. These fields are:

1. Aeronautical and Astronautical Science

[34] According to The National Science Foundation (NSF) Survey of Research and Development Expenditures at Universities and Colleges, there was a major break in data between 1997 and 1998 due to a change in the methodology of collecting academic R&D expenditures. The data before 1997 and after 1998 are not comparable. http://webcaspar.nsf.gov

2. Bioengineering/Biomedical Engineering
3. Chemical Engineering
4. Electrical Engineering
5. Mechanical Engineering
6. Metallurgical and Materials Engineering
7. Materials Engineering
8. Chemistry
9. Physics
10. Other Physical Sciences
11. Computer Sciences
12. Biological Sciences
13. Medical Sciences
14. Other Life Sciences.

More methodology details on calculating model variables are available in Appendix B. The hypotheses are tested by running cross-sectional multiple regression models on a universe of 361 metropolitan statistical areas using December 2003 boundary definition.[35]

Data

The source of data for calculating the policy variables is the National Science Foundation (NSF) Survey of Research and Development Expenditures at Universities and Colleges, which is conducted annually by the NSF Division of Science Resources

[35] OMB Bulletin No. 03-04. Statistical and Science Policy Branch, Office of Information and Regulatory Affairs, Office of Management and Budget.

Statistics (SRS). The universe of the NSF survey of R&D expenditures at universities and colleges[36] in 14 science and technology-related fields includes about 550 universities annually. While the list of universities responding to this survey changes every year, the population of universities that responded to this survey at least once between 1987 and 1997[37] is greater than any number of universities that responded to this survey for any given year. Removing from the population those universities that had annual total R&D expenditures below $100,000[38] in any year between 1987 and 1997 brought the count of research universities included in the database for the calculation of SSA and HSA to 742. The descriptive statistics of the policy variables and the dependent variables are presented in Table X.

Table X. Descriptive Statistics on the Policy and Dependent Variables

	Variables		Max	Min	Mean	St Dev
Policy Variables	University R&D, $1,000	SSA8797	1,324,169	0*	60,294	153,249
		HSA8797	444,944	0*	21,007	55,539
	Industry R&D Change, %	1987-1997	1,261.8	-84.2	93.7	200.2
Dependent Variables	Employment Change, %	1998-2004	43.5	-10.9	5.6	7.7
		1998-2001	19.5	-8.9	4.0	4.2
		2002-2004	5.9	-15.1	-1.6	3.3
	Gross Metropolitan Product Change, %	1998-2004	51.6	-7.1	17.1	10.4
		1998-2001	30.2	-14.1	6.0	6.2
		2002-2004	21.9	-3.9	7.3	3.9

*Metropolitan areas that do not have research universities or have universities that did not pass a threshold of $100,000 in annual R&D are considered as having zero average R&D expenditures (SSA and HSA).

[36] Collected from the Integrated Science and Engineering Resource Data System maintained by the National Science Foundation (NSF) at the Library of Congress WebCASPAR, http://webcaspar.nsf.gov
[37] The methodology of collecting university R&D data by NSF's university survey changed in 1998, which makes it impossible to compare 1988 data to previous years.
[38] Measured in nominal dollars of the assessment year.

The New York MSA has the highest average cumulative R&D expenditures (SSA) during the time period from 1987 to 1997 ($1.3 billion). It is followed by Baltimore and Boston, both with more than $1 billion in average annual R&D expenditures ($1.1 billion and $1.0 billion, respectively). Following these three metropolitan areas, four other MSAs (mentioned in decreasing order of their total R&D expenditures) are Los Angeles, San Francisco, Chicago, and Philadelphia (with Los Angeles spending $894 million and Philadelphia $531 million). The highest variance among these seven top metropolitan areas is observed in New York and Los Angeles.

While the high score (HSA) variable is a part of the sum score (SSA), the top metropolitan areas identified based on the largest R&D expenditures in a single field of research are the same metropolitan areas with the largest scope of total R&D expenditures across all technology-related fields of research. Nine of the top ten metropolitan areas have the largest scale of R&D expenditures in Medical Science research. The largest amounts of average annual R&D spending on university research in this field occurred in New York ($445 million), San Francisco ($401 million), Los Angeles ($385 million), and Baltimore ($296 million). Boston, Philadelphia, Chicago, Houston, and Durham, (NC), formed the next group of technical research giants. Their total R&D spending across all universities in each metropolitan area ranged from $213 to $248 million. The highest variance within these seven metropolitan areas is experienced by San Francisco, Los Angeles, and Baltimore. University R&D expenditures in metropolitan regions are complemented by industry R&D spending.

The biggest relative change in imputed industry R&D expenditures was not experienced by the largest metropolitan areas.[39] Among the total of 361 MSAs, 99 metropolitan areas more than doubled their imputed industry research funding from 1987 to 1997,[40] and only 18 were among the 100 largest metropolitan areas.[41] The large-to-medium sized metropolitan areas with the biggest increase in imputed industry R&D expenditures were Trenton (NJ), Colorado Springs (CO), Portland (OR-WA), Idaho Falls (ID), Raleigh (NC), and Worcester (MA).

Imputed industry R&D expenditures are the product of two variables – industry R&D at the state level and employment in the Science Research and Development Services industry at the county level. The two-step calculation of industry R&D expenditures included: (1) distributing state R&D expenditures to the county level using the distribution of employment in the Science Research and Development Services industry (NAICS 5417) of each county; and (2) summing county industry R&D expenditures to MSA industry R&D expenditures using the 2003 definition of U.S. metropolitan statistical areas. Therefore, the changes of industry R&D expenditures at the MSA level do not necessarily reflect the increase of total amount of industry R&D

[39] Industry R&D expenditures at the state level (Source: The National Science Foundation, Survey of Industrial Research and Development, http://www.nsf.gov/statistics/srvyindustry) were distributed at the level of U.S. counties using the distribution of employment in the industrial sector Science Research and Development Services (NAICS 5417) (Source: Moody's Economy.com), which includes scientists and technicians that are employed by private industry. From the county level the industry R&D expenditures were aggregated to the level of U.S. metropolitan statistical areas using 2003 definition of metropolitan areas.

[40] Industry research funding addresses industrial R&D expenditures, which do not include the fraction of university R&D spending funded by private industry. The classification of R&D expenditures used in this research refers to the classification by institutions that perform research and not by the institutions that provide funding.

[41] Industry R&D expenditures were distributed by Science Research and Development Services employment (NAICS 5417) and two variables contributed to the increase: total industrial R&D funds at the state level and total NAICS 5417 employment.

spending or changes in productivity of private R&D sector. It might be a result of decreased employment in the Science Research and Development Services industry.

Metropolitan areas with the largest scores in university research (SSA) and the change of industrial research during the time period from 1987 to 1997 are ranked in Table XI.

Table XI. Ten Top Metropolitan Areas in University and Industrial R&D Expenditures

MSA Name	University R&D			Industrial R&D		
	1987	1997	1987-1997[1]	1987	1997	1987-1997[2]
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
New York-Northern New Jersey-Long Island, NY-NJ-PA	1	1	1	1	1	9
Baltimore-Towson, MD	2	2	2			
Boston-Cambridge-Quincy, MA-NH	3	3	3	4	7	
Los Angeles-Long Beach-Santa Ana, CA	4	4	4	2	4	
San Francisco-Oakland-Fremont, CA	5	5	5	9	5	3
Chicago-Naperville-Joliet, IL-IN-WI	6	6	6	7	8	
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	7	7	7	6	9	
Houston-Baytown-Sugar Land, TX		9	8			
San Jose-Sunnyvale-Santa Clara, CA	8		9	8	6	5
Washington-Arlington-Alexandria, DC-VA-MD-WV			10			10
Atlanta-Sandy Springs-Marietta, GA		8	(12)			
Madison, WI	10		(13)			2
Durham, NC		10	(14)			8
San Diego-Carlsbad-San Marcos, CA			(15)	5	3	6
Ithaca, NY	9		(16)			1
Seattle-Tacoma-Bellevue, WA			(19)	10	10	4
Detroit-Warren-Livonia, MI			(56)	3	2	7

[1] MSAs are sorted by rank on the main policy variable -- sum score average from 1987 to 1997

[2] Relative rank among MSAs that are in the top 10 at least in one other category

The 17 metropolitan areas listed in the table are ranked in the top ten by university or by industry R&D expenditures. They are sorted in the table by the sum score of university R&D spending (column 4). The top seven metropolitan areas

identified by the largest university R&D spending did not change their ranking over time. The San Jose, Ithaca and Madison MSAs, which were ranked 8th, 9th, and 10th in 1987, were replaced in the list by Atlanta, Houston, and Durham. The West Coast metropolitan areas create a contiguous region with high level of industry R&D expenditures. If Combined Statistical Areas were used as a unit of analysis, more MSAs from the West Coast would be at the top of this list.

Seven metropolitan areas on the list had high levels of both academic and industry R&D expenditures. Baltimore and Houston have only larger university R&D spending, while San Diego, Seattle, and Detroit are led by private sector R&D expenditures. Interestingly, metropolitan Washington DC did not score high in any individual year in terms of university or industry R&D expenditures, but gained 10th position in both over time due to its consistent funding.

The dependent variables have high variance across the universe of metropolitan areas (Table X). The largest variances in the percentage change in employment are observed for the entire time period included in the statistical model, from 1998 to 2004. It is followed by the change during the expansion phase of the business cycle (1998-2001), which is also almost four times larger than the maximum of employment change during the contraction phase (2002-2004). Changes in gross metropolitan product (GMP) showed similar patterns; the greatest variance was observed over the entire time period (from a maximum of 51.6 to a minimum of -7.1), followed by the variance in the expansion phase of the business cycle (from 30.2 to -14.1).

Comparing the two dependent variables, change in GMP experiences larger fluctuations across metropolitan areas over time than regional employment. The means

and standard deviations for GMP are larger in both phases of the business cycle and they are comparable to the means and standard deviations of employment variables over the entire time period. These dynamics reflect greater elasticity of employment to economic fluctuations. When the economy goes into recession, employers in private industry tighten their staff and increase productivity trying to retain their market shares of GMP. The cyclical changes do not affect GMP as much as employment, especially in the regions with growing economies. The change of means in GMP from the expansion phase to the contraction phase of the business cycle was only 22% (from 6.0 to 7.3), while the similar measure of employment changed 140% (from 4.0 to -1.6).

The absolute change in the dependent variables depends on the size of the metropolitan area (Appendix D, Table D-1). After dividing the universe of metropolitan areas into five groups according to the natural breaks in their population size distribution, the largest metropolitan areas showed the most stability in regard to changes in their economic outcomes. The first group includes the 12 largest MSAs, which, due to their size, have more diversified economies and more stable employment and GMP. Population groups two and three account for 29 and 36 metropolitan areas respectively, and show increased volatility in terms of employment and GMP. The last two MSA groups, which account for 76 and 208 metropolitan areas, had the largest variance and standard deviation from their group mean of the dependent variables, especially with respect to employment changes.

Taking into account all of the descriptive characteristics of the policy variables and dependent variables, the following section presents the statistical results of modeling

the influence of university R&D expenditures on total employment and gross metropolitan product.

3.4. Impact of University R&D Expenditures on Regional Employment over the Business Cycle

University R&D expenditures show an economically meaningful and statistically significant effect on the percentage change in total regional employment over the different phases of the business cycle (Table XII). The strongest impact of university R&D expenditures on employment growth is observed during the expansion phase of the business cycle from 1998 to 2001. Both university R&D variables – the sum score of total R&D expenditures across all 14 technology-related fields of research across all universities in a metropolitan area (SSA8797) and the high score of R&D expenditures in a single technology-related field across all universities in a metropolitan area (HSA8797) – are statistically significant above the 99% critical value and are positively associated with the percentage change of total employment across the universe of the metropolitan areas in the United States. The university R&D policy variables have positive coefficients in the regression equations and, together with other variables, explain more than 40% of variation in the dependent variables.

The positive impact of the scope and scale of university research are reinforced by the strong positive association of industry R&D expenditures (IRD8797) with employment growth in this phase of the business cycle (with positive slope coefficients of the regression and statistical significance above the 99% critical value). It is

Table XII. Impact of University R&D Expenditures on Regional Employment

Variable			Dependent Variable: percentage change of employment:					
			1998-2001		2002-2004		1998-2004	
Constant		Coefficient	-1.255	-1.343	1.305	1.293	-4.481	-4.544
POLICY VARIABLES								
Sum score average of university R&D expenditures 1987-97	SSA8797	Coefficient	0.000006		0.0000038		0.0000024	
		t-statistic	3.700***		2.498**		0.754	
High score average of university R&D expenditures 1987-97	HSA8797	Coefficient		0.000014		0.000011		0.0000024
		t-statistic		2.897***		2.468**		0.263
Industry R&D Spending, percentage change 1987-1997	IRD8797	Coefficient	0.003	0.003	0.001	0.001	0.003	0.003
		t-statistic	3.112***	3.107***	0.937	0.939	1.685*	1.679*
REGIONAL INDUSTRIAL ORGANIZATION VARIABLES								
Ratio of regional business establishments to U.S. business establishments, percentage change 1988-1997	COMP8897	Coefficient	0.091	0.089	-0.052	-0.055	0.145	0.143
		t-statistic	3.258***	3.126***	-2.061**	-2.177**	2.722***	2.695***
Number of large establishments, 1988	LRG88	Coefficient	-0.015	-0.011	0.001	0.001	-0.023	-0.018
		t-statistic	-2.149**	-1.529	0.091	0.107	-1.730	-1.333
Single-establishment start-ups normalized by population, 1990	ENT90	Coefficient	0.096	0.091	-0.039	-0.045	0.193	0.192
		t-statistic	2.581**	2.393**	-1.173	-1.349	2.742***	2.725***
Industrial Specialization, 1987	SP87	Coefficient	-0.037	-0.034	0.019	0.021	-0.053	-0.050
		t-statistic	-1.839*	-1.640	1.025	1.148	-1.363	-1.315
Industrial Diversification, 1987	DV87	Coefficient	0.011	0.014	-0.027	-0.025	0.048	0.049
		t-statistic	0.236	0.295	-0.655	-0.605	0.545	0.558
PATH-DEPENDENCY VARIABLES								
Employment growth rate 1982-1986	E8286	Coefficient	0.109	0.113	-0.041	-0.041	0.202	0.205
		t-statistic	5.331***	5.441***	-2.186**	-2.190**	5.241***	5.315***
Employment growth rate 1987-1991	E8791	Coefficient	0.137	0.138	-0.041	-0.044	0.247	0.269
		t-statistic	5.231***	5.136***	-1.694**	-1.832*	5.383***	5.407***
Employment growth rate 1992-1997	E9297	Coefficient	0.100	0.104	-0.082	-0.081	0.191	0.192
		t-statistic	3.537***	3.602***	-3.210***	-3.127***	3.561***	3.556***
Employment growth rate 1998-2001	E9801	Coefficient			-0.193	-0.172		
		t-statistic			-4.049***	-3.679***		
		R Square	0.430	0.421	0.298	0.291	0.408	0.409
		Adjusted R square	0.414	0.405	0.275	0.268	0.391	0.392

* significant at the .10 confidence level ** significant at the .05 confidence level *** significant at the .01 confidence level
Number of observations metro group = 361

impossible to conclude that industry research follows university R&D spending, considering simultaneity of university and industry R&D expenditures in this model. The positive association between regional employment growth and the two variables that capture regional industrial organization, regional competition (defined as *the change in the ratio of regional business establishments to U.S. business establishments*), and entrepreneurial culture (defined as *single-establishment start-ups normalized by population*), suggests that the more business establishments a region has compared to the nation and the greater number of new start-ups that are formed in a region, the more successful the region is at transforming university R&D expenditures into employment growth. These two variables have positive and statistically significant effects on the percentage change of total employment in both equations– the equation that includes the sum score (university R&D expenditures summed across all technology-related fields of research across all universities within a metropolitan area) and the equation that includes the high score (university R&D expenditures summed across a single technology-related field of research across all universities within a metropolitan area).

Two other variables that capture regional industrial organization, the presence of large companies in a region (approximated in the model as the number of establishments with more than 1,000 employees) and the concentration of employment within the five largest industries (which approximates industrial specialization), are negatively associated with employment growth when a metropolitan area's university R&D expenditures are operationalized by the sum score average. The statistical results of the model on the scope of academic research suggest that as more large companies are located in an area, the less likely regional employment will grow when compared to

metropolitan areas with a smaller number of large companies.[42] Since the correlation between changes in the industry R&D spending from 1987 to 1997 and the number of large establishments in metropolitan areas in 1987 is negative and weak (only 8%), the presence of large companies is not likely to explain private R&D changes that relate to the economic business cycle.

The negative association between the high concentration of regional employment in the five largest industries is consistent with Glaeser, Kalla, Schenkman, & Shleifer's (1992) results and their argument that economic diversification, and not specialization, better contributes to economic growth. However, the results of statistical models in this research does not support Glaeser et al.'s (1992) hypothesis about the positive association of economic diversification and regional employment growth; the economic diversification variable is not statistically significant across all models.

Neither *the number of large establishments* nor *the concentration of employment within the five largest industries* are statistically significant in the model of the academic research scale policy variable. It reinforces the previous argument suggesting that even in case of specialized academic research, co-location of research universities and large companies that consume their research product is not a dominant mode of economic interaction.

[42] In 1987, the correlation between the number of large establishments and industry R&D expenditures was 89%, and the correlation between the sum score average of university R&D spending from 1987 to 1997 and the high score average of university R&D spending during 1987-1997 was 75% and 76%, respectively. Such a high level of correlation suggests that the number of large establishments correctly approximates the presence of big companies that are more likely to have an internal research and development functions and, therefore, more likely to have greater R&D expenditures. However, a high correlation of number of large establishments and university R&D expenditures with the population of metropolitan areas suggests simultaneity and not causality between these two variables in the model. The model does not exclude a possible causal relationship between the location of large companies and universities, but it is structured in a way that does not allow disproving the opposite hypothesis. The high correlation between the university policy variables and the presence of large companies simply suggests that universities and large companies are both likely to locate in larger metropolitan areas.

Strong universities with large research capacity and sizable R&D expenditures positively affected the change of employment through the contraction phase of the business cycle. This happens both where university research is specialized in a single technology area and where there is an accumulation of strong university research fields across a number of research universities in a region. Both policy variables, sum score and high score, are positively associated with the employment change variable and hold their statistical significance during the contraction phase of the business cycle, from 2002 to 2004. The positive association of academic research variables with employment changes in the contraction phase of the business cycle implies that employment was declining in MSAs where university R&D expenditures were falling and the reverse, metropolitan employment was growing in regions with increases in university R&D expenditures. The regression coefficients of the policy variables during the contraction phase of the business cycle are significantly smaller than those in the expansion phase.

The regression results for the contraction phase of the business cycle show that both policy variables (SSA and SSH) are statistically significant. Among all independent variables that characterize regional industrial organization, only the variable describing the level of competition in a region (operationalized as *the change in the ratio of regional business establishments to U.S. business establishments*) is statistically significant and has a negative coefficient in the regression equation. The negative regression coefficients of this variable in the equations with both policy variables suggest that tighter regional competition yields greater employment losses in the region. Neither change in industry R&D spending nor other independent variables that capture regional industrial organization are statistically significant in equations describing the contraction phase of

the business cycle. Lagged dependent variables are statistically significant and negatively associated to dependent variables in these equations.

The pattern of statistical significance of the policy variables, regional industrial organization variables, and the lagged dependent variables, is different during the expansion and contraction phases of the business cycle. Over the entire time period, from 1998 to 2004, the policy variables show no statistical significance in their association with the dependent variables, and the slope coefficients of the regression equations of the two policy variables appear to average the coefficients from the two phases. The percentage change of industry R&D expenditures remains statistically significant but only barely crosses the threshold of the 90% critical value. The variables describing regional industrial organization reflect the pattern of statistical significance and the sign of the expansion phases of the business cycle.

The path-dependency variables also show a distinct pattern. The path dependencies in employment growth models are statistically significant and positive during the expansion phase of the business cycle and over the entire time period (the critical value of the lagged values of employment growth rate exceeds 99%). They are strong, negative, and statistically significant during the contraction phase of the business cycle. During the contraction phase, the two most recent employment segments have the statistical association and largest impact on the dependent variables, exceeding the 99% critical value (employment growth rates from 1992 to 1997 and from 1998 to 2001). The pattern of the path-dependency variables suggests that, during the expansion phase of the business cycle, employment growth was occurring in regional economies that grew during the previous years, going back to 1982.

The consistent statistical significance of the path-dependency variables in all models indicates that economic momentum captured by these variables is associated with the increase in total employment in the expansion phase and over the entire time period (having positive signs of regression coefficients in these equations), and the decline in employment during business downturns and economic restructuring (having negative coefficients of path-dependency variables). It confirms that the effect of scope and scale of university R&D expenditures on employment growth is a departure from the long-term regional trend of growth and verifies that the departure from the regional trend is not simply due to cyclical economic fluctuations.

The difference in the patterns of statistical significance and signs of the coefficients of regression suggests structural differences in the equations that describe the two phases of the business cycle. Hill and Lendel (2007) compared equations describing employment changes during the expansion and contraction segments of the business cycle to determine if there were structural differences in employment growth during the two phases of the business cycle. They found statistical evidence that different employment structures existed in the two portions of the business cycle. In addition, in the model of employment growth and per capita income growth, the different relationships between the policy variables and the lagged dependent variables was also observed and is disclosed below.

3.5. Impact of University R&D Expenditures on Gross Metropolitan Product over the Business Cycle

The results for the impact of university R&D expenditures on the percentage change of GMP over the different phases of the business cycle appear to be very different from the results for employment change. Across the universe of U.S. metropolitan areas, the policy variables show economically meaningful and positive effects on GMP growth during the expansion phase of the business cycle (Table XIII). Both policy variables exceeded the 99% critical value and illustrated that for every percentage point increase in the policy variable *sum score average* (the scope of university R&D expenditures across all technology-related fields of research across all universities within a metropolitan area), the growth rate of GMP increased 0.00001 percentage points. The similar gain from the every percentage point increase in *high score average* (scale of university R&D expenditures in a single technology-related field of research across all universities within a metropolitan area) was 0.000025 percentage points.

Very similar gains in GMP are associated with the policy variables in regression equations over the entire time period. The policy variables were statistically significant at the 95% critical value for the sum score average and at the 90% critical value for the high score average. For the contraction phase of the business cycle, from 2002 to 2004, the policy variables were not statistically significant and their coefficients in regression equations were negative.

Table XIII. Impact of University R&D Expenditures on Gross Metropolitan Product

Variable			Dependent Variable: percentage change of GMP:					
			1998-2001		2002-2004		1998-2004	
Constant		Coefficient	-8.352	-8.319	0.306	0.293	-11.681	-11.607
POLICY VARIABLES								
Sum score average of university R&D expenditures 1987-97	SSA8797	Coefficient	0.00001		-0.000002		0.00001	
		t-statistic	3.554***		-1.005		2.085**	
High score average of university R&D expenditures 1987-97	HSA8797	Coefficient		0.000025		-0.000005		0.000026
		t-statistic		2.991***		-0.877		1.916*
Industry R&D Spending, percentage change 1987-1997	IRD8797	Coefficient	0.001	0.0015	-0.0013	-0.001	0.000011	0.000023
		t-statistic	0.930	0.963	-1.232	-1.261	0.0001	0.009
REGIONAL INDUSTRIAL ORGANIZATION VARIABLES								
Ratio of regional business establishments to U.S. business establishments, percentage change 1988-1997	COMP8897	Coefficient	7.165	6.976	5.386	5.424	17.193	17.021
		t-statistic	3.777***	3.660***	4.124***	4.165***	5.501***	5.466***
Number of large establishments, 1988	LRG88	Coefficient	-0.023	-0.0178	-0.0026	-0.0011	-0.0335	-0.0314
		t-statistic	-1.891*	-1.474	-0.032	-0.137	-1.707*	-1.588
Single-establishment start-ups normalized by population, 1990	ENT90	Coefficient	0.257	0.256	0.0046	0.0077	0.313	0.312
		t-statistic	4.016***	3.963***	0.103	0.174	2.969***	2.953***
Industrial Specialization, 1987	SP87	Coefficient	0.012	0.0169	0.0152	0.0150	0.0802	0.0890
		t-statistic	0.343	0.486	0.652	0.646	1.409	1.517
Industrial Diversification, 1987	DV87	Coefficient	0.012	-0.0072	-0.0040	-0.0056	-0.0155	-0.0125
		t-statistic	-0.146	-0.090	-0.075	-0.105	-0.120	-0.096
PATH-DEPENDENCY VARIABLES								
GMP growth rate 1998-2001	GP9801	Coefficient			0.113	0.107		
		t-statistic			3.145***	2.992***		
GMP growth rate 1987-1997	GP8797	Coefficient	0.0325	0.000025	0.0021	0.0199	0.0974	0.0985
		t-statistic	2.042***	2.991***	1.931*	1.845*	3.721***	3.771***
		R square	0.254	0.249	0.174	0.17	0.292	0.291
		Adjusted R square	0.237	0.232	0.152	0.148	0.276	0.275

* significant at the .10 confidence level ** significant at the .05 confidence level *** significant at the .01 confidence level
Number of observations metro group = 361

This pattern of statistical significance and change in the signs of the slope coefficients suggests that university R&D expenditures are associated with the increase of GMP when the economy is growing, both in the short run during the expansion phase of the business cycle (from 1998 to 2001) and in the long run (the entire period of study, from 1998 to 2004). The policy variables were not associated with changes of GMP during the contraction phase of the business cycle (2002-2004). The trend variables for these two time periods are positive and statistically significant at the 99% critical value, which ensures that changes in the dependent variable are not simply a result of the path dependencies in regional economies.[43] It suggests that additional growth of GMP can be attributed to the impact of scale and scope of university R&D expenditures and the other independent variables.

The regional industrial structure variables affect GMP in ways that are similar to their association with employment growth. Regional economies with relatively more establishments compared to the national level (approximating competition) and with a greater number of single-establishment start-ups (approximating the regional entrepreneurial culture) are associated with positive GMP growth. The number of large establishments in a region (approximating the presence of large companies) is negatively associated with changes in GMP during periods of economic growth.

The two variables that characterize regional industrial structure, *the change in the ratio of regional business establishments to U.S. business establishments* and the *single-establishment start-ups normalized by population,* were statistically significant at the

[43] The model with the GMP trend variables structured across the segments of the business cycle, i.e. 1982-1986, 1987-1991, 1992-1997 did not yield reliable results. This is consistent with the point many economists make when they argue that the dollar-value economic indicators such as per capita income and gross regional product have a longer period of path dependence and better explain long-term trends when structured over at least a 10-year period.

99% critical value and had a positive slope coefficient with both policy variables. These results were true not only for the expansion phase of the business cycle, but also for the equations describing the entire time period. The presence of large companies specified as *the number of establishments with more than 1,000 employees* was statistically significant at the 90% critical value and had a negative slope coefficient in both time periods but, similar to the models on employment change, only in equations with the scope of academic research. It appears that the metropolitan areas with more large establishments are less successful at transforming university R&D into growth of GMP than metropolitan areas with fewer large companies.

The percentage change of industry R&D is not statistically significant in any of the equations with GMP as a dependent variable. The imputed nature of industry R&D expenditures reflects employment in the private R&D sector, which might cause this variable to carry employment-type properties, i.e., to reflect the employment structure of the research enterprise but not its productivity and value-generating capacity.

The models measuring change in metropolitan product during the contraction phase of the business cycle have the least explanatory power (explaining only 15% of a variation in the dependent variable) and had the fewest statistically significant independent variables. The change in ratio of regional business establishments to U.S business establishments (approximating level of competition in regional economies) is very strong and statistically significant in both equations and it is positively related to GMP change. The strongest predictive variable for the GMP change during the contraction phase of the business cycle (2002-2004) is the path-dependency variable

operationalized as a lagged dependent variable over the time period immediately preceding the dependent variable change (1998-2001).

The dissimilarities in the patterns between equations describing growth periods of the economy and the contraction phase suggest that the different structures of the models are at work. The significant decline in the explanatory power of the models (23-28% for the expansion phase and the entire time period and 15% for the models describing the contraction phase of the business cycle) also testify to the structural differences of the GMP models.

3.6. Comparison of the Impact of University R&D Expenditures on Employment and Gross Metropolitan Product over the Business Cycle

Examining the pattern of statistical significance across all of the equations helps to assess the robustness of the statistical results (Table XIV). The policy variables hold their statistical significance in a majority of the models, including all of the models describing the expansion phase of the business cycle. This indicates the strong influence of university R&D expenditures on regional economies. Sum score and high score are statistically significant in the employment models over the contraction phase of the business cycle. This result illustrates that research universities help to retain regional employment through the periods of cyclical decline. The significance of the policy variables in the models of GMP over the entire time-period studies indicates that regional economies that house research universities grew at a faster rate than the average. There

Table XIV. Statistical Significance of Independent Variables in the University R&D Expenditures Impact Models

Variable	Variable Name	Dependent Variables, Percentage Change											
		1998-2001				2002-2004				1998-2004			
		Empl	GMP	Empl	GMP	Empl	GMP	Empl	GMP	Empl	GMP	Empl	GMP
POLICY VARIABLES													
Sum score average of university R&D expenditures 1987-97	SSA8797	***	***			**					**		
High score average of university R&D expenditures 1987-97	HSA8797			***	***			**					*
Industry R&D Spending, percentage change 1987-1997	IRD8797	***		***						*		*	
REGIONAL INDUSTRIAL ORGANIZATION VARIABLES													
Ratio of regional business establishments to U.S. business establishments, percentage change 1988-1997	COMP8897	***	***	***	***	**	***	***	***	***	***	***	***
Number of large establishments, 1988	LRG88	**	*								*		
Single-establishment start-ups normalized by population, 1990	ENT90	**	***	**	***					***	***	***	***
Industrial Specialization, 1987	SP87	*											
Industrial Diversification, 1987	DV87												
PATH-DEPENDENCY VARIABLES		***	***	***	***	***	***	***	***	***	***	***	***
R Square		0.430	0.254	0.421	0.249	0.298	0.174	0.291	0.170	0.408	0.292	0.409	0.291
Adjusted R square		0.414	0.237	0.405	0.232	0.275	0.152	0.268	0.148	0.391	0.276	0.392	0.275

* significant at the .10 confidence level ** significant at the .05 confidence level *** significant at the .01 confidence level

Number of observations metro group = 361

are similarities in the patterns of statistical significance of independent variables and equations with interchangeable policy variables.

The industry R&D expenditures variable shows a different pattern of impact on regional economies across the models. This variable is extremely strong in the employment equations during the expansion phase of the business cycle (from 1998 to 2001) and, although the results are weaker, it is still statistically significant over the entire time period (from 1998 to 2004). The variable shows no impact on GMP in any of the models. It also shows no statistical significance in the employment and GMP equations over the contraction phase of the business cycle (from 2002 to 2004).

The greater share of private research is concentrated in large companies, and many of these companies tend to locate near prominent research universities in large metropolitan areas. These companies tend to finance university research or participate in joint university-industry research projects (Scibany, Schartinger, Plot, & Rammer, 2000). Therefore, it is reasonable to expect that the volume of research activities in university-industry projects and academic research funded by private industry have similar variation over time and add to the strength of the policy variables.

Industry R&D has limited impact on regional economic outcomes for a second reason – private businesses are more sensitive to market fluctuations and respond quickly with employment changes. This variation in companies' employment precedes changes in their output figures. Changes in companies' employment directly contribute to fluctuations in total regional employment before the impact of the changes shows in the regional metropolitan product. Finally, it is possible that the method used to estimate industry R&D expenditures at the metropolitan level may introduce a bias that causes this

variable to reflect employment fluctuations over time more than it reflects changes of GMP.

The pattern of the statistical significance of regional industrial organization variables suggests that the null hypothesis on the important role of the regional industrial organization factors for transforming university R&D expenditures into regional outcomes cannot be rejected. Among the five variables describing regional industrial organization in the models the null hypothesis cannot be rejected for competition *(ratio of regional business establishments to US business establishments)*, entrepreneurship *(single-establishment start-ups normalized by population)*, and presence of large companies *(number of large establishments)* variables. At the same time, the results disprove this hypothesis for the factors of industrial *specialization* and *diversification* of the regional economy. These results suggest that, in the average US metropolitan statistical area, the level of specialization and economic diversification of the regional economy does not influence the transformation of university research into regional economic outcomes of employment and gross product.

The pattern of statistical significance and the signs of the coefficients of the regression are most consistent for the variables approximating regional competition and entrepreneurial culture. Strong competition in the regional economy has an economically meaningful and positive association with growth in regional employment and an increase in GMP. Moreover, the changes of employment show greater sensitivity to the proxy for regional competition than the changes in GMP.[44]

[44] For example, from 1998 to 2001, one percentage point change in GMP is associated with a seven percentage point change in the proxy for regional competition, while the same change in employment was associated with less than one percentage point change in this variable.

The variable of single-establishment start-ups normalized by population (which approximates entrepreneurial culture) was strongly associated with employment and GMP change during the expansion phase of the business cycle and over the entire time period. It is not statistically significant in the models describing the contraction phase of the business cycle.[45]

The presence of large companies in a region, specified as the number of establishments with more than 1,000 employees, was statistically significant in only three of 12 models that describe change of employment and GMP.[46] The negative signs of the regression coefficients in this variable pointed to negative effects of large companies' presence in regional economies. The model does not differentiate between large companies with research potential and large employment establishments. Large establishments may provide many jobs but, at the same time, might negatively affect entrepreneurial culture, as well as cultural attitudes toward educational attainment.

Across all of the statistical tests, the research models explains between 15% and 41% of the variation in regional economic outcomes, with larger coefficients of regression in employment equations than in equations for the change in GMP.

[45] Similar to the variable that approximates competition, a 0.3 percentage point increase in *the level of single-establishment start-ups normalized by population* was associated with one percentage point change in GMP and only a 0.1 percentage point increase in employment. This variable exceeded the 99% critical value in all models describing the entire time period (1998-2004) and models of the expansion phase of the business cycle for employment growth. The models for GMP growth over the expansion phase of the business cycle show this variable statistically significant at the 95% critical value.

[46] This variable was statistically significant at the 95% critical value in the equation describing employment growth at the expansion phase of the business cycle with the association to the sum score average policy variable (the accumulation of multiple technology-related university research fields in a metropolitan area). The presence of large-employment establishments is statistically significant at the 90% critical value for two models of GMP growth: one in the expansion phase of the business cycle equation, and another – over the entire time period.

3.7. Impact of University R&D Expenditures

The findings of the statistical models tested in this chapter lead to the conclusion that academic research, when conducted in universities in large metropolitan environments, generates a number of desirable externalities. These externalities change the industrial structure of regional economies and lead to improved regional economic outcomes. There are two sources of regional growth: one that is based on the scale of academic research in a single technology-related area and one that is based on the scope of academic research in multiple areas of research relating to technology-based economic development.

The quantitative impact of university R&D expenditures on regional employment and GMP is calculated using the regression equation coefficients for the policy variables, the scope of academic research (sum score average of university R&D expenditures across all technology-related areas of research in all universities within a metropolitan area) and the scale of academic research in a single field (high score average of university R&D expenditures in a single research field across all universities within a metropolitan area) (Tables XV and XVI).

On average, across all metropolitan areas, one standard deviation increase in the sum score average of university R&D expenditures (SSA) fosters 3-year employment growth of 0.95 percentage points, nearly 0.33% per year in a growing economy. One standard deviation growth in the concentration of university R&D expenditures within a single field of research (HSA) increases 3-year employment growth by 0.90%, an annual increase of 0.30 percentage points. Similarly, one standard deviation growth in the

concentration of university research across all fields in a region yields a 3-year increase in GMP of $1.586 million or about $0.529 million a year. The concentration of university research within a single field of research in a region yields a 3-year increase in GMP of $1.363 million or about $0.454 million a year.

The impact of university R&D expenditures on GMP is almost the same using the model describing the expansion phase of the business cycle and the model describing the entire time period (Table XV and XVI). One standard deviation growth in the accumulation of research expenditures across multiple technology-related fields (SSA) yields a 3-year GMP increase of $1.589 million, or about $0.530 million annually. One standard deviation growth in the concentration of academic research expenditures in a single technology-related field (HSA) yields a 3-year increase of $1.363 million, or about $0.454 million annually.

University R&D expenditures create a greater impact on employment during the expansion phase of the business cycle, especially if the academic research spending is concentrated within a single area of technology-related research. One standard deviation increase in university R&D expenditures across multiple technology-related research fields yields a 3-year employment growth of 0.95% during the expansion phase of the business cycle (1998-2001), or about 0.32% annually. One standard deviation increase in the university R&D expenditures concentrated in a single field of research generates a 3-year employment growth of 0.90% during the expansion phase of the business cycle (1998-2001), or about 0.30% annually.

Table XV. Impact of University R&D Expenditures at One Standard Deviation Based on the Expansion Phase Model

Variable	Mean	Standard Deviation	Regression Coefficient, 1998-2001		Increment 1 Standard Deviation	
			Employment	GMP	Employment	GMP
POLICY VARIABLES						
Sum score average R&D	60,294	153,249	0.00000622	0.00001037	0.95	1.589
High score average R&D	21,007	55,539	0.0000139	0.00002454	0.90	1.363

Number of observations metro group = 361

Table XVI. Impact of University R&D Expenditures at One Standard Deviation Based on the Entire Time Period Model

Variable	Mean	Standard Deviation	Regression Coefficient, 1998-2004		Increment 1 Standard Deviation	
			Employment	GMP	Employment	GMP
POLICY VARIABLES						
Sum score average R&D	60,294	153,249	0.0000024	0.000010	0.37	1.532
High score average R&D	21,007	55,539	0.0000024	0.000026	0.90	1.444

Number of observations metro group = 361

3.8. Conclusions

Since the mid-1980s, growth in metropolitan economies has been greater in locations with prominent research universities. Known as hubs of research, these cities attracted businesses that located near their universities, encouraged graduates to pursue science careers, and built a foundation for the regional economies that allowed faster growth than the national average. Research universities that were ranked by the NSF survey as the institutions with the most R&D spending responded to the growing demand for innovation; they created a set of university products that includes the generation of *new knowledge*, *new products* and *new industries.* To do this they had to develop mechanisms that *commercialized inventions*, performed *contract research*, and educated *graduates* with technical skills.

The models discussed in this chapter demonstrate the successful impact of the university products on regional economies. The statistical results show that during times of economic growth, academic research and the university products associated with that growth converted more effectively into economic outcomes. These results are amplified in regions with a strong competitive and entrepreneurial culture that encouraged private companies to adopt university products. The final result is growth in the final demand for regional labor and increased GMP.

Comparing the segments of the business cycle, the demand for university products is the strongest during the expansion phase. The attractiveness of university products encourages greater funding of academic research and, as a result, growth of employment and GMP due to their deployment and multiplier effects in their respective regional

economies. Growing businesses and high salaries of professors and scientists trigger spending for real estate and business and personal services, which guarantee steady regional growth.

When the economy declines, resources for R&D tighten and the demand for academic research diminishes. Economic decline not only affects university R&D expenditures directly, but it shrinks the multiplier effects that also transform university research products into regional economic outcomes. Economies with research universities maintain their employment more than the average metropolitan area.

Because economic returns change signs and significance during the two phases of the business cycle in the employment equations, the policy variables are not statistically significant in equations over the entire time period. However, regions with hubs of academic research perform better over the entire time period only in GMP.

During the expansion phase of the business cycle and over the entire time period, regional economies with more competitive environments and with a greater than average number of newly created companies can better absorb university products and enhance regional economic outcomes. The presence of large companies in a region makes this process more difficult, negatively affecting entrepreneurial culture. Another complexity in the process of transforming university R&D expenditures into regional outcomes is resulting from the cyclical economic fluctuations and volatility in university R&D funding.

University research has always been viewed as an important effort to create new knowledge, especially by conducting basic research. According to the annual Science and

Engineering report conducted by NSF,[47] since 1998, academia has accounted for more than half of the basic research performed in the United States. Spending $48 billion in 2006, academic institutions increased their share of R&D performance from 10% in the early 1970s to about 14% in 2006. The federal government pays for the majority of university R&D expenditures, accounting for 63% in 2006 and declining slightly after an increase from 58% to 64% between 2000 and 2004. In 2006, the latest year statistics are available for university R&D funding, the federal government failed to outpace inflation for the first time since 1982. However, the large share of federal funding in university R&D did not mitigate a decay of other sources in university R&D funding, especially a decline in industry funding that started in 2000 and continued to 2004.

As with most large enterprises, universities adjust to economic fluctuations. While they have abundant research resources during periods of economic growth, they tighten their research budgets during economic declines. The greatest assets of universities, their scholars and technicians and the continuity of research, are preserved during harder economic times. Overall, all of the equations indicate that long-term regional strategies aimed at creating hubs of university research helped to retain employment throughout the business cycle. These research hubs create positive long-term impacts on GMP.

Statistical models on the influence of research and development expenditures on regional growth emphasized the importance of strong research universities to technology-based economic development. Producing new knowledge, creating a highly skilled labor force, and conducting industry-relevant research, universities influence economic growth

[47] Science and Engineering Indicators 2008, Chapter 5: Academic Research and Development. Source: http://www.nsf.gov/statistics/seind08/c5/c5s1.htm, entered September 2, 2008.

through products deployed within regional economies. They strengthen the competitiveness of their regions by developing new knowledge via contracted research, creating new products and industries, and by improving cultural amenities and creating regional synergies through dialogs among important regional players.

University products that are highly dependant on university quality include technology diffusion, new market products and new industries, contracted research, and the creation of new basic knowledge. The capacity of universities to create these products should be the focal point of regional leadership and public policy officials. Public policy should create an environment highly favorable for regional innovation. Involvement of research universities in creating a regional competitive advantage must be central to that environment. State and local officials should consider making public investments in research capacities of universities, creating innovation and generating local demand. They should also provide continuous base-funding to universities that will help to meet that demand by producing highly skilled labor and enhancing human capital.

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APPENDICES

APPENDIX A

UNIVERSITY-BASED ECONOMIC GROWTH: LITERATURE REVIEW

University-Based Economic Growth

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Prepared for
The Routledge International Handbook of Higher Education

Introduction

Many public policies are based on the popular assumption that investment in university research and infrastructure benefits regional economies. After all, we live in a knowledge economy and universities are seen as a core element of a regional intellectual infrastructure - an essential factor in building technology-based industries and competitive firms. This argument is attractive to many politicians who seek to promote economic growth, and economic development has become the third mission of universities (Etzkowitz, 2003). Still, there are skeptics who doubt the ability of universities to promote economic development (Feller, 1990) and who worry about the effect of this emphasis on the integrity of the academic enterprise (Slaughter & Leslie, 1997). Leaving normative concerns aside, this chapter examines the relations between higher education, industry and economic development. We provide a review of the literature with emphasis on how universities impact economic development and technological change with specific emphasis on the places where they are located.

A body of empirical work concludes that universities are necessary but not sufficient for positive regional economic outcomes. The operative question is under which circumstances universities affect economic growth; specifically, what characteristics of universities promote knowledge transfer and what characteristics of places promote

[48] The input of the first author to the article constitutes about 85%.

knowledge absorption? While we debate the merits of increased emphasis on commercial activity, universities are moving aggressively into active technology transfer and engagement with commercial activity. The operative question here is how to best manage these relationships to ensure that all of society's goals are met.

This chapter will begin by introducing the student of higher education to the theoretical background of university-based growth, including major concepts of increasing returns to scale and institutional economies. The following section looks at the ways universities affect regional economies and addresses the literature that presents the concepts of tacit and codified knowledge and agglomeration economies to explain the mechanisms of knowledge spillovers from universities to companies and industries. The concept of Regional Innovation Systems (RIS) helps to place universities within regional economies and makes a framework to observe the evolution of the universities' role in the regional economy from the concept of *learning regions* to the model of *university products*, where universities are presented as endogenous to the regional systems. The conclusions in the chapter synthesize the thoughts behind the literature on economic development theories and the knowledge spillovers concept, suggesting the major hypothesized systems linking universities with regional growth: mechanisms of knowledge spillovers due to agglomeration economies of scale and specific economic environments where the knowledge spillovers occur.

Framing the Problem

As a field, regional economic development is a complex topic that incorporates theories from different disciplines. The notion of how wealth is generated and distributed has been a topic in economics beginning with Adam Smith's (1776) theory of the market

economy. Joseph Schumpeter (1934) was the first economist to study innovation and entrepreneurs as the actors who create innovation in the economy. Olson (1982) and North (1955), in discussing institutional economies, highlighted the importance of public environments and their effect on economic growth. The social capital theory of Putnam et al. (1993) and Granovetter (1985) draw attention to social relationships in the process of creating innovation. Increasingly there is a recognition that geography provides a platform on which to organize economic activity in ways that are more efficient and productive (see Feldman reviews in Handbook).

Innovation, after all, is a social process. Cities are centers of economic activity that provide externalities that result from the co-location of firms (Audretsch & Feldman, 1996). Externalities are defined by economists as the unintended effects of market transactions that are difficult to capture through the price mechanism. The classic example is the bee keeper and the fruit orchard – both gain from co-location but it would be difficult to imagine how they might compensate one another. Agglomeration economies are the external effects associated with the spatial concentrations of resources. In dense urban environments, linkages between firms, either forwards to the market or backwards to suppliers, work more efficiently, producing more revenue per unit of resources. The concentration of activity in cities allows for increased specialization and a deeper division of labor among firms. The observed benefits of agglomeration not only lowered the costs, but also created better opportunities for innovating and designing new products and services. Moreover, co-location creates greater opportunities for interaction, lowering the costs associated with gathering information. Economists say that agglomeration economies lower transaction costs and thus knowledge-based activity is enhanced. A number of scholars including Weber

(1929), Tiebout (1956), Nelson (1986), Chinitz (1961), and Young (1999) established the positive effect of externalities, characteristics of agglomeration economies, phenomena of the increasing returns to scale, deepened specialization of production, and increased elasticity of supply. These scholars tried to understand the variation of economic performance among regions. Technology is key to this effort.

Robert Solow's Nobel Prize-winning work on the technological residual is credited with emphasizing technology-based economic development. Solow (1957) empirically tested the relationship between economic growth and capital stock, or the presence of physical plant and equipment. The growth that could not be explained by the model was called the residual and is associated with technological change. The presence of the residual implied a contribution of technology advances other than a simple industrialization of economy through the substitution of labor for capital. Solow's residual stood for technology shocks over the business cycle frequencies and was a very important input into the emerging New Growth Theory.

In the late 1980s, Paul Romer built upon Young's concept of increasing return and Solow's technological residual and formulated a set of principles that established his new growth theory — the main theoretical basis for technology-based regional strategies (Romer, 1986). The new growth theory places its main emphasis on endogenous growth based on industries that generate increasing returns to scale. These industries have a high accumulation of knowledge in the form of new technologies: "the model here can be viewed as an equilibrium model of endogenous technological change in which long-run growth is driven primarily by the accumulation of knowledge by forward-looking, profit-maximizing agents" (Romer 1986,p.1003). The model is based on three main elements: externalities of

new knowledge, increasing returns in the production of output, and decreasing returns in the production of new knowledge. In his later work, Romer illustrated the historical origins of developing a new growth model into a neoclassical growth model rooted in Marshall's concept of increasing returns that are external to a firm but internal to an industry (Marshall, 1890), and Young's basis of increasing returns through increasing specialization and division of labor. Romer further developed Solow's concept of exogenous technological residual and argued Arrow's (1962) view of knowledge as a purely public good, and he resolved optimization problems by applying a competitive equilibrium with externalities derived from a partially excludable nature of new knowledge to a new dynamic growth model. Romer introduced and analytically evaluated three important premises of the new growth theory: (1) "The first premise … implies that growth is driven fundamentally by the accumulation of partially excludable, nonrival inputs", (2) "The second premise implies that technological change takes place because of the action of self-interested individuals, so improvements in the technology must confer benefits that are at least partially excludable[49]", and (3) "The third premise … implies that that technology is a non-rival input" (Romer,1990, p.S74).

Romer argued that excludability is a function of the technology and the legal system, and therefore prevents anyone other than the owner from using new knowledge to create quasi rents. "The advantage of the interpretation that knowledge is compensated out of quasi rents is that it allows for intentional private investments in research and development.… What appeared to be quasi rents are merely competitive returns to rival factors that are in a fixed supply." (Romer, 1990, pp.S77-S78). He emphasized the importance of human capital

[49] Paul Samuelson developed the theory of public goods where he assigned all goods to four categories by their two essential characteristics: rivalry and excludability. Knowledge is a public good, which is non-rivalrous and non-excludable. However, developing applications of new knowledge in a form of practical value for the market benefits developers who are earning a profit from selling the applications. The self-interests of developers make the new knowledge of improving technology to become partially-excludable goods.

in the research process and pointed to agglomeration economies that occur at the intersection of highly specialized firms and a diverse environment that encourages innovations. His theory also states that simple urbanization and specialization itself can only create an economy predisposed to innovation, but what actually creates that economy is the immense investment in research and development combined with a supporting infrastructure of transportation, communication, information, and education.

The concept of increasing returns implies the existence of knowledge spillovers and the benefits of the co-location for innovative activity (Feldman, 1994). Known alternatively as the New Industrial Geography (Martin & Sunley, 1996; Martin, 1999) or the New Economic Geography (Krugman, 1991, 1995, 1998, 1999; David, 1999), there has been an active intellectual effort to study the relationship of location to economic growth.

The Real Effects of Academic Research

The production function approach suggests that firms that are located in a region with large stocks of private and public R&D expenditures are more likely to be innovative than those located a greater distance from such stocks. This advantage is due to benefits from knowledge spillovers and agglomeration effects. Many studies combine geography (distance from the source of knowledge) and innovation (tacit nature of knowledge leakages) within the knowledge production function developed by Griliches (1979). These studies imply that innovative inputs (R&D expenditures) produce innovative outputs (patent or innovation counts) due to localization of R&D spillovers. Moreover, in the early 1980s, a popular hypothesis discussed in the literature relates the spatial distribution of knowledge to its core generator, the university. Jaffe modified the Cobb-Douglas production function to incorporate the influence of technology spillovers on productivity or innovation (Griliches,

1979; Jaffe, 1986, 1989). Using the state as the level of analysis, Jaffe (1989) classified patents in technological areas and showed that the number of patents is positively related to expenditures on university R&D, after controlling for private R&D and the size of the states. He interpreted these positive relationships as localized technological spillovers from academic institutions to local firms. Moreover, his model established the importance of a research university to the location of industrial R&D and inventive activity.

In the mid-nineties the Griliches-Jaffe knowledge production function became a major framework for modeling the impact of universities on separate industries and whole regions (Acs et al., 1991, 1994a; Almedia & Kogut, 1994; Acs et al., 1995; Audretsch & Feldman, 1996; Audretsch & Stephan, 1996; Acs, 2002). Feldman (1994) and co-authors, in a series of papers, extended this analysis to consider innovative activity. In 1994, Acs, Audretsch, and Feldman differentiated the production function for large and small firms, finding that geographic proximity to universities is more beneficial for the small firms, as university R&D may play a substitution role for firms' internal R&D, which is too costly for small firms (Acs et al., 1994b). Feldman and Florida (1994) used the knowledge production function to study 13 three-digit SIC industries[50] on a state level and reach conclusions regarding the influence of agglomeration through the network effect: "Concentration of agglomeration of firms in related industries provide a pool of technical knowledge and expertise and a potential base of suppliers and users of information. These networks play an especially important role when technological knowledge is informal or of a tacit nature…" (Feldman, & Florida, 1994, p.220). Using less aggregated industrial classification (four-digit SIC sectors), Audretsch and Feldman (1996) found that the geographical concentration of the

[50] Established in the 1930s, the Standard Industrial Classification (SIC) is a United States government system for classifying industries by an up to four-digit code. In 1997, it was replaced by the six-digit North American Industry Classification System (NAICS).

innovation output is positively related to the industrial R&D, which proves the existence of knowledge spillovers within the industrial cluster.

This literature, however, often looks at the single link that channels knowledge created in a university to a specific industry, but never assesses the comprehensive impact of all university products on a regional economy. Jaffe (1989) is very careful in interpreting his research noting: "It is important to emphasize that spillover mechanisms have not been modeled. Despite the attempt to control for unobserved 'quality' of universities, one cannot really interpret these results structurally, in the sense of predicting the resulting change in patents if research spending were exogenously increased" (Jaffe, 1989, p.968). Varga (1997) confirmed this position in his literature survey "Regional Economic Effects of University Research: A Survey." He reviewed the literature on the impact of university research in four areas: (1) the location choice of high tech facilities, (2) the spatial distribution of high tech production, (3) the spatial pattern of industrial research and development activities, and (4) the modeling of knowledge transfers emanating from academic institutions. Varga found that:

> "Regarding the effect of technology transfer on local economic development, the evidence is still vague. Its main reason is that no appropriate model of local university knowledge effects has been developed in the literature. Studies either test for a direct university effect on economic conditions or focus on academic technology transfer, but none of them provides an integrated approach" (Varga, (1997, p.28).

Audretsch (1998) also expressed his caution regarding the interpretation of knowledge spillovers in several empirical studies:

> "While a new literature has emerged identifying the important role that knowledge spillovers within a given geographical location plays in stimulating innovative activity, there is little consensus as to how and why this occurs. The contribution of the new wave of studies … was simply to shift the unit of observation away from firms to a geographic region" (Audretsch, 1998, p. 24).

The other major stream of literature (sometimes using the knowledge production function as well) was established by Jaffe, Trajtenberg and Henderson (1993) by using patent citations data as knowledge flows that can reveal the relationships between innovation in terms of geography, time, and sequence. These scholars found that innovative firms more often quote research from local universities, as compared to the universities that conduct similar research in a more distant place. Almedia, Kogut, and Zander in their multiple studies concluded that localized knowledge builds upon cumulative ideas within regional boundaries and depends on the ability of the local labor market to accommodate engineers, scientists, and workers who hold the knowledge (Kogut, & Zander, 1992, 1996; Almedia ,& Kogut, 1994). The Almedia and Kogut (1997) study of the semiconductor industry finds that knowledge spillovers from university research to private companies are highly localized. Other studies draw similar conclusions using different levels of geography and different industries (Maurseth, & Verspagen, 1999; Verspagen, & Schoenmakers, 2000; Kelly, & Hageman, 1999).

Many scholars explored the agglomeration effect of urbanization on the efficiency of university knowledge spillovers. Utilizing Polanyi's concept of tacit knowledge (Polanyi, 1962, 1967) and Innis' concept of encoding personal knowledge (Innis, 1950, 1951), scholars classified knowledge as either tacit or codified and then related them to the process of learning and the spatial distribution of knowledge.

Using these concepts of tacit and codified knowledge, Lucas (1988), Caniels (2000), and Audretsch and Feldman (1996), among others, emphasized that knowledge is neither evenly distributed nor equally accessible in every location. The accumulation of tacit knowledge has regional boundaries while the utilization of codified knowledge depends more

on the susceptibility of the recipient to accumulate and employ it. Feldman and those who contributed to the stream of research initiated by Adams and Jaffe (Feldman, 1994; Adams & Jaffe, 1996; Adams, 2000; Adams, 2001, 2002, 2004), focused on the localization of university spillovers and found significant evidence that knowledge flows travel a certain geographical distance within regions. While studying commercialized academic research, Agrawal and Cockburn (2002), among others, found strong evidence for the co-location of upstream university research and downstream industrial R&D activity at the level of metropolitan areas.

Agglomeration effects result not only in localized knowledge but also in creative ideas that combine different types of knowledge as a result of urbanization effects or the co-location of a large number of firms in different industries. The line of reasoning is that local diversification stimulates the occurrence of different types of knowledge and their innovative combinations (Harrison et al., 1996; Adams et al., 2000; Adams, 2001; Desrochers, 2001).

Many scholars acknowledged the differences in regional performance and they attributed these differences to the patterns of knowledge spillovers and regional absorption of innovation. Doring and Schnellenbach (2006) surveyed the latest theoretical concepts of knowledge spillovers and concluded that "despite its public good properties, knowledge does not usually diffuse instantaneously to production facilities around the world. Regional patterns of knowledge diffusion, as well as barriers to the diffusion of knowledge, can therefore feature prominently in explaining the differential growth of production and incomes between regions."

There are two major obstacles to knowledge spillovers. The first obstacle arises from the proprietary rights for explicit (codified) knowledge at some phase of its development

(patenting innovation). At the same time, exclusive rights for new knowledge cannot ensure its total secrecy -- for example, publishing scientific articles and presenting at conferences require disclosing information at the phase prior to patenting. The second obstacle is the cognitive abilities of individuals who can utilize tacit knowledge. Some regions might not have enough scientists with the specific skills or knowledge needed to comprehend and utilize new information. That is, the recipients of knowledge spillover might be not able to absorb the information made available to them. If human capital is sophisticated enough to absorb technical knowledge, then the positive benefits for knowledge spillovers may be realized. Few studies paid attention to path dependencies and the impact of existing industry mix, production culture, and other legacies of a place on current regional economic outcomes.

The University as an Important Regional Player in Regional Innovation Systems

Since the 1980s, studies have analyzed innovation processes within geographical systems (Edquist, 1997; Freeman, 1991; Freeman & Soete, 1997; Lundvall, 1992; Maskell et al., 1998). This stream of research started with identifying national innovation systems (NIS) in Europe, assuming that the occurrence of innovation depends on the structure and organization of industries and companies within a nation, institutions and existing social networks, size of the region, and infrastructure (physical, financial, cultural). The model recognizes universities as institutions supportive to innovation. The role of universities is seen as either direct - through the education of students and production of ideas, or indirect - through knowledge spillovers from research and education.

Over time, the locus of innovative activity changed from the national level to regional economies. Certainly, part of this attention was due to the idea of clusters (Porter, 1990).

Yet the literature differentiates between the location of production and the location of innovation (Audretsch & Feldman, 1996). Precise attention of scholars to the regional innovation systems only emphasized the role of universities as regional institutions that matter most to innovative activity.

In the 1990s, through the introduction of the concept of learning regions, social scientists looked at universities as endogenous to the regional systems (Morgan, 1997; Florida, 1995; Lundvall & Jonson, 1994; Hudson, 1999; Keane & Allison, 1999). They concentrated on the creation of knowledge and its absorption by local firms through the social and organizational networks mainly at the regional level. The increased interest in regional information systems (RIS) was triggered by the regionalization of production and the growing importance of a region in global competition. Forced to compete globally, regions were striving for developing regional competitive advantage.

The necessity for continuous innovation with the purpose of developing or retaining a regional competitive advantage changed the whole paradigm of learning. Universities started to see a new client – spatial clusters and relational networks of small and medium-size firms that substituted for large corporations (Chatterton & Goddard, 2000). The dynamic of learning shifted from a model where learning occurs at universities and knowledge is then applied at the workplace, to a model where interactive learning occurs throughout the lifetime -- at the university, work place, and networking functions.

In late 1990s and early 2000s, the concept of RIS has been widely studied and empirically tested, especially in Europe (Amin & Thrift,1995; Braczyk et al., 1998; de la Monthe & Paquer, 1998; Cooke, 1998; and Hassink, 2001. Scholars have developed a typology to assess structural differences of RISs (Cooke, 1998, p.19-24) and conducted

comparative analyses of regional information systems (Hassink, 2001, p.224). Iammarino and McCann (2006) classified industrial clusters within four different stages in the evolution of technological innovation systems. Each life-cycle stage of innovation systems has a corresponding knowledge base, a distinctive type of industrial regime, is based on a different phase of knowledge spillovers, and has different requirements in the presence of knowledge-generating institutions within the regional system of innovation.

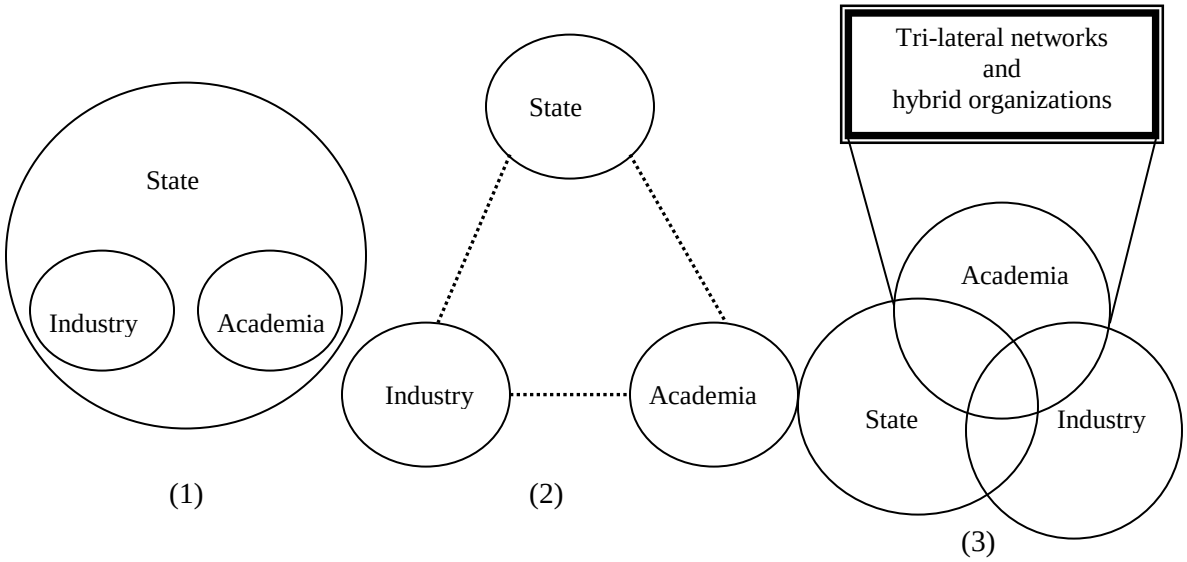
The concept of differentiating phases of innovation systems within the technological life-cycle is consistent with the stream of research on innovation systems and their spatial and knowledge components by Oinas and Malecki (Oinas & Malecki, 1999, 2002; Malecki, 1997). Analyzing the knowledge component of innovation systems, along with local conventions (e.g. tolerance toward failure, risk-seeking, enthusiasm for change and rapid response to technological change), they emphasize the increasingly important role of regional creativity within the context of regional knowledge.

Acknowledging different types of regional institutions, Etzkowitz (2003) introduced the Triple Helix[51] model that conceptualizes university-industry-government relations. This model describes changes in relationships among three main regional players: academia, business, and government. With the growing importance of knowledge, and as the production of knowledge transforms into economic enterprise, the university is given a more prominent role in the regional economy. The university develops an organizational capacity not only to produce knowledge, but also to deploy knowledge into the regional economy or to sell the products derived from new knowledge outside the region. This process is consistent with an innovation being changed from an internal process of a single firm into one that takes place

[51] The discussion on this model is led by Henry Etzkowitz – associate professor of sociology at Purchase College and Director of the Science Policy Institute at the State University of New York. He is co-convener of the bi-yearly International Conference on University-Industry-Government Relations: "The Triple Helix"

among many firms and knowledge-producing institutions. These changes trigger a transformation in the relationships among university, industry, and government (Figure 1) from a "statist" model of government controlling academia and industry (1),[52] to a "laissez-faire" model, which separates the roles of industry, academia and government, interacting only across strong boundaries (2), and, finally to the Triple Helix model with each institutional sphere maintaining its identity while taking on the role of each of the others (3).

Figure 1. "Anthropology" of Triple Helix Model



Source: Etzkowitz, H. (2003). "Innovation in innovation: the Triple Helix of university-industry-government relations." Studies of Science, 42(3), p.302.

With each of the three players, industry, state, and academia, partially taking on the roles of the others, the established match of an institution to its traditional role and functions is outmoded. The Triple Helix model implies interactions across university, industry, and government; and the interactions are mediated by organizations such as industrial liaisons, university technology transfer offices, university contract offices, and other entities. These mediators have a mission to ease legal and organizational barriers in the interaction of the

[52] This model is more relevant to European systems of education.

three players to benefit the deployment of innovation within the region or to benefit the profitable sale of the knowledge products resulting in benefits to the region through a multiplier effect.

According to Pires and Castro, Gulbrandsen, and Leydesdorff and Etzkowitz, as the Triple Helix model evolves, each of the three institutions begin to assume the traditional roles of the others in the technology transfer process (Gulbrandsen, 1997; Pires, & Castro, 1997; Leydesdorff, & Etzkowitz, 1998). For example, the university performs an entrepreneurial role in marketing knowledge, in creating companies, and also assumes a quasi-governmental role as a regional innovation organizer.

Direct Effects of University Research

In 1980, the United States Congress passed the Bayh-Dole Act and the intellectual property landscape in the U.S. changed dramatically. Universities were allowed to retain intellectual property rights and to pursue commercialization even though the basic research had been funded by the federal government. In the late 1990s, technology transfer activities of research universities began to be recognized as important factors in regional economic growth. Scientists started to look at the different factors and mechanisms stimulating transfer of new technology from university to industry (Cohen et al., 1994; Campbell, 1997; Lowen, 1997; Slaughter, & Leslie, 1997; DeVol, 1999). Discussing the benefits of such technology transfer, Rogers, Yin, and Hoffmann (2000) hypothesized that "research universities seek to facilitate technological innovations to private companies in order to: (1) create jobs and contribute to local economic development, and (2) earn additional funding for university research" (Rogers, Yin, & Hoffmann, 2000, p. 48). They illustrated the potential impact of

university research expenditures on jobs and wealth creation through the process of simple technology transfer.

Beeson and Montgomery (1993) tested the relationship between research universities and regional labor market performance. They assessed a university's impact on local labor market conditions by measuring quality in terms of R&D funding, the total number of bachelor's degrees awarded in science and engineering, and the number of science and engineering programs rated in the top 20 in the country (Beeson, & Montgomery, 1993, p.755). Beeson and Montgomery identified four ways in which colleges and universities may affect local labor markets: (1) increasing skills of local workers (together with rising employment and earnings opportunities), (2) increasing the ability to develop and implement new technologies, (3) affecting local demand through research funds attracted from outside the area (a standard multiplier effect), and (4) conducting basic research that can lead to technological innovations (Beeson, & Montgomery, 1993, p.753).[53]

Link and Rees (1990) emphasized the important role of graduates to a local labor market, particularly for new start-ups and the local high tech market, assuming they do not leave the region. Gottlieb (2001) took this idea further in his Ohio "brain-drain" study, emphasizing that exporting graduates is a sign of long-run economic development problems for a region. In their study of 37 American cities, Acs, FitzRoy and Smith (1995) tested university spillover effects on employment, and, like Bania, Eberts and Fogarty (1993), tried to measure business start-ups from the commercialization of university basic research. These studies produced mixed results, showing that university products are statistically significant in their impacts in one case and insignificant in others.

[53] Also discussed by Nelson (1986).

Following Adams' findings about the positive effect on industrial research from the geographical proximity to university research (Adams et al., 2000; Adams, 2001), many studies (Audretsch, & Feldman, 1996; Audretsch, & Stephan, 1996; Cortright, & Mayer, 2002) found that for most industries, activities that lead to innovation and growth take place within only a few regions nationally or globally. Whether it was the impact of universities on regional labor markets or the impact of university R&D and technology transfer on the growth of employment or per capita income, a broader framework was needed to measure the impact of all products created in universities.

Each university interacts with the regional economy as represented by local businesses, government agencies, and the region's social and business infrastructure. The actual interaction is based on its set of products and their value to the region. The university can create sources of regional competitive advantage and can significantly strengthen what Berglund and Clarke (2000) identify as the seven elements of a technology-based economy: (1) regional, university-based intellectual infrastructure – a base that generates new ideas, (2) spillovers of knowledge – commercialization of university-developed technology, (3) competitive physical infrastructure, including the highest quality and technologically advanced telecommunication services, (4) technically skilled workforce – an adequate number of highly skilled technical workers, (5) capital creating adequate information flows around sources of investments, (6) entrepreneurial culture – where people view starting a company as a routine rather than an unusual occurrence, and (7) the quality of life that comes from residential amenities that make a region competitive with others.

The university's influence on these factors is of interest to economic development because each university product can be an asset used by a regional economy or can be sold

outside the region, generating regional income. Each university makes a choice about what product will be a priority to produce and sell, assigns its resources, and creates policies to implement its goals.

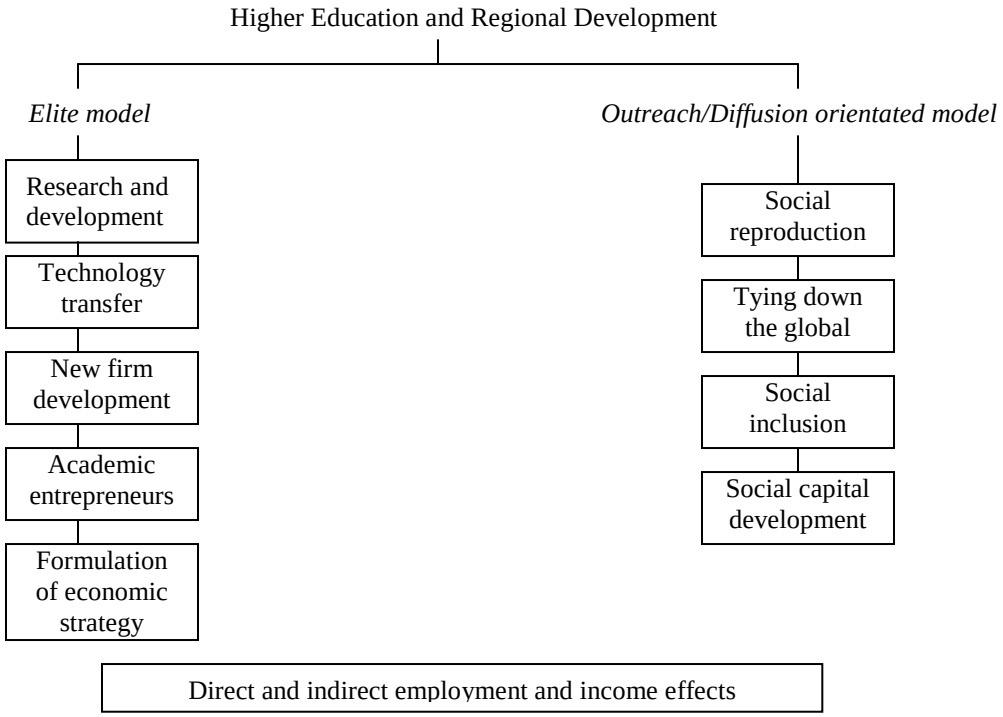
Many studies are focused solely on showing the impact of university presence using the multiplier effect of university expenditures. These studies are confusing the impact of university products (which we identify as purposefully created outcomes according to a university mission) and the impact of university presence in a region (which depends on university expenditure patterns). In the traditional multiplier-effect studies, the models usually take into account two factors of university impact: (1) the number of university students and employees (which is a non-linear function of university enrollment) and the impact of their income through individual spending patterns and (2) a pattern of university expenditures via a university budget. These two factors (sometimes called university products) are indirect functions of enrollment and endowments and are highly collinear with university size. While normalized to per-capita indicators, they highly correlate with university reputation and, apart from the reputation, are to a large degree uniform across regions.

Morgan (2002) tried to bridge the gap between two concepts of university products and create a conceptual model of the two-tier system of higher education institutions in the United Kingdom. Using Huggins' (1999) and Phelps' (1997) concept of the globalization of innovation and production in regional economies, he discusses two models of direct and indirect employment effects – the elite model and the outreach/diffusion-oriented model (Figure 2). Morgan emphasizes the increased role of universities in developing local social capital by acting as "catalysts for civic engagement and collective action and networking"

and "widening access to cohorts from lower socio-economic backgrounds" improving local social inclusion (Morgan, 2002, pp. 66-67).

Bringing elements of globalization into understanding the role of universities for the local economy is widely emphasized in the MIT Industrial Performance Center's study led by Richard Lester. The 2005 report "Universities, Innovation, and the Competitiveness of Local Economies" discusses an important alignment of the university mission with the needs of the local economy, emphasizing that this alignment is affected by the globalization of knowledge and production and depends on "the ability of local firms to take up new technologies, and new knowledge more generally, and to apply this knowledge productively".

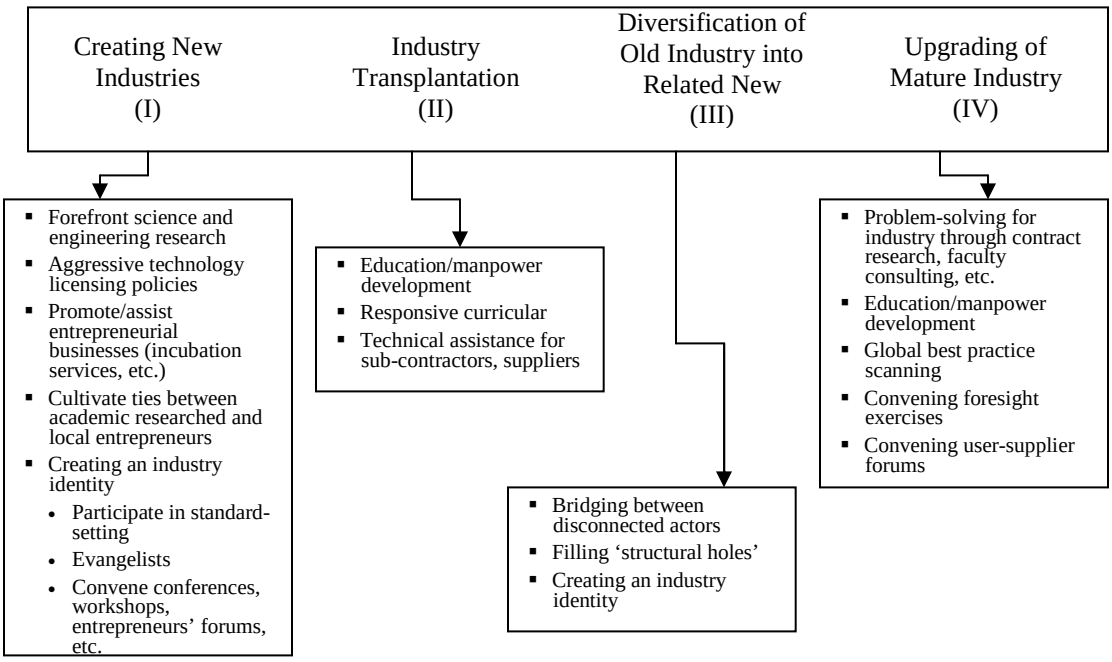
Figure 2. Universities and Regional Development: Two Paradigms



Source: Morgan, B. (2002) "Higher Education and Regional Economic Department in Wales: An Opportunity for Demonstrating the Efficacy of Devolution in Economic Development," Regional Studies, Vol. 36.1, p.66.

Through the different roles played by universities, this study acknowledges diverse pathways of transferring knowledge from universities to local industries (Figure 3). Some of these paths are common to economies with different core industries, and some are unique to the regions. For example, *education/manpower development* is as valuable for the economy as *industry transplantation* and *upgrading mature industry economy*. *Forefront science and engineering research* and *aggressive technology licensing policies* are unique and critical for *creating new industries economies*, and *bridging between disconnected actors* is as distinctive for the economy as *diversifying old industry into related new industry.*

Figure 3. University roles in alternative regional innovation-led growth pathways



Source: Lester R. (2005) "Universities, Innovation, and the Competitiveness of Local Economies," Industrial Performance Center, MIT, p.28.

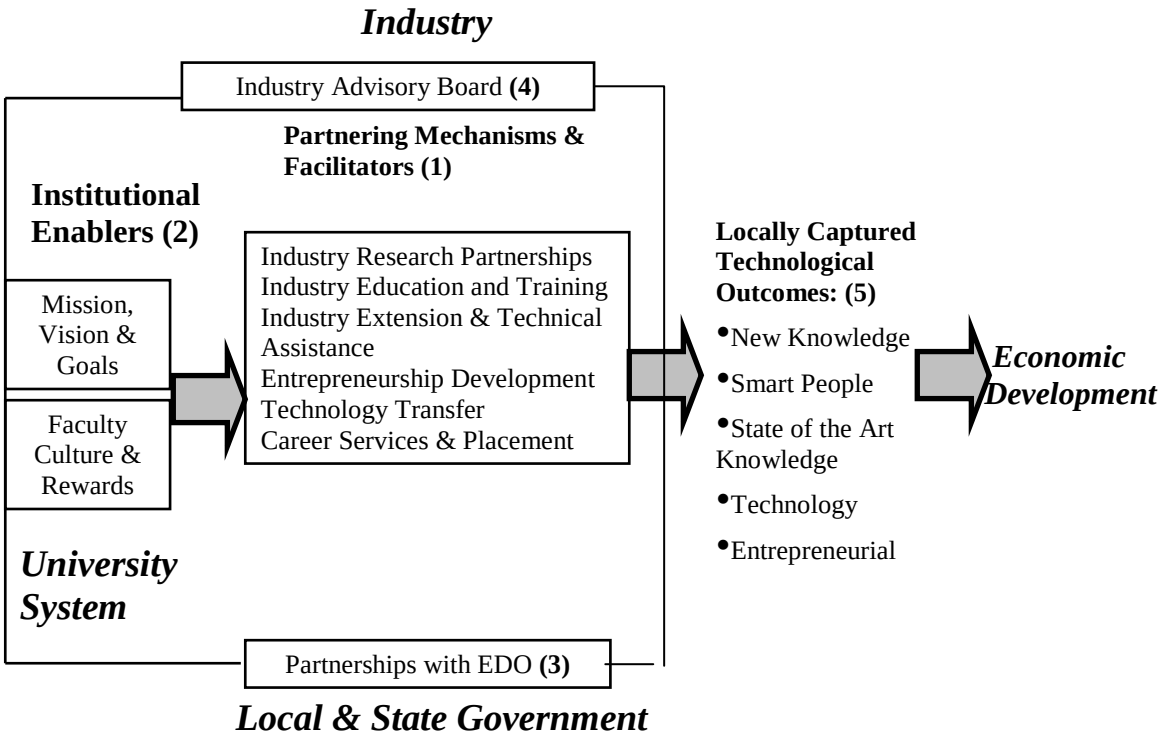
These unique and common pathways for economies with different industrial structures imply existence of universities products that, besides teaching and research, include faculty consulting, publications, and collaborative research.

The discussion about the role of a university in the regional economy has been enriched by a model created by Louis Tornatzky, Paul Waugman, and Denis Gray (Tornatzky, et. al., 1995; Tornatzky, et. al., 1997; Tornatzky, et al., 1999, 2002). These researchers advocate the importance of research universities for regional economic development and examine whether the influence of a university on a local economy differs geographically. The authors conclude:

"While we agree with skeptics who argue this [university's impact on a local economy] is not easily accomplished and that some universities and states appear to be looking for a quick fix, we believe that there is enough evidence to demonstrate that universities that are committed and thoughtful can impact their state or local economic environment in a number of ways" (Tornatzky, Waugaman et al., 2002, p.15-16).

Tornatzky's hypothesis of the ways that universities can affect regional economies is presented in Figure 4.

Figure 4. Innovation U.: New University Roles in a Knowledge Economy



The research team identified 10 “dominants” of institutional behavior that enable the university’s external interactions with industry and economic development interests and lie beneath organizational characteristics and functions that facilitate those interactions. Tornatzky et al. (2002) group these dominants, or interactions, characteristics, and functions into the three broad groups depicted in Figure 4. The first group (1) represents partnering mechanisms and facilitators identified as “functions, people, or units that are involved in partnership activities that allegedly have an impact on economic development” (Tornatzky et al., 2002, p.16). The list of programs or activities in this component includes, but is not limited to industry research partnerships, industry education and training, and other activities.

The second group (2) includes institutional enablers (university mission, vision, & goals and faculty culture & rewards) that facilitate partnering through the “relevant behavior of faculty, students, and administrators [that] are supported by the values, norms, and reward systems of the institution” (Tornatzky et al., 2002, p.18). The third group is represented by two boundary-spanning structures and systems: formal partnerships with economic development organizations (labeled (3) in the figure) and industry-university advisory boards and councils (labeled (4)). They are positioned to link the university system to the economic development intermediaries and business community. As a result of communication between all of the components, the framework captures locally-generated technological outcomes (5), such as new knowledge and technologies that trigger economic development.

Tornatzky, Waugman and Grey acknowledged that, while the local economic environment of universities is complex, only universities that are actively involved in extensive industry partnerships can successfully transfer their products into local economies. Such universities will “tend to adopt language in mission, vision, and goal statement that

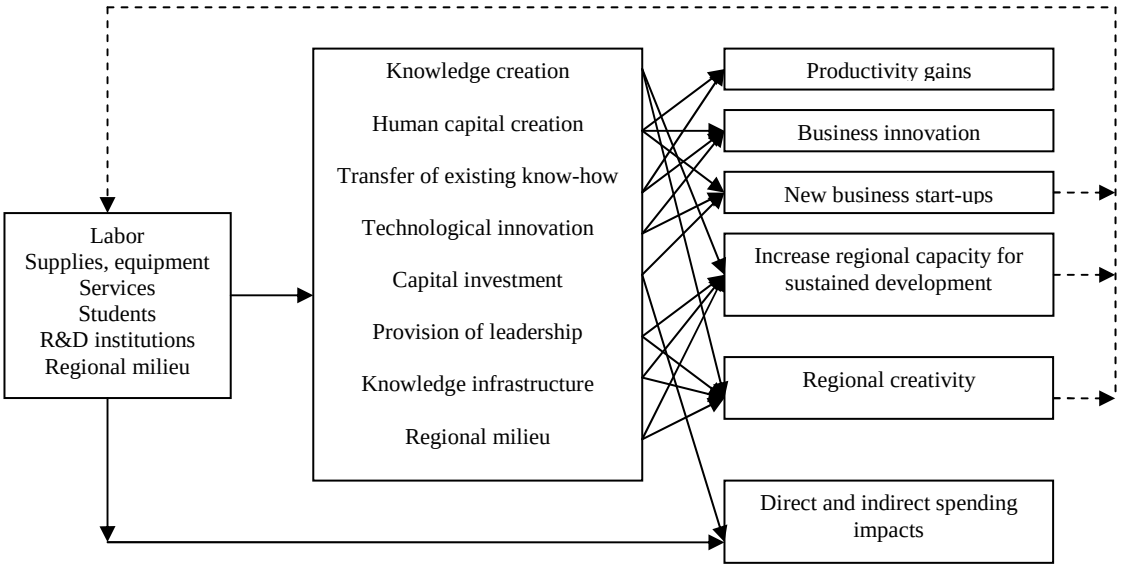
reflects that emphasis. They [universities] also tend to incorporate different versions of those statements in reports, publications, press releases, and speeches directed at the external world" (Tornatzky et al., 2002, p.19).

Paytas and Gradeck (2004) tested this hypothesis in their case studies of eight universities by examining the scope of universities' economic engagement in local economies. They assessed the breadth of involvement of universities with their regions and local communities and concluded that, for a university to play an important role in the development of industry clusters; it "must be aligned with regional interests and industry clusters across a broad spectrum, not just in terms of technical knowledge. … The characteristics of the clusters are as important, if not more important than the characteristics of the university" (Paytas & Gradeck, 2004, p.34).

Goldstein et al. (1995) developed a set of university outputs that is also broader than the traditional understanding of university products, which includes only *skilled labor* and *new knowledge*. Their framework (Figure 5) distinguishes between knowledge creation and co-production of knowledge infrastructure, human capital creation, and technological innovation and technology transfer. This model adds a new and very important understanding of leadership value and regional milieu. This framework was operationalized by Goldstein and Renault (2004) and tested with the modified Griliches-Jaffe production function.

A similar approach is used by Porter (2002) in a report for the Initiative for a Competitive Inner City. He studied six primary university products using a multiplier-effect approach. Porter identifies the main impacts on the local economy through the university's (1) employment, by offering employment opportunities to local residents; (2) purchases,

Figure 5. University Outputs and Expected Economic Impacts



Source: Goldstein H., Maier G., Luger M., (1995). The University as an Instrument for Economic and Business Development: U.S. and European Comparison., p.115

redirecting institutional purchasing to local businesses; (3) workforce development, addressing local and regional workforce needs; (4) real estate development, using it as an anchor of local economic growth; (5) advisor/network builder, channeling university expertise to local businesses; and (6) incubator provider, to support start-up companies and advance research commercialization.

These approaches mix university products – goods and services that are produced by universities according to the university mission, with university impacts – results of university influence on surrounding environments. For example, universities influence appreciation of surrounding real estate value without including this in their mission statement. Lester's study acknowledges that "working ties to the operating sectors of economy are not central to the internal design of the university as an institution, and as

universities open themselves up to the marketplace for knowledge and ideas to a greater degree than in the past, confusion over mission has been common" (Lester 2005, p.9).

According to Hill and Lendel (2007), higher education is a multi-product industry with seven distinct products: (1) education, (2) contract research, (3) cultural products, (4) trained labor, (5) technology diffusion, (6) new knowledge creation, and (7) new products and industries. These products become marketable commodities that are sold regionally and nationally or they became part of a region's economic development capital base. Growth in the scale, quality, and variety of these products increases the reputation and status of a university. An improved, or superior, reputation allows universities to receive more grants and endowments, attract better students, increase tuition, conduct more R&D, and develop and market more products. This reinforcing mechanism between a university's reputation and university products transforms universities into complex multi-product organizations with a complicated management structure and multiple missions. A university manages its portfolio of products as defined in the university's mission statement and expressed through the university's functions and policies.

Conclusions

The new growth theory and the concepts of increasing returns to scale, knowledge spillovers and knowledge externalities form a basis for creating a framework for technology-based regional economic development. They enable an understanding of the factors that influence regional knowledge creation and implementation of an innovation into regional economic system.

The studies on knowledge spillovers and agglomeration effects apply a variety of approaches and methodologies to studying the impacts of knowledge. Even as they lead to a

better understanding of the impact of universities, the results are often fragmented to specific industries and extracts of geographies, primarily due to constraints on data availability. However, even with this fragmentation the empirical results prove the significance of university- based research effects on follow-up industry R&D, increased numbers of intermediate results such as patents, start-up companies, growing employment and wages. It is evident that the positive role of the university in regional economic performance cannot be ignored.

However, the effect of university products on regional economic outcomes is not evident. New knowledge and innovation directly create only intermediate results, such as patents, spin- off companies, graduates, new products and technologies, and new economic, social, and cultural regional environments. Deployed within regional economies, these effects create local competitive advantage. Positive externalities of agglomeration economies of scale allow knowledge spillover and explain the mechanism that enables both, creating the intermediate results of university products and deploying them into regional economies.

Synthesis of thoughts behind the literature on economic development theories and the knowledge spillovers concept suggests that there are two major hypothesized systems linking universities with regional growth: (1) mechanisms of knowledge spillovers due to agglomeration economies of scale, and (2) specific economic environments where the knowledge spillovers occur. The environment of knowledge spillovers and deployment of the results of knowledge spillovers into regional economies can be described by characteristics that reflect the intensity of agglomeration economies and their qualitative characteristics, such as quality of the regional labor force, level of entrepreneurship, intensity

of competition in a region, structural composition of regional economic systems and industries, and social characteristics of places, such as leadership and culture.

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APPENDIX B

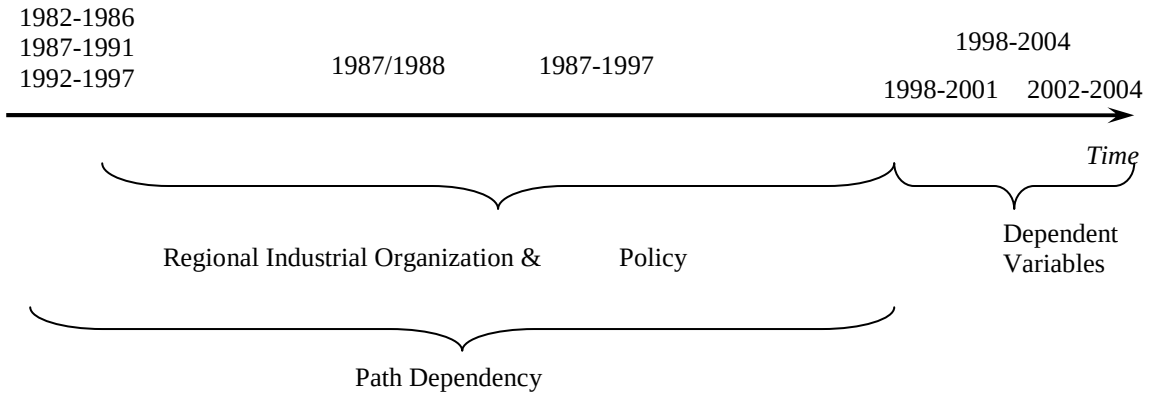
DEFINITION OF THE VARIABLES

A very important characteristic of the research model is the time frame. To ensure that the policy variables and the characteristics of regional industrial organization explain changes in the dependent variables, the independent variables of the model include lagged dependent variables that capture effects of university products and industrial research over the long term (Figure B-1).

Figure B-1. Time Frame of the Research Models

$$RO_j = \alpha_0 + \alpha_1 UR_j + \alpha_2 PR_j + \alpha_3 E_j + \alpha_4 RCM_j + \alpha_5 RS_j + \alpha_6 RD_j + \alpha_7 RL_j + \alpha_8 H_j + e_{ij} \quad (1)$$

Dependent Variables | Policy variables | Regional Industrial Organization | Path Dependency



UR_j - policy variables in region j, where region is a metropolitan statistical area;

PR_j - the size of industrial R&D expenditures in region j;

E_j - the level of entrepreneurship in region j;

RCM_j - the level of competition in region j;

RS_j - the specialization of the industries in region j;

RD_j - the diversification of the industries in region j;

RL_j - the presence of establishments with more than 1,000 employees (approximates a presence of large companies) in region j;

H_j - path dependency represented by variables that reflect the previous performance of region j.

The policy variables (UR_j) and the factors of regional industrial organization ($E_j, RCM_j, RS_j, RD_j, RL_j$) are measures from 1988 to 1997, the years preceding the changes in the dependent variables (RO_j). Industry R&D expenditures (PR_j) play the role of a control variable that allows for assessing the impact of the policy variables on dependent variables separately from the industry R&D activities performed in a region.

To measure the departure from a historical trend, the path-dependency variables (H_j) follow the segments of the business cycles – 1982-1986, 1987-1991, and 1992-1997. They cover the period of time before the impact of the policy and regional industrial organization factors (1982-1986) and, in some equations, during the phase of their influence (1987-1991 and 1992-1997).

The dependant variables are assessed by the impact of policy variables over the entire time period studied (1998-2004) and during the expansion (1998-2001) and the contraction (2002-2004) phases of the business cycle. The policy variables are measured from 1987 to 1997.

There are two major arguments behind the calculation of policy variables during this particular time. First, it covers the period of time following the Bayh-Dole Act[54] that empowered universities to capture the intellectual rights of research products. In addition, it reflects the growth phase of the old industrial economy, which was accompanied by the growth of large corporations capable of carrying significant R&D activities. The regional industrial organization variables are measured at the beginning of the policy assessment period (1987/1988) or as change variables during the assessment period (1988-1997).

Statistical tests assess the influence of the policy variables on regional outcomes, the percentage change in gross metropolitan product $\left(GMP_j\right)$ and the percentage change in total employment $\left(E_j\right)$ over the period of time $\left(t_2 - t_1\right)$:

$$E_{t_2-t_1} = \left(E_j\right)_{t_2} - \left(E_j\right)_{t_1} \tag{2}$$

$$GRP_{t_2-t_1} = \left(GMP_j\right)_{t_2} - \left(GMP_j\right)_{t_1} \tag{3}$$

The number of new start-ups in a metropolitan area normalized by population is used to approximate entrepreneurial culture in each metropolitan area (E_j, where *j* is a region). Following Luger and Koo (2005), a new firm is defined as "a business entity which did not exist before a given time period (new), which starts hiring at least one paid employee during the given time period (active), and which is neither a subsidiary nor a branch of an existing firm (independent)" (Luger & Koo, 2005, p.19). Therefore, new branch offices (plants) of existing firms or new firms created through mergers or acquisitions are not included in the

[54] Enacted on December 12, 1980, the Bayh-Dole Act (P.L. 96-517, Patent and Trademark Act Amendments of 1980) created a uniform patent policy among the many federal agencies that fund research, enabling small businesses and non-profit organizations, including universities, to retain title to inventions made under federally-funded research programs. This legislation was co-sponsored by Senators Birch Bayh of Indiana and Robert Dole of Kansas. http://www.autm.net/aboutTT/aboutTT_bayhDoleAct.cfm

entrepreneurial activity variable. This variable is normalized by the total population to eliminate the variance of population-serving companies (Edmiston, 4004; Mauno, 2005). The normalization of the number of new establishments by population also prevents this indicator from reflecting changes in population over time and from reflecting the cross-sectional demographic structure of the region. The entrepreneurship variable is included in the model as a cross-sectional variable, measuring the 1990 level of new establishments, the earliest year of data available from the Census Bureau's Statistics of U.S. Businesses (http://www.census.gov/csd/susb/susbdyn.htm).

Specialization, competition, and diversification represent forms of industry organization that are hypothesized to trigger different types of agglomeration economies that are associated with regional growth. These characteristics of regional industrial organization are based on Glaeser et al's (1992) research on employment growth in 170 U.S. cities between 1956 and 1987.

Glaeser operationalized specialization as the employment share of the five largest industries in an MSA. He defined the largest industries by the share of their employment in the total employment of the region. In this dissertation the four-digit NAICS is used to calculate industry specialization (RS_j). The methodology to calculate industry specialization is described in the following four steps.

Step1: Three types of industries were excluded from the list of the 290 four-digit NAICS industries: population-serving industries (including Private Household Employment, Farming, and Forestry & Hunting), military, and government sectors.

Step 2: The location quotient of employment was calculated for each of the remaining 233 four-digit NAICS industries for each metropolitan area for 1987.

Step 3: The 233 four-digit NAICS industries were ranked by their 1987 employment location quotient within each metropolitan area.

Step 4: The first 5 industries were considered the industries in which a region was most specialized. The 1987 employment of 233 industries was summed and divided by 1987 population to derive the share of employment in the top 5 four-digit NAICS industries that approximates industrial specialization.

Economic diversification of a region (RD_j for a region *j*) was calculated as the ratio of employment in the lower 5 of the 10 largest four-digit NAICS industries in each region (industries #6, #7, #8, #9, and #10). After step 3 in the methodology for calculating regional specialization, the 4th step required summing 1987 employment of industries #6, #7, #8, #9, and #10 from the list of 233 four-digit NAICS industries that were ranked by their 1987 employment location quotient within each metropolitan area. Glaeser et al. calculated this measure as the share of employment in the lower 5 of the 10 largest two-digit SIC industries in each region (industries #6, #7, #8, #9, and #10).

The variable of regional competition (RCM_j in region *j*) is calculated as the percentage change in the ratio of establishments per employee at the regional and national levels from 1988 to 1997.[55] As an alternative measure, the Hirshman-Herfindahl index of deviation of the number of establishments at a regional level versus the national level was included in the exploratory models. This variable was not statistically significant in any of the results.

[55] The data for 1987 were not available from the County Business Patterns.

$$RCM_j = \frac{RCM_{1997_j} - RCM_{1988_j}}{RCM_{1977_j}} x100\,, \qquad (4)$$

where RCM_{1997_j} is the level of local competition in region *j* in 1997,

and RCM_{1988_j} is the level of local competition in region *j* in 1988.

$$RCM_{1997_j} = \frac{Est_{1997_j} / E_{1997_j}}{Est_{1997_{US}} / E_{1997_{US}}}\,, \qquad \text{where} \qquad (5)$$

Est_{1997_j} is the number of business establishments in region *j* in 1997,

E_{1997_j} is total regional employment in 1997,

$Est_{1997_{US}}$ is the number of business establishments in the US in 1997,

$E_{1997_{US}}$ is total US employment in 1997.

$$RCM_{1988_j} = \frac{Est_{1988_j} / E_{1988_j}}{Est_{1988_{US}} / E_{1988_{US}}} \qquad (6)$$

As a result, the formula (4) is:

$$RCM_j = \frac{\frac{Est_{1997_j} / E_{1997_j}}{Est_{1997_{US}} / E_{1997_{US}}} - \frac{Est_{1988_j} / E_{1988_j}}{Est_{1988_{US}} / E_{1988_{US}}}}{\frac{Est_{1997_j} / E_{1997_j}}{Est_{1997_{US}} / E_{1997_{US}}}} x100 \qquad (7)$$

This methodology introduces a better definition of the regional industrial base, utilizing a more specific industry classification (four-digit NAICS in comparison to two-digit SIC used by Glaeser), and incorporating additional measures of regional industrial structure.

The presence of the large companies in a region (RL_j in a region j) is approximated by the number of business establishments with more than 1,000 employees.[56] The variable is calculated for 1988, the earliest year available.

Since we cannot attribute all the changes in dependent variables to the influence of the policy variables and the variables that describe the region's industrial organization, the path-dependency variables are added to reflect the lag effects and the bundled nature of university products.

The outcomes of university research are not gained instantaneously and require years of investments and deployment in regional economies. Therefore, the outcomes observed currently are the lagged results of investments over a very long time period. Moreover, changes in dependent variables are related to past growth rates because of many factors unaccounted for in our model, for example, population migration or formation and disappearance of companies. Lastly, due to the high level of interdependency of university products, it is hard to operationalize the influence of university research and graduates as separate from the influence of new knowledge development, cultural products, and new industries on regional economic development.

Path-dependency variables are constructed over the segments of the business cycle that occurred between 1982 and 1997. The three control variables in the employment regression equations are the percentage growth in total regional employment from 1982 to 1986, from 1987 to 1991, and from 1992 to 1997. For the change in gross metropolitan product (GMP), the path-dependency variable represents the percentage growth of GMP from 1987 to 1997. The definition of all variables is summarized in Table B-1. Table B-2

[56] The source of these data is the County Business Patterns.

indicates the data sources of the dependent and independent variables in the model. Table B-3 discusses the hypotheses that are tested by each variable.

Table B-1. Definition of Variables in the Research Models

Type of Variable		Name of Variable	Definition
Dependent variables		Employment, percentage change	Dependent variables characterize changes in regional economy that are affected by policy variables tested in this dissertation, university R&D expenditures, university reputation, and university presence. They reflect two major regional outputs, changes in total regional employment and changes in gross metropolitan product
		Gross metropolitan product, percentage change	
Independent variables	Policy variables	Sum score average	This policy variable reflects the cumulative reputation or R&D expenditures across 14 technology-related fields across all universities in a metro area and stands for economies of scope of academic research.
		High score average	This policy variable reflects the cumulative reputation or R&D expenditures in one of 14 technology-related fields that has the highest sum across all universities in a metro area that have this field of research.
		University Presence	This policy variable reflects the presence of research universities in a metropolitan area that have at least one of the 14 selected fields associated with high tech or at least one university ranked among the top 100 or top 5 research universities by NSF
	Control variable	Industry R&D expenditures, percentage change	Private/industry R&D expenditures that constitute a significant portion of total R&D. Industry R&D at the metropolitan level is imputed from the state level industry R&D expenditures using the distribution of employment in NAICS 5417 at the county level.
	Regional industrial organization variables	Ratio of business establishments, percent change, 1988-1997	This variable approximates the level of competition among companies in a region. It is calculated as the ratio of business establishments per employee at the regional level to the national level (following the structure of a location quotient).
		Number of large establishments, 1988	This variable is approximated by the number of large business establishments with more than 1,000 employees and approximates the impact of the presence of large companies in a region.
		Single-establishment start-ups normalized by population, 1990	The number of new start-ups normalized by population approximates entrepreneurial culture in a region.
		Industrial specialization, 1987	Measured as the employment share of the five-largest base/export industries in a region. This variable approximates the level of concentration of employment within a few economic sectors, i.e. industry specialization.
		Industrial diversification, 1987	Measured as the employment share in the lower five of the ten largest regional base/export industries, this variable approximates diversification of regional economy.
	Path depen-dency variables	Lagged dependent variables, employment or gross metropolitan product	These variables are structured after the segments of the previous business cycle. They reflect historical path dependencies.

Table B-2. Data Sources for the Variables in the Research Model

Type of Variable		Name of Variable	Data Source
Dependent variables		Employment, percentage change	Moody's Economy.com
		Gross metropolitan product, percentage change	
Independent variables	Policy variables	Sum score average	National Science Foundation Survey of Research and Development Expenditures at Universities and Colleges
		High score average	National Science Foundation Survey of Research and Development Expenditures at Universities and College
		University Presence	National Science Foundation Survey of Research and Development Expenditures at Universities and College National Science Foundation Ranking of the Top 100 Research Universities
	Control variable	Industry R&D expenditures, percentage change	National Science Foundation Survey Research and Development in Industry and Moody's Economy.com
	Regional industrial organization variables	Ratio of business establishments, percent change, 1988-1997	U.S. Census Bureau, County Business Patterns
		Number of large establishments, 1988	U.S. Census Bureau, County Business Patterns
		Single-establishment start-ups normalized by population, 1990	US Census Longitudinal Establishment and Enterprise Microdata (LEEM) and Moody's Economy.com
		Industrial specialization, 1987	Moody's Economy.com
		Industrial diversification, 1987	Moody's Economy.com
	Path dependency variables	Lagged dependent variables, employment or gross metropolitan product	Moody's Economy.com

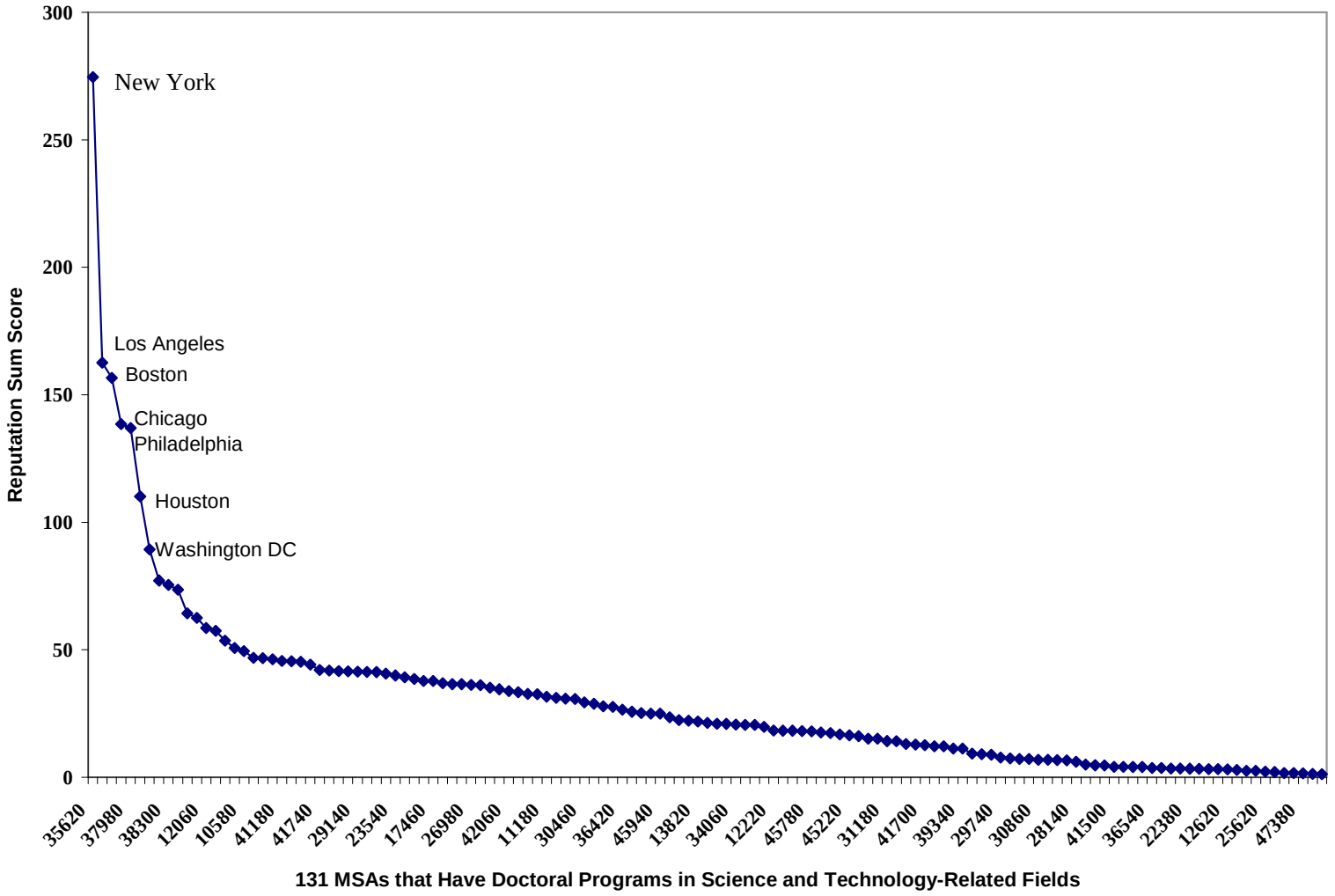
Table B-3. Hypothesis Tested by the Variables Included into the Research Models

Variable Type		Name of Variable	Hypothesis Test
Dependent variables		Employment, percentage change	These variables indicate the change of final demand for labor in a region and a final product developed by companies, both those that directly adopt university products and those that are indirectly affected by university products. The output variables are tested in the models during three time periods: the expansion phase of the business cycle, from 1998 to 2001; the contraction phase of the business cycle, from 2002 to 2004; and the entire time period, from 1998 to 2004.
		Gross metropolitan product, percentage change	
Independent variables	Policy variables	Sum score average of university R&D expenditures	This policy variable stands for the economies of scope of academic research. It tests for the existence of positive economic spillovers produced by the sum of university reputation and sum of R&D expenditures across of technology fields in all universities in a metropolitan region.
		High score average of university R&D expenditures	This policy variable stands for the economies of scale of academic research. It tests for the existence of positive economic spillovers from specialization in a single technology-oriented field of research across all universities in a metropolitan area.
		University Presence	This policy variable stands for the presence of academic research. It tests for the existence of positive economic spillovers from the university presence in a metropolitan area.
	Control variable	Industry R&D expenditures, percentage change	This variable controls for private/industry R&D expenditures that constitute a significant portion of total R&D. The presence of this variable in the models allows for distinguishing between the impact created by university research and the impact of industry R&D.
	Regional industrial organization variables	Ratio of business establishments, percent change, 1988-1997	Following the structure of a location quotient, a ratio >1 of this variable suggests competition greater that the average competition in the average metropolitan area; and a ratio <1 indicates regional competition lower than the average. The positive association of this variable with the dependent variable suggests that greater competition facilitates the adoption of university products within the region.
		Number of large establishments, 1988	This variable stands for the presence of large companies that avert entrepreneurship. Large companies create a false sense of job security in a region and discourage entrepreneurship and the pursuit of education that might affect long-term regional competitiveness.
		Single-establishment start-ups normalized by population, 1990	The number of new start-ups normalized by population approximate entrepreneurial culture in a region. This variable suggests the relationships between economic outcomes and the level of entrepreneurial culture that can support adoption of university products within the region.
		Industrial specialization, 1987	If positively related to the dependent variables, this variable suggests that greater industrial specialization supports the adoption of university products by local companies due to positive externalities of agglomeration from specialization that create better conduits with local universities and greater demand for university products.
		Industrial diversification, 1987	If positively related to the output variables, industrial diversification suggests that university products are better adopted by regional economy that is balanced across a greater number of industries and benefits from positive externalities of agglomeration of urbanization – the co-location of different industries in a metropolitan area.
	Path-dependency variables	Lagged dependent variables, employment or gross metropolitan product	These variables control for lagged effects and the bundled nature of university products in the models. They capture the long-term trend of the dependent variables and changes in dependent variables related to past events and factors unaccounted in these models. Structured after the segments of the previous business cycle, these variables assure reflection of true effect of policy variables on regional output changes.

APPENDIX C

DISTRIBUTION OF THE POLICY VARIABLE

Figure C-1. Distribution of Sum of Cumulative Quality Scores across 131 MSAs



APPENDIX D

DESCRIPTIVE STATISTICS AND CORRELATION AMONG VARIABLES

Table D-1. Descriptive Statistics of the Dependent Variables in Groups of MSAs Divided by Population Size

MSA group	N in a group	Statistics	E9801	E9804	GMP9801	GMP9804
1	12	Mean	5.39	3.83	8.45	16.37
		Variance	6.52	26.08	15.67	47.59
		St Dev	2.55	5.11	3.96	6.90
2	29	Mean	4.97	5.46	6.89	16.15
		Variance	13.79	59.96	26.56	107.71
		St Dev	3.71	7.74	5.15	10.38
3	36	Mean	4.49	4.77	5.70	15.56
		Variance	13.49	41.29	29.72	84.53
		St Dev	3.67	6.43	5.45	9.19
4	76	Mean	3.90	5.34	6.22	16.80
		Variance	14.31	53.47	33.22	110.63
		St Dev	3.78	7.31	5.76	10.52
5	208	Mean	3.67	6.01	5.64	17.65
		Variance	20.06	65.87	44.63	116.50
		St Dev	4.48	8.12	6.68	10.79

Table D-2. Correlation among Variables

		Policy Variables							Regional Industrial Organization						Path-dependency		
		IRD 8797	SSA 8797	SSV 8797	UPA 8797	UPV 8797	BACH 9000	RUP	POP SIZE	SP 87	DV 87	COMP 88	LRG 88	ENT 90	EMP 8286	EMP 8791	EMP 9297
Policy Variables																	
Industrial R&D	IRD8797	1.00															
Average of university R&D	SSA8797	-0.02	1.00														
Variance of university R&D	SSV8797	0.05	-0.58	1.00													
Average of university patents	UPA8797	0.03	-0.51	0.07	1.00												
Variance of university patents	UPV8797	-0.03	0.30	-0.20	-0.74	1.00											
Bachelor's or higher degree	BACH9000	0.03	0.03	0.01	0.07	-0.07	1.00										
Research university presence	RUP	0.05	-0.15	0.09	-0.01	0.03	0.16	1.00									
Regional Industrial Organization																	
Population size	POPSIZE	-0.03	0.10	-0.10	0.16	-0.14	0.06	0.23	1.00								
Specialization	SP87	-0.04	-0.09	0.05	-0.15	0.14	0.11	0.15	-0.41	1.00							
Diversification	DV87	0.02	0.03	-0.02	-0.14	0.15	-0.04	0.06	-0.21	0.28	1.00						
Competition	COMP88	-0.13	0.00	0.03	0.10	-0.11	0.15	0.18	-0.23	0.33	-0.04	1.00					
Large companies	LRG88	-0.04	0.10	-0.45	-0.34	0.22	-0.08	0.06	0.20	0.11	0.09	-0.06	1.00				
Entrepreneurship	ENT90	-0.13	0.05	-0.10	-0.10	0.07	-0.21	-0.11	0.13	-0.10	0.01	-0.55	0.06	1.00			
Path-dependency Variables																	
Employment trend 8286	E8286	0.04	-0.06	0.03	0.03	-0.01	-0.29	-0.05	0.09	-0.09	-0.10	0.10	0.04	-0.26	1.00		
Employment trend 8791	E8791	-0.01	-0.02	-0.05	0.01	0.02	-0.31	-0.20	-0.07	-0.19	0.08	-0.14	0.10	-0.10	0.22	1.00	
Employment trend 9297	E9297	-0.08	0.04	0.02	-0.11	0.09	-0.53	-0.10	-0.04	-0.04	-0.02	-0.07	0.04	-0.07	-0.02	-0.10	1.00