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The Role of University-Industry Collaboration in Regional Economic Development

Ranjana Srevatsan

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THE ROLE OF UNIVERSITY-INDUSTRY COLLABORATION
IN REGIONAL ECONOMIC DEVELOPMENT

by

Ranjana Srevatsan

A Dissertation
Submitted to the Graduate School
of The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

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December 2011
The University of Southern Mississippi

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Innovation has played an important role in the economic development of regions. It is believed that research collaboration between university and industry has a positive influence on regional growth and development. This research explores the role of university-industry collaboration in regional economic development at the metropolitan level. The collaboration between university and industry is examined through two measures: Industrial research funding (IRF) to universities and science and engineering graduates (SEG). The research is divided into two models. The first model studied the combined effect of the metropolitan statistical areas (MSAs) and studied the influence of IRF and SEG on per capita GDP, unemployment rate and new firm births in the MSAs. In the second model, the MSAs were partitioned in terms of population sizes into small, medium and large.

The results from regression analysis show little evidence that university-industry collaboration generates economic development in a region. Regression results indicate that higher levels of IRF are associated with higher per capita GDP for medium and large sized MSAs as well as for the combined model. However, regression analysis suggests there is almost no evidence of a relationship between IRF in terms of the other two measures, unemployment rate and new firm births. The results related to science and
engineering graduates did not support the hypothesis that higher number of science and engineering graduates can be associated with higher per capita GDP in metropolitan statistical areas. Further, in terms of unemployment rates no statistically significant results were found relative to SEG in the combined model and medium and large sized MSAs. Though SEG positively influences new firm births in medium sized MSAs, the combined model shows no relationship with SEG. An important reason for these weak relationships may be the ‘footloose’ nature of college graduates who tend to move out of the region after graduation.

Previous research has suggested that universities alone are not sufficient to create economic development in the surrounding region. Some have suggested that linkages between universities and the local economy should improve economic development outcomes. However, this research found that some specific measures of university-industry collaboration did little to explain regional economic development.
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CHAPTER I
INTRODUCTION

Purpose of the Study

This research explores the role of university-industry collaboration (UIC) in economic development in a region. Knowledge and technology transfer from universities to the industrial sector and community can be an advantage, but does the collaboration support a region’s economic development? The purpose of this research is to analyze the development outcomes within a region in relation to university-industry collaborations. The main research question is: Does university-industry collaboration affect economic development outcomes in a region (Metropolitan Statistical Area)? The economic development outcomes are: per capita GDP, unemployment rates and new firm births.

This dissertation seeks to determine if collaboration between university and industry in terms of industrial research funding and human capital results in economic growth in a region.

In the United States, university-industry research collaborations have been influential in regional development in many regions. The role of such collaborations in regional development has been emphasized in some regions such as Silicon Valley, Route 128 and the Research Triangle. Other similar cases are Princeton Corridor in New Jersey, Silicon Hills in Texas, Optics Valley in Arizona and the Golden Triangle at The University of California, San Diego (Atkinson 1994). There has been a rise in the university-industry collaboration after the WWII, the National Science Foundation (NSF) data shows that industry funding to universities was around 8 percent in 1950s, in 1960s
it went down to 2.5 percent, but rose during the 1980s and 1990s with 7.1 percent in 1997 (Hane 1999).

In the United States various research universities have developed effective policies, practices and institutional framework for collaborating with industries. A main feature of technology policy has been an effective system of collaboration between industry and university for economic growth (Abramson, et al. 1997). Regions with less institutional research activities are becoming aware that scientific knowledge applied to local resources is the basis of economic and social development. Thus the research funds in the United States are now available not only to the east and west coasts, but other regions also and thus all regions get a share of research funding (Etzkowitz & Leydesdorff 2000).

Innovation and Economic Development

This study is based on the theory of Innovation Systems with emphasis on regional innovation system. Theory of innovation systems considers innovation to be at the core of a system. A system is formed of linkages or collaborations among various institutions such as academia, government, private sectors, markets, culture or social and political systems with innovation being at the center of all the activities among these partnerships. The interactions between the institutions lead to a new learning process and new knowledge. This results in increased regional technological capability and economic growth.

Innovation is one of the important components of university-industry collaboration. Regions have depended on new innovative ideas for economic development. The regional innovation capabilities influence productivity and
consequently growth in a region. Innovation increases productivity which leads to higher per capita growth in a region (Romer 1990). Feldman and Florida (1994) describe innovation as the culmination of “individual capitalists firms, entrepreneurs and organizations which function to organize and harness the various inputs required for innovation, profit and growth” (374). Several studies have shown the relationship between innovation and economic growth at the regional level (Feldman & Florida 1994, Kirchhoff, et. al 2002, Varga 2000, Jaffe 1989).

Innovation can be small incremental changes or radical, which is creating an entirely new product, process or technology. The region’s capacity in using knowledge for economic benefits is crucial for its economic and technological development. Innovation happens when economically valuable knowledge is used in new innovative ways (Feldman 2000). Developed economies have moved from manufacturing to knowledge-based industries and regional economies are increasing depending on innovation for economic growth. This has led to new innovative regions and their locations are determined by access to information, skilled and specialized human capital, suppliers and financiers (Malecki 1997).

Regional growth is often associated with the concept of ‘learning economy’. Lundvall and Johnson (1994) suggest that in a learning economy, success of individuals, firms and regions are dependent on their ability to learn new innovative methods and replace old skills. Thus learning is widespread in every sector in the economy, and new jobs are created in knowledge sectors. The region’s growth and development often depends on network knowledge. Network knowledge is knowledge transfer from one sector to another such as university and industry and skilled workforce in a region.
The linkage between regional innovation and regional development is generally based on the assumption that as innovation increases, per capita incomes are expected to increase (Romer 1990) leading to economic growth. Innovation can improve regional development and competitive advantage. Feldman and Florida (1994) suggest that geography has an important role in innovation and it is a geographical process. Jacobs suggests that growth in a region is related to its innovation capabilities and the regions that do not develop are lacking in new ideas for innovation in goods and services (Jacob 1969). Certain regions have practiced this policy: An incubator program in Fresno, CA, illustrates this. The program connects small and independent suppliers to bigger buyers using electronic commerce. This technology-driven process allows smaller businesses to supply to larger buyers, and connects them to new marketing avenues. It also provides opportunity for small and remote suppliers in rural areas to connect to larger markets (Montana et al. 2001).

Universities’ involvement in regional innovation is based on two important concepts. First, universities enhance knowledge through producing skilled new workers. Second, scientific knowledge is converted into patents, products and services which lead to university–industry research collaboration and transfer (Power & Malmberg 2008). This research will focus on the second activity of regional development.

Universities are the centers of learning and knowledge thus contributing to diffusion and exchange of innovative ideas in a region. Research support from the research universities facilitates industrial innovation, thus allowing them to compete in the market. In the year 2003, Stanford University submitted more than 300 patents and many prominent companies such as Google, Netscape, Cisco, Yahoo, Sun Microsystems
and Graphics, were a result of innovative collaboration between university and industry. Massachusetts Institute of Technology (MIT) creates almost 150 new businesses each year through faculty, students and alumni. Further MIT each year generates approximately 100 licenses and almost twenty technology firms (Palmintera 2005). Brascomb and Kodama (1999) argue that the public views universities as resources of new skills, knowledge, and innovative ideas for industrialized society problems. Further they suggest that the public expectations of economic outputs from university research are so high, that many academics feel that these expectations may be not be very realistic.

The birth of new businesses is an important factor in the university-industry collaboration which supports regional development. An example of such development initiative is seen in New Jersey which maintains seven technology related business incubators. The business incubators are managed by the state’s public and private academic sector and have more than 100 firms. They support start-up firms and small firms with business support, low-cost office, light manufacturing and lab facilities (Reisman & Cytraus 2004).

The role of innovation in the development of a region is adapting the idea for practical application, and the diffusion of the idea for general utilization. Innovative scientific ideas are generated by basic research in universities and are improved by applied research. One such example is KableFree Systems in the UK, which exploited university expertise in radio communications to develop the wireless emergency lighting system and won the Technology & Innovation Award in 2007 (Lee 2008).

Economic development policies have also suggested that innovation through collaboration between institutions influences regional development. The policies related
to economic development have been termed as “waves”. The first wave began with the Balance Agriculture with Industry (BAWI) in Mississippi from the Great Depression era focused on recruiting new industries to a region as a means of job creation. The second wave emphasized the extension and retention of present businesses and development of entrepreneurship. The third wave policies encouraged collaborations within and across communities. The first and second wave policies concentrated on growth through recruiting business and expanding existing business. However the third wave policies emphasize on regional economic development through entrepreneurship activities and regional collaborations. The universities need the collaboration of other institutions for initiating economic development in a region and industries are the best option for such an activity (Shaffer, Deller and Marcouiller 2006).

The first wave mostly focused on programs aimed at attracting industries from old industrial areas in the West or South. The second-wave programs focused on retaining and expanding existing businesses rather than attracting out-of-state firms and the policies centered on generating new firms and, increasing investment capital (Bradshaw and Blakely 1999).
## Table 1

**Waves of Economic Development**

<table>
<thead>
<tr>
<th>Waves</th>
<th>Policies</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First Wave</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial Recruiting</td>
<td>Balance Agriculture with industry</td>
<td>Focused on programs aimed at attracting industries from old industrial areas in West or South. Attracting businesses through subsidized loans, relocation expenses, tax reductions, subsidies in plant facilities or utilities cost.</td>
</tr>
<tr>
<td>1930s in response to the Great Depression</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Second Wave</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost Competitive</td>
<td>Centered on generating new firms and, increasing investment capital.</td>
<td>Focused on retaining and expanding existing businesses rather than attracting out-of-state firms.</td>
</tr>
<tr>
<td>Began in the 1970s</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Third Wave</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional Competitiveness</td>
<td>Economic development through entrepreneurship activities and regional collaborations</td>
<td>Encouraged regional growth through public-private collaborations and information networks. Developing industrial clusters and human capital.</td>
</tr>
<tr>
<td>In the early 1990s,</td>
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Human Capital in University-Industry Collaboration

Industries exploit the university intellectual capabilities for their benefits. One such example is Porsche, which utilizes academic knowledge in their production lines. The company collaborates with various universities for professional expertise for their various projects. The firm enrolls almost 600 graduate students every year into its Research & Development (R & D) facility in Weissach, Germany. These students work along with 2,000 staff engineers for four to six months. Primarily the students focus on basic R & D but eventually they participate in every stage of product development. By in-sourcing student expertise, Porsche explores promising ideas and implements these ideas faster than its competitors (Harryson & Lorance 2005).

In collaborating with industries, research universities and students gain from the research based on real-world problems. In this process, the faculty and students gain commercial experience, and the universities also gain revenue. The other ways that universities gain are through license payments, jobs for graduates, industrial grants for research projects (Goldberg 1999).

Graduate students have become an indispensable part in major research universities due to financial constraints. The easiest option to get skilled educated people for 60 hrs per week for $20,000 for industrial partners of the universities is recruiting graduate students. Graduate students and post doctoral students are available in thousands, who are among the most highly skilled and least paid technology recruits in the nation. Doctoral students spend on an average of 4 years as low salaried postdoctoral fellows in the biological sciences sector (Lafer 2003).
Scientific research is always looking for cheap skilled labor. “It’s a great system for the senior scientists to have all these slaves working for them,” are the thoughts of an official from the National Institute of Health (NIH) as Lafer (2003) states in his paper on ‘Graduate Student Unions’. Most of the universities employ graduate students to have skilled manpower for timely execution of projects, universities prefer appointing part-timers as graduate students or lecturers on non-tenure basis than new faculty as it is more beneficial financially (Bousquet 2002).

Academic labor is more exploited as there are fewer opportunities for new Ph.D.’s, easy availability of low wage graduate students. Due to budget constraints teaching assistant and adjunct faculty for teaching is increasing across university campuses in the nation (Nelson 1986). Scientific knowledge, mainly in the biological fields, has grown tremendously. Thus the research has become wider and more complicated, which requires more skilled labor hours. The influx of Ph.D.’s every year offers science faculty cheap, skilled labor and most post doctoral students feel that there is no other alternative except to keep low wage employment (Weed 2000).

The graduate student labor has reshaped the academic environment in higher education. Decline in financial aid and cuts in funding have compelled universities to adopt such strategies (Slaughter & Leslie 1997). It is more economically viable for the universities to use graduate and doctoral students for teaching purposes. According to the American Historical Association, 1999 Coalition of Graduate Employee Unions, it was estimated for around 50 to 70 percent of the total teaching hours, graduate students and adjutants were used as instructors and 90 percent of the grading was done by graduate students (Lafer 2003).
Thus graduate students are an important link in the university-industry collaboration. As suggested above, the students working with industry and as graduate workers, even if less paid gain intellectual expertise in the process. Moreover, these students provide skilled manpower to a region and thus support economic growth in the region.

History of the University-Industry Collaboration in the United States

The collaboration between university and industry has been historically through informal methods earlier such as knowledge transferred through personal discussion. The first formal collaboration is considered, the land grant college system was developed in the 1860s. In the United States university-industry collaboration can be divided into three phases, the first period being from the mid-1800s to WWII; the second from the early 1940s to the mid-1970s; and the last from the late 1970s to the present. In the first period, the collaborative efforts were mainly to support the technological needs of local or regional industries, especially the agriculture industry. In the mid 1930s, mostly federal research funds were for university-based agriculture research supporting regional development. By the early 1950s federal government agencies, especially defense, were involved in U.S. academic research, and almost 60 percent of all academic research in 1955 came from these federal agencies. The concept of basic and applied research was introduced during this period. The industrial decline during the last part of the 1970s and early 1980s led U.S. industrial regions contemplating university-industry collaborations as an important economic development tool. From the mid 1970s, due to international competition the advanced industrial nations had to restructure their economies and
technical innovation was considered the driving force for growth in the global economy (Abramson, et al. 1997).

The U.S. federal government encouraged university-industry collaborations to foster regional development. One of the earliest such efforts was the land grant college system which was created by the Morrill Act of 1862. This Act was made into a law by President Abraham Lincoln. The United States Federal government allotted 10,000 acres of land to every state. The revenue generated from its sale was used for a public university for agriculture and the mechanical engineering arts (Reisman & Cytraus 2004). Before WW II, the role of the U.S. government in research funding at the universities was through Land Grant colleges, which supported the development of agricultural economy in the regions. World War II increased research funding at the universities to enhance the technology base of the military for war efforts (Etzkowitz & Stevens 1998).

The first U.S. university technology transfer was in the 19th century which involved agricultural methods and technologies. Land Grant universities supported agricultural research and teaching and also extended into the region to educate the public. Further, the Hatch Act of 1881 allowed each state to have an Agricultural Experiment Station focusing on agricultural research. Experiment Stations received federal support through appropriations from the U.S. Department of Agriculture (Reisman & Cytraus 2004).

The University of Wisconsin-Madison (UW) is considered as an initiator of institutionalized technology transfer. In 1923, Harry Steenbock, a biochemistry professor at UW, demonstrated that ultraviolet light radiation increased vitamin D in foods and other materials. This could possibly eradicate rickets, and with proper management serve
the right cause. Thus in 1925, the university established the Wisconsin Alumni Research Foundation (WARF) to manage all UW Staff discoveries. This was one of the first cases of university research reaching to almost every region of the world through proper collaboration. The WARF foundation model of technology transfer is based on collaboration between UW-Madison and industry and is one of the most successful cases of technological innovation and public welfare in the U.S. (Reisman & Cytraus 2004).

Following World War II the university research funds mainly focused on defense and health related research. World War II also was the main reason for the formation of the Office of Scientific Research and Development (OSRD) which was led by Vannevar Bush. Research projects at OSRD resulted in a number of scientific innovations during the war such as penicillin, radar, early calculating machines, jet engines, and atomic power. These innovations were so revolutionary that even after the end of war, the policymakers emphasized on utilizing science and technology for social benefits and economic growth (Reisman & Cytraus 2004).

Vannevar Bush's 1945 report “Science the Endless Frontier” argued that economic development was an important factor in funding university research. Most of the universities considered teaching as the main mission and were not involved in the real world issues with the only exception being MIT under the direction of industrialist Bush. Other factors which led to the increase in university-industry collaborations were the end of the Cold War, long-term benefits for the U.S. economy, the US Federal government's inability in funding R & D, and a decrease in private industry in-house R&D capabilities (Atkinson 1994).
During World War II, the governments of Germany, England, Canada, and the United States utilized research universities expertise to advance war efforts. The academic research through involvement in the war effort was influential in the development of new technologies such as atomic energy, radar and aeronautics. The MIT's research labs contributed to radar, anti-aircraft gun control, and electronics. Additionally, physicists Dunning, Rabi, Enrico Fermi, and George Pegram contributed to the war through the Manhattan Project\(^1\) (Odza 1998). Some of the local industries such as Union Carbide, Simonds Saw and Steels, Titanium Alloys Manufacturing, Bethlehem Steel were also involved in this project.

After World War II, the academic research was considered an important factor in national development. U.S. Federal agencies were the main research funding source, and the university research shifted from basic to long-term applied research. During this phase, the difference between academic research and industrial research came to known as “basic research” and the other “applied research” respectively (Abramson, et al. 1997).

In the second phase of university-industry collaboration, private foundations mostly funded the academic research and development. During this period, the academic research institutions generally considered technology transfer to industry as a secondary activity and more emphasis was on training students, published research and faculty consultants. The third phase was similar to the second with more focus on collaborative research and technology transfer between the research universities and industries. In the 1970s the industries were highly commercialized and put emphasis on academic research

\(^1\) The Manhattan Project involved US, UK, and Canada for developing the first nuclear weapon during WW II. Though it began in 1939 as a small research program, it ended employing around 130,000 employees and costing almost $2 billion USD.
in technology such as microelectronics, software and biotechnology. Additionally, the technology related industries in the United States faced challenges from Japan and other developed countries resulting in increased federal and state support for academic research in technological and Research & Development (Abramson, et al. 1997).

University-industry collaborations were also supported by a series of Federal technology transfer legislative initiatives in the 1980s. The most notable legislations were the Bayh-Dole Patent Act in 1980 and a 1984 amendment to the Trademark Act. These Acts permitted universities to own patents of their inventions that resulted from federally-funded research and license them to industry. This legislation created financial incentives for universities to market technologies and encouraged them to increase technology transfer (Cooke & Morgan 1993).

The Department of Defense funded more than half of the academic research in the mid 1950s. However, in the 1980s, when federal financing was reduced, academic research universities sought the support of private sector funding. Congress and the Federal government provided the necessary support for such collaborations. The Bayh–Dole Act regulated intellectual property rights between nonprofit organizations and businesses. University-industry collaboration was also encouraged through federal funding of university based research centers. The U. S. Federal government has at times funded up to 70% of university research in sectors such as computer science (Lockemann 2004).

During the 1980s, the policies supporting university-industry collaboration in the US had three objectives: firstly university research supporting technology development in sectors important to local industry, secondly facilitating collaborative research in
university-industry centers and lastly establishing programs for university research access to smaller firms (Geiger and Creso 2005).

Economic Development Significance of University-Industry Collaboration

World War II and the Cold War between the U.S. and the Soviet Union led to new agreements and collaborations between the academic and industrial sector, thus billions of dollars were invested in scientific research as a national concern. Beginning in the 1980s, the importance of collaboration between university and industry was considered an economic driver for regional development. The third wave economic development policies emphasized regional collaboration between government agencies, educational institutions, research institutions, and private firms. Firms also began to recognize the value of collaboration with public research universities. Such collaborations were encouraged by government policies such as the Bayh Dole Act., in order to promote technology transfer and strengthen U.S. industries competitiveness in the international arena. One of the main Federal initiatives aimed at stimulating innovation in regional industries was through subsidizing university centers for collaborative research (Geiger & Creso 2005). Traditionally technology transfer involved teaching, publications, and consultations. The new policies facilitated in transferring university’s expertise and knowledge to industry through licensing, new start ups and spin-off firms (Rapinoja & Aura 2005). Technology is generally transferred from the public to private sector through publications, patents and licenses, collaborations between research universities and industries and also university start ups (Hong 2006).

Abramson, et al. (1997) suggests that there are three methods for transfer of technology from university to industry in the United States. The first method involves
education and research activities of the academic institutions such as faculty consulting and the transfer of university intellectual property through students and faculty employed by firms.

The second is related with traditional missions of the university and includes patent licensing, university acquisition of private sector licensees and the different ways for promoting sponsored university-based research. Industry sponsorship of university research includes the establishment of formal university-industry research centers, research groups involving other universities/departments, multiple firms, and government labs.

The third method facilitates commercializing research and university-industry collaborations. This method involves activities such as technical assistance programs and business incubations.

_Research Hypotheses_

This dissertation examines whether regions with higher levels of university-industry collaboration have better economic development outcomes. The hypotheses for the study are that Industrial research funding is positively related to per capita GDP, new firm births and negatively related to unemployment in a region. The other hypotheses examines whether the number of science and engineering graduates is positively related to per capita GDP, new firm births in a region and negatively to unemployment in a region.

_Plan of the Study_

Chapter I discussed the concept of university-industry collaboration and the background and history of the university-industry collaboration. Chapter II will review
the various literature related to development of university-industry collaborations. It will discuss the proposed theory, and how the literature can be applied to the dissertation in explaining the university-industry collaboration. Chapter III discusses the methodology which includes research design, and the model of the study. Chapter IV presents the data which includes missing data and normality of data sets. Chapter V discusses the findings and the discussions, and finally the last Chapter will discuss the conclusions, recommendation, and limitations of the study.
CHAPTER II

LITERATURE REVIEW

This chapter begins with the description of the important terms used in the dissertation. Further, the chapter reviews the relevant literature related to university-industry collaboration and economic growth and development. It describes the systems of innovation approach from university-industry collaboration perspective.

Definition of the Terms

*University-Industry Technology Transfer*

Association of University Technology Managers (AUTM) describes technology transfer as the official transfer of rights of new innovations and discoveries of scientifically valuable research for utilization and commercialization purposes. Technology transfer is accomplished through various flows in technology: by buying products and intermediate goods; through patenting, patent citations and scientific publications and collaborative research activities; and mobility of people through flows of skilled workers (OECD 1997). Universities typically transfer technology to their industrial partners using patents and copyrights. The process mainly includes the disclosure of innovations, patenting, research publications, and licensing rights to their industrial partners for commercial purposes (AUTM).

*Bayh-Dole Act*

According to AUTM (2007), Bayh-Dole Act (enacted on December 12, 1980) resulted in a uniform patent policy for funding research from the federal agencies. This Act encouraged universities to involve more actively in technology transfer activities and facilitated non-profit institutions, small businesses and research universities for retention
of title for inventions done under federally-funded research programs. The university technology transfer activities increased tremendously after the passage of this Act\(^2\).

**Patent**

According to USPTO, “Utility Patents are granted for the invention of a useful and new procedure, manufacture, machine, and composition of matter, a useful and new improvement. It usually allows its owner to exclude others from making, using, or selling the invention for a period of up to twenty years from the date of patent application”. Around 90% of the patents granted are utility patents, also known as ‘patents for invention’.\(^3\)

**Innovation**

Innovation is the commercialization of new innovative knowledge relating to product, process or organization. Innovation is a process where users, producers and other related units are involved in learning from each other and exchange knowledge (Cooke 2001).

Innovation is an important feature for sustained growth in terms of production growth and better standards of living. Innovation happens in small regular changes, irregular radical changes, and big changes in some general technology, also described as ‘techno-economic paradigms’ (Edquist 2001). Tether (2002) defines ‘innovation co-operation’ in his research as “active participation in joint research and development and other technological innovation projects with other organizations” (949).

\(^2\) [http://www.autm.net/Bayh_Dole_Act.html/](http://www.autm.net/Bayh_Dole_Act.html/)

\(^3\) [http://www.uspto.gov/](http://www.uspto.gov/)
Metropolitan Statistical Area

According to Office of Management and Budget (OMB) classification for the year 2000, MSAs have at least one urban area of 50,000 or more people, plus an adjoining territory which has great level of integration, both at social and economic levels with the center as measured in terms of commuting ties.

Economic Benefits of the Universities

Regions exploit their universities for economic development and growth as the universities are a source of revenue and knowledge. The research universities gained significance at the end of the 20th century when the industrial sectors became specialized and science based in manufacturing, mining and agriculture industries (Goldin and Katz 1999). Universities collaborate with industry through academic departments, institutes, centers and consortia. However there are two main driving forces that have led to increase in such collaborations: the changing structure of science and the changing economy of research funding. Industry research funding has encouraged universities to pursue applied result oriented projects (Dooris 1992).

The functions of research universities that influence development in a region are categorized as knowledge generation, skilled human resource, existing expertise transfer, innovation in technology, investment of capital, local leadership, impact on regional surroundings, and knowledge infrastructure production. Human resource creation, technology transfer and innovation impact regional surroundings, and knowledge infrastructure production functions are related to university-industry collaboration (Goldstein, Maier and Luger 1995).
The contribution of science to economic development is a source of a region’s competitiveness. Thus universities are now involved in direct interaction and collaboration with industries in addition to traditional teaching and research activities (Etzkowitz and Leydesdorff 2000). The universities contribute to regional economic development in several ways such as universities provide highly trained employees, expertise, and amenities that encourage firms to relocate to the region. The universities also provide expertise and skills for existing local businesses. The technologies developed in universities lead to new businesses and employment in the region (Stephan, et al. 2004).

The association between university and the regional economy is similar to a transmitter receiver system. Therefore a region should absorb the innovations from research universities and skillfully convert and exploit the innovative ideas created at the university. The universities alone are not sufficient for spurring development in a region and need the collaboration of other institutions. Industry is one of the institutions which support the innovative needs of universities (Florida, et al. 2006).

Economic growth is initiated by non rival characteristics of knowledge. Non rival goods and services are equally available to everyone such as national security and eradication of malaria. Since knowledge in a region is a non rival good, it has increasing returns (Cortright 2001). Romer (1986) suggests that the economic growth in a region is driven by knowledge accumulation, which is considered as basic form of capital. In knowledge driven economies wealth is generated by knowledge generation and its exploitation. Cortright (2001) suggest that all new knowledge is not easily available for public use and is partially excludable. Economically valuable knowledge such as patents,
trademarks and copyrights is partially excludable due to their legally imposed rights. Firms own the right to exclusively use certain knowledge, giving them an incentive to create or work with partners to create new knowledge.

Technological upgrading and innovation has been the real cause for improvement in standard of living in regions. Technological progress in a region needs an “intentional investment of resources by profit seeking firms or entrepreneurs” (Grossman and Helpman 1994, 24). During the 1950’s and 1960’s the rate of technical change and economic development was largely due to diffusion of innovation, rather than being leader in radical innovations. Though basic science was still considered important but regional development depended significantly on innovation technology and diffusion (Freeman 1995).

Reasons for University-Industry Collaboration

University-industry collaboration is a process where actors from the industrial and academic sectors cooperate and support each other for betterment and economic advantage, thus increasing employment opportunities through innovative start-ups and industries (Harayama 2003). The increase in competition in the global market led to the development of university- industry collaboration and strengthening of entrepreneurial activity in the developing regions. Traditionally, educational expertise was transferred to the productive sector through personal meeting. However, formal technology transfer activities such as consultancy, training centers, research labs and institutes, science parks and incubators, and technology committees also emerged (Brimble and Doner 2007). Universities collaborate with other institutions as it has innovative ideas to develop new functions and structures, for equity investors in faculty owned firms, and develop new
resources such as campus based incubator facilities. The university’s collaboration for innovative purposes generates revenue through funds obtained from faculty entrepreneurship, state economic development funds, grants and collaboration from various corporations (Baba 1988).

From an industry perspective, collaboration with the university is acquisition of new knowledge. This means more revenue and better skills for the industry and knowledge enhancement of its own scientific personnel (Poyago-Theotoky, Beath and Siegel 2002).

Etzkowitz and Goktepe (2005) explain the interaction between universities and industrial sector and the role of innovation and their association. Firstly, the product is created in a university however the industry undertakes its development process. Secondly if commercial product is created outside the university, the academic research facilitates in improving the product. In both cases the university is a resource of knowledge and innovative technology for the industry.

The four main reasons the universities collaborate with industries are: industries are a source of revenue for the universities, industrial funding involves less bureaucracy than government funding, industrial research projects at the university train students in real world problems and certain government funds for applied research are available only through collaboration between university and industry (Peters and Fusfeld 1982). Other factors such as lack of support from the government; failing university research facilities; and revenue generation have increased university’s collaboration with industry (Barber 1985). The university and industry transfer knowledge through collaboration. The knowledge transfer through collaboration takes place through different methods such as
co-funded projects, research parks, and a portfolio of patents. Knowledge transfer through also happens when a student employed at a firm applies a new relevant theory or technology in the industrial sector (Kjersdam 2004).

Earlier knowledge and technology transfer from universities to industries was typically through publication, consulting, and presentations at conferences. Currently, the academic research is more inclined toward fundamental knowledge in the sciences and the industrial research prefers immediate market applications of R & D. Publicly funded university research stimulates and enhances industrial research and development (Rosenberg and Nelson 1994). Simmie (2003) suggests that innovation increases regional export base, as leading innovations in industrial sector create wealth in a region through increase in exports. Innovation in products, processes and services is only possible through knowledge generation and application of knowledge gives competitive advantage to economies.

Advancement in knowledge is only possible through constant research and development investments, a well trained and skilled labor force, commercialization of new innovative knowledge and effective transfer technology (Lever 2002). Universities are significant entities in creating and sustaining knowledge-intensive industries. The contribution made by universities is more through skilled human capital rather than economically valuable research (Geiger and Creso 2005). Industrial benefits from the collaboration include transfer of knowledge and expertise from the university and enhancement of knowledge and skills for its scientific professionals (Poyago-Theotoky, Beath and Siegel 2002).
Universities need the support of other institutions for regional development and university-industry collaboration is an important factor for industry’s competitive advantage. Various studies have discussed the presence of a university in a region for industries’ location decisions. Premus (1982) explained that almost sixty percent of the U.S. industrial firms considered university’s presence in a region an important location factor. Further, Lund (1986) concluded that university proximity is the fifth most important factor in firm’s location decision from among 20 factors. Malecki and Bradbury (1992) found that the presence of a university in the region is the seventh most important factor among 22 in location decision factors. Another research suggested that fifty two percent of the industries considered locating close to academic institutions are beneficial for their growth (Schmenner 1982).

Collaborations lead to changes in objectives and traditional perspectives of industries. Thus the interaction among industry and science induces changes in various research organizations and research universities. This stimulating affect is due to innovation and diversity to organization’s rules, behavior, and technologies from collaboration efforts (Kaufmann and Todtling 2001). Licensing of technologies generated at the research university labs influences regional economic development. Additionally, royalties generated due to licensed technologies helps in increasing university’s revenue (Parker and Zilberman 1993).

Not all studies suggest that universities are significant instrument for regional economic development. Much of the research from the universities may not be commercially viable but certainly adds value to industrial research and development efforts (Geiger and Creso 2005). The presence of a university may not be an important
factor for every industry. A study concluded that pharma research labs in England did not regard university as a significant location factor. While 2.6 percent considered research institutes as main location factor and three-quarters of them indicated that a university presence was not a significant location factor (Howells 1986). Further Gripaios, et al. (1989) in their study found that only nine percent of the industries indicated that a university has any impact on a region. Thus “universities are necessary for high tech economic development, but have not proven sufficient” (Acs 1990, 74).

Malecki and Bradbury (1992) examined preferences and location decisions of research and development facilities and their professionals and found that the city size is a significant factor for their location decisions. Industries located in big cities consider proximity to a university a more important factor compared to small city respondents. Further, the size of the region and the quality of life in a region are significant factors for professional workers and R & D firms.

Markusen, Hall and Glasmeier (1986) studied the factors that influence high tech industries’ location decisions in 264 metropolitan statistical areas. They investigated university R & D funding to understand the research universities presence in terms of high technology industrial location and concluded that the research university is not a significant factor for firms’ location decisions.

New technology adoption by industries in a region may not necessarily mean growth and new opportunities and in a region. Most of the region’s technical abilities are process technology, as interaction between components and people governing it (Shaffer, Deller and Marcouiller 2006). Lund (1986) in his research found that fast growth among small firms is because of better organization or business processes, and not because of
higher rates of technical invention. R & D labs having less than 500 employees are more influenced by universities location and any other research institutions than those having more employees.

The university and industry have to work in collaboration to spur regional economic growth. In the 1990s California suffered economically due to reduction in Federal funds related to defense and aerospace research, which led to loss of jobs. However as a result of collaborative research between the universities and the high tech industries the state emerged from the recession. The success of the biotech industries in California is contributed to research programs that were initiated by the universities (Brighton, Smilor and Wallmark 1990). During the 1990s, two-thirds of national economic growth was due to growth in high-technology industries. The regions with growth in technology sector developed faster than without a technological sector (DeVol 1999).

Thus poor regions lack ideas, not objects which hinder their development. The advanced nations have the knowledge which can assist poor countries in improving their standard of living. Thus if poor nations invest in education and encourage people to get innovative ideas from the people across the globe, it can benefit from the publicly accessible knowledge (Romer 2007). Economic development policies of third wave also suggest that regions’ development depends on their ability to adapt to technological innovation and the thriving regions are those that follow innovative approach to development (Bradshaw and Blakely 1999).
Innovation and Growth Models

Innovative ideas can be shared and reused at no cost. The more innovative ideas and knowledge a region generates, the more it obtains from a limited set of resources and consequently leading to economic growth in a region (Cortright 2001). Cooke (2002) suggests that regional innovation starts with regional agglomeration and the universities’ function in shaping regional agglomeration is based on developing present or growing regional industrial clusters.

The exogenous growth models of Solow and other neoclassical growth models could not explain the reason for improvement in technology with time. Solow’s model regarded technology as an ongoing, ever increasing knowledge that becomes apparent with time, but is not created by economic forces alone and produces economic growth and productivity continuously. Solow’s model is known as the exogenous growth model as technology advances by forces external in the economy (Cortright 2001).

New Growth Theory (NGT) describes the role of technology in the functioning of markets and referred it as “endogenous” growth theory. The theory asserts that knowledge and technology are the source of increasing returns, and thus cause growth process. The NGT model explained the technological spillovers in the industrialization process. New theories of economic development have emphasized complementarities between the different conditions necessary for development; different things must work well, at the same time, to reach sustainable development (Todaro and Smith 2006).

Innovation Models

The linear model of innovation describes innovation as a linear process which begins with basic research, then moves to applied research, development and ends with
diffusion and production (Godin 2007). The linear model considers the impact and effect of a single variable in the innovation and diffusion process. The non-linear innovation models were developed from the evolutionary economics perspective (Nelson and Winter 1974).

Basic Research → Applied Research → Development → Production & Diffusion

Figure 1. Linear model of Innovation (Godin 2007)

The non-linear models are based on the interaction among various variables rather than a single variable, and include feedback of research, the technological and scientific knowledge, the production process, the prospective market and invention (Kline and Rosenberg 1986). The interactive innovation model explains the collaboration between university and industry. It explains economic growth through innovation in technology, and social responsibility of science and technology development (Harayama 2003).

The nonlinear innovation models are an extension of linear models which consider interactive and recurring terms through feedbacks (Etzkowitz and Leydesdorff 2000). The system of innovation approach suggests that innovation is a non-linear, interactive and evolutionary process. Further it requires collaboration and interactive feedback between different actors, between industries and other organizations such as academic institutes, innovation centers, financing institutions, industry associations and government agencies (Todtling and Trippl 2005).
Figure 2. Feedbacks and Interactions in the innovation Process-Non Linear or chain linked Model of Innovation (Kline and Rosenberg 1986).

According to non-linear concept, innovation is stimulated by various factors and entities. In the innovation process, the interactions and feedback from production, marketing, and customers are also important. The interaction in innovation process is internal associations and relationships among different departments of the industry and also knowledge providers such as universities and technology centers (Kaufmann and Todtling 2001).

Innovation is knowledge transfer revolving around actors either internal or external to a firm working in project-based teams or a project-network environment. The model for innovation processes in firms and scientific institutions is interactive rather than linear. Thus the innovation based model for regional and local economic
development has shifted to networked model from hierarchical (Cook 2001). Innovation is primarily not a single event, but an interactive process. Innovation changes during the diffusion process, thus it is not possible to record invention and innovation in timely manner (Lundvall 1992).

Theory of Innovation System

The innovation system approach considers that innovation is interactive, with constant feedbacks, and involves external institutions and actors. In the case of regional innovation systems, the exchange of tacit knowledge involves in-person interaction between personnel, mainly within regions within narrow boundaries. The relationship between systems is different from the relationship between firms. The science and business systems have diverse interpretation approaches, decision rules, objectives, and communication methods and the systems do not overlap but interact among themselves (Kaufmann and Todtling 2001).

The innovation systems approach originated from evolutionary theories of technological and economic change. Innovation systems literature perceives innovation process to be evolutionary and social (Edquist 2004). Nelson and Winter (1974) studied changes in technology and routines, using simulation and explained that if the economy is changing constantly, then there has to be some kind of evolutionary process, which is Darwinian in nature. In their model, they assumed that technical progress was due to behavior of industries in the sector and that innovation was relatively even over time. However, it is apparent that the invention possibilities, for industries in particular sectors change as a result of forces exogenous to the sector. Lundvall (1992) was one of the initiators of innovation system approach. He suggests that “elements and relationships
which interact in the production, diffusion and use of new, and economically useful
knowledge that a national, regional or local system encompasses elements and
relationships, either located within or rooted inside borders of a nation [regional, local]
state” (Lundvall 1992, 2) make a system of innovation.

The innovation systems approach was first developed by Perez and other scholars
in the 1980s. According to Perez (1983) each development approach is based on response
to a particular technological style or “techno economic paradigms” for the best
production efficiencies. Moreover its main tenet is that technical change is due to
evolution in technology systems, and technology development and innovation are the
important factors for regions competitive capacity.

Perez (1985) discussed the significance of the relation between techno-economic
process and economic growth and social change and opportunities for global advantage in
regions. Perez considers the process of technological progress in terms of knowledge and
inventions as a relatively autonomous process. However, innovation (application and
diffusion of specific techniques in the production environment) is often influenced by
social conditions and economic profit decisions.

There are different features of innovation systems. In some systems, the main
feature is a technology or a sector; while in others the focus is on geographic system
borders such as a particular country or region. Thus determining relevant geographic
boundary is a methodological and theoretical issue in a study of innovation system
(Carlsson, et al. 2002). The systemic relations among different entities or nodal points
engaged in innovation make an innovation system (Lundvall 1992 as cited in Cooke
2001). There is inter-dependence in systemic relationships and all the relationships are
not the same at all times and there might also be hierarchy involved among elements in a innovation system (Cooke 2001).

The focal point of innovation systems is generally knowledge, learning and interactivity among different actors in the system whether at national or regional level (Lundvall 1992; Freeman and Perez 1988; Nelson 1993). The National Innovation Systems (NIS) is one of the important systems approach concept (Lundvall 1992; Freeman 1988; Nelson 1988, 1993) which incorporates research and development initiatives, research institutions and universities and technology policy in a single innovation system.

The system of innovation approach also emphasizes the role institutions, both formal and informal in the innovational process. According to the innovation systems approach, innovation is a non-linear, interactive and evolutionary process, where different actors are constantly involved in interacting among themselves (Edquist 2001, 2005).

Universities are considered significant entities in NIS (Lundvall 1992). The innovation systems literature emphasis that the centre of region’s development is made of knowledge flows (Karlsson and Johansson 2006). Further, the regions capability to implement and adapt to innovative technologies to a large extent is subject to the institutional & regional infrastructure, skills and education, topography, and research & development resources (Karlsson et.al 2008). Freeman (1987) in his research of Japan’s economic development was the first to use the term “National Innovation System” (Freeman 1987, 52). He defined the NIS as “the network of institutions of
private and public sector, whose activities and interactions initiate, import, modify, and diffuse new technologies” (121).

Regional Innovation System

Regional innovation system (RIS) approach examines the regional industries that make the innovation system and also institutional units and explores characteristics that distinguish the main institutional actors. RIS focuses on regional innovation by explaining the innovation capability in reference to region’s research and development abilities, educational capabilities, technological skills and outputs in terms of patents etc. RIS also facilitates in understanding regional disparities in terms of innovative achievements and regional competitiveness (Doloreux and Parto 2004).

According to innovation systems literature, the system is formed of linkages or collaborations among various institutions such as academia, government, private sectors, markets, culture or social and political systems and innovation is at the center of all the activities among these partnerships. The interactions between institutions lead to new learning processes and result in new knowledge and technology through innovations and economic growth. In an ‘innovation system’ everything is linked to everything. Regional economy, public, technology and science are self-generating complex systems. In these systems innovation happens endogenously and is an output of interaction amongst the actors (Rosenberg 1982).

Regional innovation system includes a systematic process of relationships and interactions among the different economic entities or institutions in a region (Cooke 2001). Camagni (1995) called this the ‘innovative milieu’. Innovative milieu approach considers region as an organization connecting industries, institutions, and local
populations within a process of economic development. Regional innovation systems are considered as engines of growth in the regional innovation process. Although the process of innovation is mainly managed by the national innovation system still it is localized and centered on regional innovation (Crevoisier 2004).

An innovation system includes institutions and resources and interactions among locations’ research institutes. The industrial sector benefits from this through commercialization of innovations (Spencer 2001). RIS involves interaction between formal institutes and establishments that work in accordance with institutional planning and associations that encourage and support the creation, utilization and diffusion of knowledge (Doloreux and Parto 2004).

The innovation systems can be explained in two dimensions. First dimension is geographical as a region, while the second is a sector such as technology. The innovation systems include components, relationships and attributes. The components are the various elements as research institutions, firms and universities in a system. The relationships in a system are the associations among these the components. Attributes describe characteristics of the components and the association among them. A significant relationship in the innovation system revolves around transfer of technology, which is the main function of the system. The technology transfer may be intentional or unintentional; the unintentional is known as technology spillover while intentional is technology acquisition or transfer through collaborative process (Carlsson et al. 2002).

Montana et al. (2001) argue that technological innovation is an important economic development tool both for a region or a country, but for region’s success and development, innovation is required in sectors beyond technology. They describe
innovation as development of new technology; applications of new technologies developed elsewhere, more effective approaches to workforce development, new methods of collaborating within and across organizations, and reshaping of industrial infrastructure. Successful innovation collaborates and integrates new creative ideas from different sectors of technology, workforce, and organizational development, from within and across organizations.

Technology Transfer and Research Funding

The network of interaction between university–industry–government is considered as a ‘triple helix model’. Knowledge generating institutions, universities, industries, high-technology start-ups firms, international business corporations, and government at different stages make a triple helix. The literature related to triple helix discusses the universities’ function in facilitating regional growth by formation of new firms and other revenue generating projects, such as science parks, incubation facilities, research centers at universities and technology transfer offices (Etzkowitz 2002). The triple helix model perceives that “interaction in university-industry is the key to improving the condition for innovation in a knowledge based society” (Etzkowitz 2003, 295). Etzkowitz et al. (1998) also suggest “In addition to linkages among institutional spheres, each sphere takes the role of the other. Thus, universities assume entrepreneurial tasks such as marketing knowledge and creating companies even as firms take on an academic dimension, sharing knowledge among each other and training at ever-higher skill levels (6).
Trilateral networks and Hybrid Organizations

![Diagram](image)

**Figure 3.** Triple Helix Model of Innovation (Leydesdorff & Etzkowitz 2000).

The main mechanism of transfer and commercialization of technology from the university has been through licensing agreements between the university and firms, university generated start up firms and joint research ventures. An important transfer mechanism for technology and specialized knowledge and skills is the employment of faculty and college graduates in industry (Phan and Siegel 2006).

Theoretically, it is assumed that there is a linear relationship among R & D investments, knowledge and innovation generation, and competitive advantage and consequent economic growth in a region (Lever 2002). It is seen that researchers and universities who are competitive and successful usually combine educational expertise with entrepreneurial activities and industrial relationships (Godin and Gingras 2000). Previous studies have highlighted the commercially oriented role of university such as
patenting and licensing has been significant for scientific growth, biotech, computer software, and semiconductor industries (Rosenberg and Nelson 1994).

Technology transfer related activities are beneficial for educational institutions. They are a tool for transferring valuable research to the society and support industrial research. These activities facilitate in attracting more graduates, professional staff, and research funding at the research universities (Carlsson and Fridh 2002).

In United States, industries support university research through various forms, ranging from individual research funds to funding research facility through a group of industries. The main types of such collaborations are individual research support through consulting jobs and grants, single research collaboration projects with university, and a few projects are government co-funded. Other types are funding large labs by industrial groups and partially funded centers from federal government funding such as university-industry research centers (Hall 2004).

In a research investigating technology transfer in 170 US research institutions, hospitals and universities during 1991–1996, it was found that the amount of research expenditure was positively related to number of startup firms and similarly institution size correlated positively to number of patents (Carlsson and Fridh 2002). In a survey study of 400 joint ventures between industry and university, industries ranked their collaborating motives with universities as access to new research, new products development, relationship with the academic institutes, new patents acquirement and solutions for technical problems (Lee 1996).
Summary

The chapter examined the literature on technology and economic growth and various concepts related to innovation and knowledge. Innovation in a region is an important factor for sustained economic growth (Edquist 2001).

University-industry collaboration has an essential role in accelerating knowledge and technological innovation in a region, thus enhancing economic growth in a region. Regional economic growth also depends on the quality of educational institutions, venture capital, risk taking and innovation (Karlsson, et al. 2007). Universities collaborate with industries for research funds, training students, business incubation and research parks. Industries collaborate with the universities for access to skilled and knowledgeable manpower such as students and faculty and also access to basic and applied research for industrial innovation. As mentioned in the literature, after the end of Cold War, US Federal government defense related funding to universities was reduced. Thus universities started looking for other options in funding research and, industry was the best alternative for the university as they had funds and the need for such collaborations (Abramson, et al. 1997).

Research universities facilitate in generating new innovative ideas for the regional industries and thus affecting the regional economy directly. The indirect impacts are new firms in the region and economic gains from the innovative ideas generated at the universities (Varga 1997).

The main reason for the university-industry collaboration was their individual benefit and financial gains. Regional growth was not an intended outcome in this collaboration. However, economic developers visualized that such an activity could be a
tool for regional development. The U.S. Federal government also encouraged greater university-industry collaborations by funding university based research institutes through the years such as NSF’s Industry- University Co-operative Research centers in 1973, Engineering Research Centers in 1985, Supercomputer centers in 1986, Science & Tech Centers in 1987, and Materials Research Science and Technology Centers in 1993. Each of these research organizations are designed to serve different objectives and have commitment to facilitate university-industry research collaboration and technology transfer (Abramson, et al. 1997).

Table 2

*Advantages from University-Industry Collaborations*

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<thead>
<tr>
<th>Universities’ Advantage</th>
<th>Industry’s Advantage</th>
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<tr>
<td>Faculty</td>
<td>Human Capital</td>
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<tr>
<td>Access to Industrial facilities and equipment</td>
<td>Access to skilled human resources</td>
</tr>
<tr>
<td>University researchers and firm employees publishing together</td>
<td>Improving skills for employees through education and training</td>
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<tr>
<td>Revenue through R&amp;D with Industry</td>
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<tr>
<td>Join in Startup business</td>
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<tr>
<td>Update curriculum and program in accordance with the market</td>
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<tr>
<td>Students</td>
<td>Innovation and S&amp;T development</td>
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<tr>
<td>Improve skills in working with real world problems at industries</td>
<td>Research and development for products and processes</td>
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<tr>
<td>Finding jobs after graduation</td>
<td>Regular acquisition of university research</td>
</tr>
<tr>
<td>Business Incubation</td>
<td>Permanent or temporary transfer of knowledge from universities to industries</td>
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<tr>
<td>Students’ doctoral and master’s theses are sometimes directed by university and sponsoring industry jointly</td>
<td>Purchase of successful university research such as patents.</td>
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<td>Resources and Funding</td>
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<td>Investment in university facility</td>
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<td>University researchers and firm employees publishing together</td>
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<tr>
<td>Creation of business incubators and research centers</td>
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Adapted from Inzelt (2004)
Research Questions and Hypotheses

Most of the research involving innovation and regional economic growth has been at the national or state level, though there have been various researches on technology regions promoting economic development (DeVol 1999). The research related to university and industry has focused on issues such as research and development expenditures, patents granted, and mostly to economic impact of universities in regions. The universities and industries collaborate in various ways from informal information transfer such as consulting, training, to more structured cooperation such as contract research, research consortia, business incubators, and research centers (Geisler 1995). Regions that support the development of its university research facilitate regional innovation through industrial R & D and thus increasing growth (Jaffe 1989). This dissertation considers university-industry collaboration in terms of industrial research funding to universities in Metropolitan Statistical Area and will study the effect of such collaboration on measures of economic development.

In a personal communication (17 March, 2011) Maryann Feldman (her research has focused on technological change and economic growth in a region, innovative regions and academic research commercialization) suggested that the factors that could be analyzed to study the influence of university-industry collaborations in a region would be employment patterns and per capita growth.

The main research question for the study is:

Does university- industry collaboration affect economic development outcomes in a region (MSAs)? The economic development outcomes in a region are measured in terms of per-capita GDP, unemployment rates, and new firm births in the MSAs. Better
outcomes include higher per capita GDP, lower unemployment rates and the more new firm births. The regions analyzed for this research are Metropolitan Statistical Areas (MSAs) in the United States.

The hypotheses generated from the main research question are:

\[ H_{1a} \]: Industrial research funding is positively correlated to per capita GDP in a region.

\[ H_{1b} \]: The number of science and engineering graduates is positively correlated to per capita GDP in a region.

\[ H_{2a} \]: Industrial research funding is negatively correlated to unemployment in a region.

\[ H_{2b} \]: The number of science and engineering graduates is negatively related to unemployment in a region.

\[ H_{3a} \]: Industrial research funding is positively correlated to new firm births in a region.

\[ H_{3b} \]: The number of science and engineering graduates is positively correlated to new firm births in a region.
CHAPTER III

METHODOLOGY

The main purpose of this research is to measure the impact of university-industry collaboration on economic development in the selected US metropolitan areas. This chapter describes the research methodology used to evaluate the research hypotheses introduced in the previous chapter.

Research Design

There are three main types of quantitative research: randomized experiment, quasi experimental, and non-experimental.

Randomized experiment

In randomized experiments, subjects are randomly assigned to treatment and control groups. The treatment group receives a treatment, while the control group receives a placebo or no treatment. Thus, any results or changes in the subjects are due to the given treatment and not due to the differences between the groups. Randomized experiments are often termed as true experiments. Researchers often use the term true experiment when the independent variable is manipulated to evaluate a dependent variable. In most cases randomized experiments are not practical in social science research, especially in studies of regions (Shadish, Cook and Campbell 2002).

Quasi experimental

In a quasi experimental design subjects are not assigned randomly to treatment and control groups created by the researcher and may already belong to an existing group. In quasi-experiments, the treatment can be observed and happens before the effect is measured (Shadish, Cook and Campbell 2002).
Since the samples are not assigned randomly in quasi experimental design, there are threats to external validity not present in randomized designs. Common quasi-experimental designs include interrupted time series, equivalent time samples, and non-equivalent control groups. In interrupted time series design, multiple observations are made before and after the independent variable is introduced in the study, thus the influence of independent variables is tested only once. Equivalent time sample involves doing time series with introduction of independent variables a number of times (Giannatasio 1999).

Another quasi-experimental design uses control groups, but unlike randomized experiments, subjects are not randomly chosen for the treatment and control groups. Shadish, Cook and Campbell (2002) describe the designs having pretest and posttest and untreated control group as “frequently called the nonequivalent comparison group design, this may be most common of all quasi experiments” (136).

Goldstein and Renault (2004) suggest that while using quasi experimental designs in analyzing relationship between knowldege producing institutions and economic development in a region, the treatment variable would be the knowledge producing establishment in the region such as universities. The dependent variables are the measures of economic development, such as average earning in their study. The authors used quasi experimental design in their study by the manipulation of the time period into two parts. In their study, the groups having top 50 universities were considered as treatment group and the regions not having top 50 universities were considered as control groups. The study found that universities’ entrepreneurial activities influence
development in a region rather than traditional activities of the universities such as human capital development through teaching.

Goldstein and Drucker (2006) included both quasi and cross sectional designs to study the influence of universities at the metro level in US. For studying the change in regional earnings from 1986-2001, the regions were segregated into three groups in terms of base employment. Quasi experimental design was used by adjusting the dependent variable to include the change in macroeconomic conditions to control for regional disparities, and cross sectional analysis was used by including a number of measures related to university functions. The authors concluded that university research and teaching positively affects regional earnings.

Non Experimental

The third type of research is non-experimental, also termed as correlational, passive observational. In non experimental research there is an evaluation of cause and effect, but the structured experimental method is not present. There is no randomization and there are no control groups or pretests and posttests as in experimental designs. In such studies alternative interpretations are measured and statistical control is used. In cross-sectional studies, since the data is gathered at one time, it is difficult to know the cause effect relationships, unless the plausible explanations are measured validly (Shadish, Cook and Campbell 2002).

There are two dimensions of non experimental research. The first is according to the main purpose of the research and the second in accordance with time frame of collection of data (Belli 2009).
The first dimension classifies non-experimental studies as: descriptive, predictive and explanatory. Descriptive studies as the name suggests focus on the description of some phenomenon and/or documentation of its attributes. Predictive studies focus on prediction of criterion variables through information analyzed from the predictor variables or predict the dependent variables in the study. Explanatory research explains how and why of functioning of a certain phenomenon and focuses on testing a theory related to the phenomenon (Belli 2009). This dissertation focuses on predictive aspect of the research.

The second dimension focuses on time and classifies non-experimental research as: cross-sectional, prospective and retrospective. Cross-sectional research involves data collection at one single point in time. In prospective or longitudinal, data is gathered from the current and into the future and compared. In retrospective research as the name suggests, the research is accomplished back in time using existing data to explain and explore an existing phenomenon (Belli 2009). This dissertation focuses on cross-sectional data for the year 2000 for analysis.

Data sets in different kinds of research are divided into cross-sectional, time-series and longitudinal data in terms of time periods. In cross-sectional design, the variables are measured at a one point in time. Thus the cross-sectional data analysis is a snapshot of one point in time, while the time series and longitudinal consider different time periods for analysis. Certain cross-sectional cases are individual subjects, students, or patients, cities, states, and even nations (Burbridge 1999). In this research, MSAs in the United States are used for analysis.
Research Variables

Belli (2009) explains that variables in the experimental studies are defined in terms of independent variable (IV) and dependent variable (DV) based on the roles assumed by the variables. For non-experimental studies, the terms criterion and predictor are more appropriate for dependent variable and independent variable respectively. Criterion is the assumed result of the predictor.

The research uses three dependent variables namely, per capita GDP, unemployment rates and new firm births in the US metropolitan areas. The independent variables included are industrial research funding (IRF) and, number of science and engineering graduates (SEG) in the MSAs.

Further Belli (2009) suggests that, in order to assume that an independent variable \(X\) causes dependent variable \(Y\), the following causality requirements should be met:

- The first assumption is that there exists a relationship between the independent variable \(X\) and the dependent variable \(Y\). If they are not related one variable cannot cause the other. In this study, this is achieved through statistical analysis.
- The second assumption is the time order of the independent and dependent variables. The independent variable \(X\) should have occurred before the observed changes in dependent variable \(Y\). A cause occurred before an effect has to be explained logically. In this study, the measurement of the independent variables precedes the dependent variables by one year. The independent variables are for the year 2000, and the related dependent variables are for the year 2001.
• The third assumption is that the observed relationship between independent X and dependent Y is explained by no other outside variable meaning that there is no likely third variable that explains or causes the observed relationship. A number of factors (outside of U-I collaboration) were identified in the literature for this research that might explain positive impact on economic development outcomes. Measures of these factors are included as control variables in the statistical analysis.

This research uses a quantitative approach for the collection, analysis of data and interpretation of results. Quantitative research is empirical which uses numerical and quantifiable data. Experimental research determines cause and effect relationships and involves at least one independent or treatment variable, the independent variable is manipulated through treatments to get various effects from the dependent variables. In non-experimental research the variables are studied without any manipulations (Belli 2009).

Cross Sectional Design

The cross-sectional designs provide greater in-depth analysis of data and the data can be compared and analyzed across different dimensions. An important feature of cross sectional design is to study relationships among different variables (O'Sullivan and Rassel 1999).

The other advantages are that in cross sectional analysis, the data can be collected from a large sample of variables and results are obtained faster. Cross-sectional studies comparatively cost less and are easy to conduct than other kinds of studies. In cross sectional analysis different groups can be compared and with large sample sizes,
inferential analysis and conclusions are possible. Some of the disadvantages of cross-sectional analysis are that it does not measure changes due to passage of time. The cross-sectional analysis does not allow for causal analysis and there is no control of independent variables. The results in cross-sectional studies can change significantly if any one variable is removed (Cohen and Manion 1994).

One of the most commonly used cross-sectional data is US Census. US Census data and population surveys are often used to examine differences in employment and earnings, differences in race, etc. Inter-industry differences and regional variations in employment and earnings are also examined using cross sectional design (Burbridge 1999). This study deviates slightly from a pure cross-sectional design by using dependent variables that are occurring one year after the independent variables. This is done to address Belli’s (2009) point that changes in the independent variable precede observed changes in the dependent variable.

Further Goldstein and Renault (2004) explain that in cross-sectional design, a large number of variables are selected randomly from the population, then the measures related to the variables as discussed in the literature are employed and the inferences are drawn by conducting regression analysis. The effect is determined and explained by the sign, significance of the coefficient estimated for the measure. The statistical control is established by entering the measures in the model.

Formal empirical studies on impact of academic institutions on regional growth have been limited in their scope. Most have used cross-sectional as they are more flexible and do not require a formal model. In cross-sectional analysis, a sample is selected from a population and the relationship between the variables is studied (Goldstein and Drucker
Since the influences of the university academic activities are very widely felt across the regions, it is not easy to have control groups or regions that are not influenced by university activities (Goldstein and Drucker 2006, 2007). Goldstein and Drucker (2007) have cited a number of studies that have used cross sectional analysis for studying the economic impact of knowledge producing institutions (Anselin, Acs & Varga 1997; Bania, Eberts & Fogarty 1993; Kirchhoff, et al. 2002; Markusen, Glasmeier & Hall 1986).

Based on the studies and explanations provided through the works of Goldstein and Renault (2004), Goldstein and Drucker (2006) and Goldstein and Drucker (2007), this dissertation employs cross sectional approach and includes all the MSAs for analysis with complete data. Due to time constraint and the difficulty in accessibility of data, cross sectional approach was found most appropriate for this research.

The Model

This study is divided into two models. The first model studies all the selected MSAs and the combined effect of variables related to regional economic development in reference to university-industry collaboration functions. Multivariate regression analysis is performed to analyze the importance of the impact of related to university-industry collaboration on the MSAs.

The second model analyzes the MSAs in terms of sizes. The MSAs for this research are divided in terms of the population in the MSAs as small, medium and large before regression analysis. According to US Census Bureau and Office of Management and Budget, the MSAs are termed as:

1. Small: Less than 250,000 population
2. Medium: Metropolitan areas with 250,000 - 999,999 population

3. Large: Metropolitan areas with 1 million or more population.

The dataset includes variables that influence economic development in the MSAs. The dependent variables are per capita GDP, unemployment rates, and new birth firms in each MSA for the year 2001. The independent variables are industrial research funding to universities and science and engineering graduates in the universities in each selected MSAs. The control variables are: manufacturing employment and services employment and number of proprietors, percentage change in population from 1990 to 2000, college enrollment for undergraduates, crime data, cost of living index and population.

Table 3

Description of Variables

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Capita GDP (GDP)</td>
<td>BEA</td>
</tr>
<tr>
<td>Unemployment Rates (UE)</td>
<td>US Census</td>
</tr>
<tr>
<td>New Birth Firms(NF)</td>
<td>USSBA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Research Funding (IRF)</td>
<td>NSF</td>
</tr>
<tr>
<td>S &amp; E Graduates (SEG)</td>
<td>NSF</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Control Variables</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No of Patents Granted (PAT)</td>
<td>USPTO</td>
</tr>
<tr>
<td>Manufacturing Employment (MEmp)</td>
<td>US Census</td>
</tr>
<tr>
<td>Services Employment (SEmp)</td>
<td>US Census</td>
</tr>
<tr>
<td>College Enrollment (ENR)</td>
<td>US Census</td>
</tr>
<tr>
<td>Cost of Living (CL)</td>
<td>ACCRA(C2ER)</td>
</tr>
<tr>
<td>Crime Rate (CR)</td>
<td>FBI</td>
</tr>
<tr>
<td>Population Change (POP)</td>
<td>US Census</td>
</tr>
<tr>
<td>Number of Proprietors (PRO)</td>
<td>US Census</td>
</tr>
<tr>
<td>Population (PPL)</td>
<td>US Census</td>
</tr>
</tbody>
</table>
As described in chapter 2, there are three sets of hypotheses being tested for this research which are discussed in the section below. The first set of hypotheses proposed to explore the relationship between per capita GDP and the Industrial Research Funding and the number of science and engineering graduates. These are:

NH1a: Industrial research funding is not correlated to per capita GDP in a region.
H1a: Industrial research funding is positively correlated to per capita GDP in a region.

NH1b: The number of science and engineering graduates is not correlated to per capita GDP in a region.
H1b: The number of science and engineering graduates is positively correlated to per capita GDP in a region.

The following model is employed to analyze the impact of industrial research funding on economic performance of the Metropolitan Statistical Area in terms of university-industry collaboration. The dependent variable per-capita GDP is denoted by GDPI, the regression model is represented as follows:


The independent variables are the industrial research funding (IRF) to the universities; and the number of science and engineering graduates (SEG) from the universities in the respective MSAs.

The remaining variables in the above regression model are the control variables, which according to the literature affect economic growth in a region. PAT is the number of patents granted. Employment in manufacturing and services is denoted by MEmp & SEmp respectively and PRO is for number of proprietors in each MSA.
enrollment for undergraduates is represented by ENR. POP is the percentage change in population in the MSA from the year 1990 to 2000. The last three control variables are CR for crime rate, CL for cost of living index and PPL for the population of the MSA.

The second set of hypotheses proposed to explore the relationship between unemployment and the Industrial Research Funding and the number of science and engineering graduates. These are:

\( NH2_a \): Industrial research funding is not correlated to unemployment in a region.

\( H2_a \): Industrial research funding is negatively correlated to unemployment in a region.

\( NH2_b \): The number of science and engineering graduates is not correlated to unemployment in a region.

\( H2_b \): The number of science and engineering graduates is negatively correlated to unemployment in a region.

The dependent variable unemployment rate is denoted by UE with independent and control variables represented as earlier described.

The following employment related hypotheses are tested:

\[
UE_{2001} = F (IRF_{2000} + SEG_{2000} + PAT_{2000} + MEmp_{2000} + SEmp_{2000} + PRO_{2000} + ENR_{2000} + POP_{1990-2000} + CR_{2000} + CL_{2000} + PPL_{2000})
\]

The third set of hypotheses proposed to explore the relationship between new firm births and the Industrial Research Funding and the number of science and engineering graduates. These are:

\( NH3_a \): Industrial research funding is not correlated to new firm births in a region.

\( H3_a \): Industrial research funding is positively correlated to new firm births in a region.
NH3b: The number of science and engineering graduates is not correlated to new firm births in a region.

H3b: The number of science and engineering graduates is positively correlated to new firm births in a region.

The third hypothesis is represented below with new firms in the MSA denoted by NF.

\[ NF_{2001} = F (IRF_{2000} + SEG_{2000} + PAT_{2000} + MEmp_{2000} + SEmp_{2000} + PRO_{2000} + ENR_{2000} + POP_{1990-2000} + CR_{2000} + CL_{2000} + PPL_{2000}) \]

These relationships are analyzed and evaluated in this research using multiple regression analysis. Each hypothesis is tested using the regression coefficient from the appropriate variable and its corresponding level of significance. The overall model is evaluated using the \( R^2 \) and F-statistic. A significance \( R^2 \) test is used in multiple regressions to establish the influence of independent variables in explaining a variance in a dependent variable (Huck 2008)

Determining the Variables

In order to find the effects of university-industry collaboration on regional economic development outcomes, the various dependent, independent and control variables are selected based on the review of existing literature that influences economic growth in a region. These variables are described below; they will be further analyzed in the next chapter. As discussed earlier, in order to establish temporal precedence, dependent variables are from 2001 and independent variables from 2000. All variables are measured at the MSA level.
Dependent Variables

One of the important measures for economic development in a region is per capita gross domestic product (GDP). This is considered the broadest measure of overall economic activity in the MSAs. Panek (2011) explains that per capita GDP is the metropolitan area’s equivalent as the U.S. nation’s GDP and that “GDP in metros derived as the sum of the value added originating in all of the industries” (34). Policy makers and strategists consider that overall index of living standards and economic status of a region is best explained by per capita growth in a region (Berger 1997).

The next measure for measuring economic development in a region is the unemployment rates. High unemployment rates are usually related with poor economic conditions in a region (Kirchhoff, et al. 2002).

The final measure for evaluating economic development outcome in a region is the new firm births. Arminton and Acs (2002) suggest that economic activity in a region can also be measured by rate of birth of new firms. Growth in spinoff firms have been related to university technology transfer activities and have been influential in generating economic growth in some high tech regions. It is generally believed that new technology starts a series of activities that often changes industrial structure and results in growth of new industries (Melkers, Bugler and Bozeman 1993). Kirchhoff, et.al (2002) examined effect of research and development expenditures on firm births and concluded that university research and development expenditures support firm births rates as research universities increases local innovative activity. Their research also supported that firm birth rates have a positive effect on regional growth. Bania, Fogarty and Eberts (1993) in their study of manufacturing industries in twenty-five U.S. metropolitan areas, concluded
that new firm births are influenced by university research activities particularly in electrical and electronic equipment, but not in the instruments and other related industries.

*Measures of University-Industry collaboration*

In order to examine the university-industry collaboration functions that effect regional economic development, the study employs measures that indicate the levels of such university-industry collaboration. The first such measure is the total amount of industrial research funding granted to universities in the MSAs. These datasets are compiled by National Science Foundation (NSF) and are available by zip codes for the year 2000. For the purpose of this research this data was assimilated according to the MSAs. Industrial research and development funding is the funding at individual universities and colleges, measured in thousands of dollars.

Academic research investments often lead to significant benefits to the local and national economies. Between 1975 and 1985, almost one-tenth of the innovative processes and products in some high tech sector were possible because of university research support (Mansfield 1991). Supporting universities in developed regions may have positive economic development outcomes (Varga 1997). Industries collaborate with the universities for skilled labor, trained graduates and faculty expertise which are not easily available in industrial sectors (Atlan 1987). Jaffe (1989) suggests that university research causes industrial R & D. Thus any region that supports its university research will facilitate regional innovation through attracting industrial R & D expenditures and increasing its productivity.
The second measure of economic development in a region is the creation of human capital. University graduates are instrumental in transferring new ideas and knowledge from university to the regional high tech industrial sector (Varga 2000). The increase in human capital is achieved through formal and informal education and the training of the labor force. Human capital is a significant input in the production of knowledge or ideas in region (Mathur 1999). According to Human Capital theory it is suggested that by imparting knowledge and skills through education and training, productivity of the workforce is enhanced, which is an important factor for economic growth. This results in raising future incomes of the workers by increase in their earnings (Becker 1964). Goldstein and Renault (2004) in their study measured the human capital creation by the number of degrees given in the MSAs in all higher institutions. This measure of economic development (variable) is measured by the number of science and engineering graduates in the MSAs. This data is also obtained from NSF for the year 2000.

Control Variables

There are various other factors outside of university-industry collaboration activities that effect regional economic development outcomes were identified in the literature. These are also based on the review of existing literature.

One of these control variables is the number of patents granted in MSAs. This variable measures the innovation capabilities of a region. Patents are considered a reliable indicator for measuring innovative activity in a region and there is a strong relation between R & D expenditures and the number of patents (Griliches 1990). Lever (2002) suggests that economic development in a region is associated with the quality of
knowledge available. He further suggests that the knowledge in a region is depended on the investment in research and development.

For the purposes of this research employment data is included from both employment in manufacturing and business services. Markusen and Yu (2009) explain that services jobs are as important as manufacturing jobs for employment growth in a region. Employment in service sector has grown faster than in the manufacturing around the world. Further they add that in the U.S., science and technology employment in service sector has grown more services sector than in manufacturing sector. U.S. metropolitan areas added high tech jobs more in high tech services than in manufacturing and eight out of the top ten high tech employments in metros are in high tech services than in high tech manufacturing.

The number of proprietors and college enrollment in the MSAs are considered as two other important control variables related to regional economic development. Universities play a crucial role in seeding startups, and attracting technical students with industry contacts, experience, and entrepreneurial interests. Further university faculty contributes in sharing beneficial technical knowledge to technical firms. The entrepreneurial and commercial function of the universities often needs the industrial collaboration (Etzkowitz 2002).

Regions with higher college graduates have more entrepreneurial activity than those regions with less skilled populations (Armington and Acs 2002). Education and institutional development are considered important in determining the crime rates, which is an important indicator for development of a region (Soares 2004). Becker (1964)
suggests that educating and training the human resources are most important investments for development.

There are many other factors that influence regional growth patterns. Regional development also depends on the quality of life in a region, which is measured by the crime rate, cost of living, and population change in the region. The costs of city living in cities are most commonly associated with health costs, crime rates, societal and environmental problems. Advancements in technology have reduced health and environmental issues, but crime is still an issue of concern (Glaeser 1998). Development is also associated with crime reporting rates, which means that an educated public will support reduction in crime by reporting crimes (Soares 2004). It has been observed that people move away from their locations due to higher crime rates. It is interesting to note that the studies that suggest that the cities that are good for legal practices are also centers of crime as agglomeration effects can also be good for criminal activities (Glaeser 1998). Soares (2004) in his study found that higher education level lead to decrease in thefts and contact crimes and also the higher growth in a region is inversely related to the lower the number of thefts.

The rate of change in the population determines general attractiveness of a region and also growth in population means growth in new firms due to increase in demand for more goods and services (Kirchhoff, et al. 2002). Further Goldstein & Drucker (2006) suggest that change in population is associated with regional development, growth in population means that there has been growth in opportunities for economic progress.
CHAPTER IV
DATA

The data set contains detailed information on MSAs for the year 2000. After eliminating observations where the values were missing in the various variables and also the outliers, there were 220 MSAs to be analyzed.

Missing Data

There were certain data points which were not reported and were not available in the combined dataset which reduced the number of observations for analysis. The missing data were in almost every category. After eliminating observations where the values were missing in the various variables, the number of MSAs to be analyzed was reduced to 232 MSAs from the original 365 MSAs for the year 2000. There were few outliers in some variables and the number of MSAs was further reduced to 220.

In the dependent variables category, the data for per-capita GDP and unemployment rates was complete with no missing values. There were 72 missing values for new firm births in the total MSAs.

In the independent variable category the industrial research funding (IRF) data and science and engineering graduates (SEG) were either missing or not reported for some MSAs. The missing values for IRF were just two and for SEG were 15.

Most of the values missing were in the control variable category as crime rate and cost of living index. The employment values in manufacturing and services were not reported for few MSAs from Bureau of Economic Analysis with nine missing values in manufacturing employment and 5 missing in services employment. The number of proprietors was available for all of the MSAs except for one.
Correlation Analyses

Before conducting the main analyses, the Pearson correlations for the dependent and independent variables in the study were examined through statistical analysis (see Table 3). The linear relationship between the two variables is measured by correlation coefficient and it takes any value between +1 and -1. The positive correlation indicates a direct relationship between the measured variables and negative correlation represents indirect or inverse relationship between the variables (Huck 2008).

Table 4

Correlation Matrix

<table>
<thead>
<tr>
<th></th>
<th>GDP per capita</th>
<th>Log Unemployment Rate</th>
<th>Log New Firm Births</th>
<th>Log S&amp;E Graduates</th>
<th>Log Number of Proprietors</th>
<th>Log College Enrollment undergraduates</th>
<th>Log College Enrollment Change, 1990 to 2000</th>
<th>Crime Index Rate</th>
<th>Log COLI</th>
<th>Log Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP per capita</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log Unemployment Rate</td>
<td>-0.4063</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log New Firm Births</td>
<td>0.5684</td>
<td>-0.0714</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IRF</td>
<td>0.5356</td>
<td>-0.0074</td>
<td>0.6400</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S&amp;E Graduates</td>
<td>0.5540</td>
<td>-0.0628</td>
<td>0.7158</td>
<td>0.0120</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log S&amp;E Graduates</td>
<td>0.4933</td>
<td>-0.0778</td>
<td>0.0026</td>
<td>0.8354</td>
<td>0.7152</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log Melt Employment</td>
<td>0.5692</td>
<td>-0.1110</td>
<td>0.8166</td>
<td>0.0221</td>
<td>0.7100</td>
<td>0.9156</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log Services Employment</td>
<td>0.6339</td>
<td>-0.1335</td>
<td>0.9553</td>
<td>0.0535</td>
<td>0.7425</td>
<td>0.6409</td>
<td>0.8770</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log Number of Proprietors</td>
<td>0.5699</td>
<td>-0.0098</td>
<td>0.9515</td>
<td>0.6896</td>
<td>0.7461</td>
<td>0.6521</td>
<td>0.8587</td>
<td>0.9161</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Log College Enrollment undergraduates</td>
<td>0.4796</td>
<td>-0.0795</td>
<td>0.0625</td>
<td>0.6400</td>
<td>0.6667</td>
<td>0.5418</td>
<td>0.7821</td>
<td>0.8845</td>
<td>0.8718</td>
<td>1</td>
</tr>
<tr>
<td>Population Change, 1990 to 2000</td>
<td>0.4316</td>
<td>0.0373</td>
<td>0.6882</td>
<td>0.7057</td>
<td>0.6426</td>
<td>0.7440</td>
<td>0.5971</td>
<td>0.7206</td>
<td>0.0426</td>
<td>1</td>
</tr>
<tr>
<td>Crime Index Rate</td>
<td>-0.0644</td>
<td>0.2266</td>
<td>0.1218</td>
<td>0.0021</td>
<td>-0.0641</td>
<td>-0.0301</td>
<td>0.0186</td>
<td>0.1004</td>
<td>0.0091</td>
<td>0.1092</td>
</tr>
<tr>
<td>Log COLI</td>
<td>0.5912</td>
<td>-0.0659</td>
<td>0.5722</td>
<td>0.5607</td>
<td>0.4952</td>
<td>0.6111</td>
<td>0.3066</td>
<td>0.4134</td>
<td>0.4025</td>
<td>0.3776</td>
</tr>
<tr>
<td>Log Population</td>
<td>0.4754</td>
<td>-0.0030</td>
<td>0.0640</td>
<td>0.5094</td>
<td>0.5568</td>
<td>0.7463</td>
<td>0.8557</td>
<td>0.7910</td>
<td>0.6301</td>
<td>0.0427</td>
</tr>
</tbody>
</table>

Normality

Data sets that are distributed normally are bell shaped curve. Some distributions are skewed, which means that they are not symmetrical. In skewed distributions, most of the data points are either high or low. Another measure of normality is Kurtosis. Kurtosis denotes the shapes of the distribution, whether it more peaked or less peaked as
leptokurtic and platykurtic respectively. Most researchers consider data normal if the values for skewness and kurtosis are between -1 and +1 (Huck 2008).

As the sample was large, the shapes of the distribution were assessed for normality. It was seen that some variables had values for skewness and kurtosis that did not fall between -1 to and1 range. Thus those values were logged for normality of the data.

The values of industrial research funding and science and engineering graduates could not be logged (inspite of having values of skewness and kurtosis not within the limits) as there were many ‘zero’ values in the data. Similarly the change in population values was not logged for normality as there were certain MSAs with decline in population. The descriptive statistics shown below is for the MSAs (220) included in the study

Dependent Variables

*Per capita Gross Domestic Product (GDPI)*

Regional economic development is measured in terms of per-capita GDP in a MSA. In this study, per-capita GDP is used as a dependent variable. The values for per capita GDP are obtained from Bureau of Economic Analysis (BEA) and the values were available for all MSAs. The per-capita GDP is obtained for the year 2001. The descriptive statistics for this GDP per capita is shown below.

Table 5

*Descriptive Statistics for Per Capita GDP*

<table>
<thead>
<tr>
<th>Data</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Kurtosis</th>
<th>Skewness</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>30222.1</td>
<td>29686</td>
<td>7777.82</td>
<td>0.1023</td>
<td>0.5808</td>
<td>13534</td>
<td>55094</td>
</tr>
</tbody>
</table>

Source: Bureau of Economic Analysis
**Unemployment**

The second dependent variable unemployment is measured by unemployment rates in the MSAs. The unemployment rates for the MSAs are obtained from Bureau of Labor Statistics for the year 2001. All the values for the MSAs were available. The descriptive statistics for the variable is shown below. Since the raw values were not in the normal distribution range, the values are logged for analysis.

Table 6

**Descriptive Statistics for Unemployment Rates**

<table>
<thead>
<tr>
<th>Data</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Kurtosis</th>
<th>Skewness</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log</td>
<td>1.5317</td>
<td>1.5041</td>
<td>0.2808</td>
<td>2.2478</td>
<td>0.8538</td>
<td>0.8755</td>
<td>2.8034</td>
</tr>
<tr>
<td>Raw</td>
<td>4.8295</td>
<td>4.5000</td>
<td>1.6260</td>
<td>13.6920</td>
<td>2.7798</td>
<td>2.4000</td>
<td>16.5000</td>
</tr>
</tbody>
</table>

Source: Bureau of Labor Statistics

**New Firm Births**

The third dependent variable is birth of new firms in the MSAs. The values for the new firm births were obtained from US Small Business Administration for the year 2001. The total values available for analysis were 293 with 72 missing values. The data were logged to correct problems with skewness and kurtosis.

Table 7

**Descriptive Statistics for New Firm Births**

<table>
<thead>
<tr>
<th>Data</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Kurtosis</th>
<th>Skewness</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log</td>
<td>6.7923</td>
<td>6.6345</td>
<td>1.0762</td>
<td>0.3402</td>
<td>0.8544</td>
<td>5.1180</td>
<td>10.2376</td>
</tr>
<tr>
<td>Raw</td>
<td>1849.80</td>
<td>761.00</td>
<td>3421.05</td>
<td>29.98</td>
<td>4.82</td>
<td>167.00</td>
<td>27933.00</td>
</tr>
</tbody>
</table>

Source: US Small Business Administration
Independent Variables

*Industrial Research Funding*

The first independent variable is the total amount of funding from industry to university or universities in a region. This data is compiled by National Science Foundation (NSF) on an annual basis.

Data on industrial research funding to universities is obtained from National Science Foundation for the year 2000. The IRF data was available according to university and zip codes from NSF. For example for Hattiesburg metropolitan statistical area, the zip code was 39406 and the university mentioned was University of Southern Mississippi. The universities under the different zip codes in the MSAs were selected and according to that the data was complied. The data for industrial research funding was almost complete and it was not available for 2 MSAs: Manhattan, KS and Mankato-North Mankato, MN.

Huck (2008) explains that the outliers are the data points that are located away from the most of the data and cause the size of a correlation coefficient to deflate or inflate the relationship between the variables. There were 6 outliers Iowa City, IA, College Station-Bryan, TX, Lafayette, IN, Lawrence, KS, Gainesville, FL and State College, PA. The outliers had high values when the histograms were plotted and thus data with 3 standard deviations away from the mean were removed. There were many MSAs with no research funding, so the values in the data could not be logged and taken as original for analysis. The descriptive statistics for industrial research funding is shown in table 8.
Table 8

*Descriptive Statistics for Industrial Research Funding*

<table>
<thead>
<tr>
<th>Data</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Kurtosis</th>
<th>Skewness</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>4904.94</td>
<td>34.5</td>
<td>11822.04</td>
<td>13.7643</td>
<td>3.5862</td>
<td>0</td>
<td>70657</td>
</tr>
</tbody>
</table>

Source: National Science Foundation

*Science and Engineering Graduates*

Data on science and engineering graduates (science and engineering students and post graduates) is obtained from National Science Foundation for the year 2000. The data was available according to zip code from NSF. The different zip codes in the MSAs were selected and according to that the data was assimilated. Since the data were available according to zip code, the missing data points were only 15. The larger value in this category or an outlier was Bloomington IN which was 3 standard deviations from the mean. The values were used as original and could not be logged as there were many ‘zero’ values in the data. The descriptive statistics for science and engineering graduates is shown below.

Table 9

*Descriptive Statistics for Science and Engineering Graduates*

<table>
<thead>
<tr>
<th>Data</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Kurtosis</th>
<th>Skewness</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>1119.19</td>
<td>170</td>
<td>2839.836</td>
<td>64.4617</td>
<td>6.9868</td>
<td>0</td>
<td>31274</td>
</tr>
</tbody>
</table>

Source: National Science Foundation

**Control Variables**

*Patent*

The number of patents granted to each MSA was available from United States Patent and Trademark Office (USTPO) for the year 2000. The data for the analysis is
obtained for utility patents. The data for patents granted for 78 MSAs was not reported. There was only one outlier which was Salt Lake City, UT. As there is no access to the patent activity directly to universities, this is considered as a control variable. The values were also used as original and could not be logged as there were ‘zeros’ in the data. The descriptive statistics for the patents data is shown below.

Table 10

Descriptive Statistics for Patents Granted

<table>
<thead>
<tr>
<th>Data</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Kurtosis</th>
<th>Skewness</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>200.932</td>
<td>41</td>
<td>417.078</td>
<td>10.2855</td>
<td>3.2123</td>
<td>0</td>
<td>2348</td>
</tr>
</tbody>
</table>

Source: United States Patent and Trademark Office

Manufacturing Employment

Manufacturing employment values for the MSAs were taken from Bureau of Economic Analysis, Department of Commerce for the year 2000. From the list of 365 MSAs the values for 9 MSAs were missing with eight not reported and one missing. In this category there were four outliers as Elkhart-Goshen, IN, Kokomo, IN, Hickory-Lenoir- Morganton, NC and Atlantic-Hammonton, NJ. As the raw data distribution was not normal, the values were logged for analysis. The descriptive statistics for this variable are shown in table 11.

Table 11

Descriptive Statistics for Manufacturing Employment

<table>
<thead>
<tr>
<th>Data</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Kurtosis</th>
<th>Skewness</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log</td>
<td>9.8986</td>
<td>9.7666</td>
<td>1.1950</td>
<td>0.3522</td>
<td>0.4860</td>
<td>7.1899</td>
<td>13.7143</td>
</tr>
<tr>
<td>Raw</td>
<td>46345.4</td>
<td>17442</td>
<td>98992.9</td>
<td>41.3721</td>
<td>5.8043</td>
<td>1326</td>
<td>903723</td>
</tr>
</tbody>
</table>

Source: Bureau of Economic Analysis, US Department of Commerce

According to USPTO, “Utility Patents are granted for the invention of a useful and new procedure, manufacture, machine, composition of matter, a useful and new improvement. It usually allows its owner to exclude others from making, using, or selling the invention for a period of up to twenty years from the date of patent application”. Around 90% of the patents granted are utility patents, also known as ‘patents for invention’.
**Services Employment**

The values for services employment were also obtained from Bureau of Economic Analysis, Department of Commerce for the year 2000. Five values were not reported in the data from the total 365 MSAs. The values for this variable were also logged because of non-normality of the data. The descriptive statistics for the variable are shown below.

Table 12

**Descriptive Statistics for Services Employment**

<table>
<thead>
<tr>
<th>Data</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Kurtosis</th>
<th>Skewness</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log</td>
<td>10.9911</td>
<td>10.7897</td>
<td>1.1587</td>
<td>0.7354</td>
<td>1.0120</td>
<td>9.3832</td>
<td>15.1567</td>
</tr>
<tr>
<td>Raw</td>
<td>148629</td>
<td>48520</td>
<td>363476.4</td>
<td>58.4956</td>
<td>6.81884</td>
<td>11887</td>
<td>3823734</td>
</tr>
</tbody>
</table>

Source: Bureau of Economic Analysis, US Department of Commerce

**Number of Proprietors**

The value for the number of proprietors for the year 2000 was obtained from Bureau of Economic Analysis, US Department of Commerce. All the values for the MSAs were available except for one MSA, Weirton-Steubenville, WV-OH (MSA), the value for this MSA was not reported. The values for number of proprietors were logged for normality of the data. The descriptive statistics for the variable is shown in table 13.

Table 13

**Descriptive Statistics for Number of Proprietors**

<table>
<thead>
<tr>
<th>Data</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Kurtosis</th>
<th>Skewness</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log</td>
<td>10.3967</td>
<td>10.1509</td>
<td>1.0587</td>
<td>1.0086</td>
<td>1.0631</td>
<td>8.6748</td>
<td>14.1902</td>
</tr>
<tr>
<td>Raw</td>
<td>159263</td>
<td>71311.3</td>
<td>159263</td>
<td>48.7363</td>
<td>6.3117</td>
<td>5854</td>
<td>1454551</td>
</tr>
</tbody>
</table>

Source: Bureau of Economic Analysis, US Department of Commerce

**College Enrollment**

The values for this variable were obtained from US Census 2000 data under the college enrollment undergraduate. The total values available were 253 with 112 MSAs
values not available. The values for this variable were also logged for normality of the data. The descriptive statistics for the variable are shown below.

Table 14

*Descriptive Statistics for College Enrollment*

<table>
<thead>
<tr>
<th>Data</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Kurtosis</th>
<th>Skewness</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log</td>
<td>9.8879</td>
<td>9.7774</td>
<td>1.1689</td>
<td>0.4287</td>
<td>0.7737</td>
<td>7.8906</td>
<td>13.8149</td>
</tr>
<tr>
<td>Raw</td>
<td>47333.1</td>
<td>17631.5</td>
<td>110642</td>
<td>50.1303</td>
<td>6.44905</td>
<td>2672</td>
<td>999346</td>
</tr>
</tbody>
</table>

Source: US Census 2000

*Population Change*

The population changes included for analysis were from 1990 to 2000, these values were obtained from U.S.Census. As there were negative values in the data, the values could not be logged and original values were included for analyses. The descriptive statistics for population change is shown in Table 15.

Table 15

*Descriptive Statistics for Population Change 1990-2000*

<table>
<thead>
<tr>
<th>Data</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Kurtosis</th>
<th>Skewness</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>99893</td>
<td>30770.5</td>
<td>233072.7</td>
<td>26.0936</td>
<td>4.6896</td>
<td>-36116</td>
<td>1842116</td>
</tr>
</tbody>
</table>

Source: US Census 2000

*Crime Rate*

The crime rate index values were obtained from Federal Bureau of Investigation website. The crime index included violent crimes and property crimes in each MSA. The missing values were 126 in number. The original values were taken as the data was normally distributed. The descriptive statistics for crime rate is shown in table 16.
Table 16

*Descriptive Statistics for Crime Rate Index*

<table>
<thead>
<tr>
<th>Data</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Kurtosis</th>
<th>Skewness</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>4586.27</td>
<td>4526.65</td>
<td>1376.05</td>
<td>-0.206</td>
<td>0.2888</td>
<td>1701</td>
<td>8923.9</td>
</tr>
</tbody>
</table>

Source: Federal Bureau of Investigation

*Cost of Living Index*

The cost of living index is obtained from ACCRA (American Chamber of Commerce Researchers Association) now known as C2ER (Council of Community and Economic Research). The largest numbers of values were missing for this variable. From the list of 365 MSAs, 127 values were missing. The values for this variable were also logged for normality of the data. The descriptive statistics for the variable in table 17.

Table 17

*Descriptive Statistics for Cost of Living Index*

<table>
<thead>
<tr>
<th>Data</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Kurtosis</th>
<th>Skewness</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log</td>
<td>4.5996</td>
<td>4.5839</td>
<td>0.1088</td>
<td>24.3611</td>
<td>3.6901</td>
<td>4.3820</td>
<td>5.4604</td>
</tr>
<tr>
<td>Raw</td>
<td>100.132</td>
<td>97.9</td>
<td>13.9441</td>
<td>50.7631</td>
<td>5.9852</td>
<td>80</td>
<td>235.2</td>
</tr>
</tbody>
</table>

Source: Council of Community and Economic Research

*Population*

The population values for the MSAs were obtained from US Census. There were no missing values in this category. Since the values for kurtosis and skewness were not within the limits, they were logged for the normality of the data.

Table 18

*Descriptive Statistics for Population*

<table>
<thead>
<tr>
<th>Data</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Kurtosis</th>
<th>Skewness</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log</td>
<td>12.782</td>
<td>13.000</td>
<td>1.116</td>
<td>0.876</td>
<td>1.040</td>
<td>11.105</td>
<td>16.870</td>
</tr>
<tr>
<td>Raw</td>
<td>844754.24</td>
<td>294880.50</td>
<td>2056264.926</td>
<td>58.404</td>
<td>6.899</td>
<td>66533</td>
<td>21199865</td>
</tr>
</tbody>
</table>

Source: US Census 2000
CHAPTER V
RESULTS

The values were entered in Statistical Package for Social Sciences (SPSS) software version 19 and the hypotheses were tested using regression analysis results of the previously mentioned equations. To serve as the basis for testing the hypotheses, the dependent variables were each regressed in separate equations.

Each model is tested in this study and the following statistics were generated:

- $R^2$ – $R^2$ explains the percent variation of the dependent variable in the regression. The value $R^2$ is between one and zero. $R^2 = 1$, then all data points are on the regression line and for lesser values of $R^2$, the data points are away from the regression line. Thus for higher value of $R^2$, the better is the fit. $R^2$ gives a measure of fit. For $R^2 = .65$ means that approx 65 percent variation in dependent variable can be explain by explanatory variable (Cirincione 1999).

- Adjusted $R^2$ – It indicates the degree to which the variability in dependent variable is explained by the set of independent variables and eliminates bias related with $R^2$ by reducing its value. Conceptually the difference between $R^2$ and adjusted $R^2$ is that as $R^2$ based on sample data, it always gives an overestimate of corresponding population value of $R^2$ (Huck 2008).

- Significance of beta coefficients -The beta coefficients explain the degree of relationship between the independent variable and the dependent variable and the correlation coefficient between the two variables (Johnson and Reynolds 2005).

- The F-distribution indicates that a combination of specific independent variables predicts the dependent variable.
Analysis for the Combined Model

*Per capita GDP*

The first set of hypotheses focus on the relationship between per capita GDP and IRF and science & engineering graduates. The following are the hypotheses:

- **NH1\(_a\):** Industrial research funding is not correlated to per capita GDP in a region.
- **H1\(_a\):** Industrial research funding is positively correlated to per capita GDP in a region.

- **NH1\(_b\):** The number of science and engineering graduates is not correlated to per capita GDP in a region.
- **H1\(_b\):** The number of science and engineering graduates is positively correlated to per capita GDP in a region.

The Table 19 provides the statistical summary for per capita GDP. The results show that set of independent variables significantly predicts per capita GDP (F=19.125, Sig .000). The adjusted $R^2$ indicates that 47.7 percent of the variation in per capita GDP is explained by the independent variables. If the null hypotheses are rejected, the results are significant (Huck 2008). The first null hypothesis is rejected, supporting the hypothesis that IRF is positively related to per capita GDP. However, the results for SEG are significant, but with negative coefficient, thus SEG does not positively influence the per capita GDP in the MSAs as the results do not show statistical support for H1\(_b\).
Table 19

Per capita GDP Analysis for the Combined Model

<table>
<thead>
<tr>
<th>Model 1</th>
<th>B</th>
<th>Std. Error</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>-52147.161</td>
<td>22172.579</td>
<td>-2.352</td>
<td>0.020</td>
</tr>
<tr>
<td>IRF</td>
<td>0.169</td>
<td>0.075</td>
<td>2.261</td>
<td>0.025</td>
</tr>
<tr>
<td>S&amp; E Graduates</td>
<td>-0.624</td>
<td>0.325</td>
<td>-1.922</td>
<td>0.056</td>
</tr>
<tr>
<td>Patents</td>
<td>1.442</td>
<td>1.824</td>
<td>0.791</td>
<td>0.430</td>
</tr>
<tr>
<td>Log Manu Employment</td>
<td>484.711</td>
<td>708.256</td>
<td>0.684</td>
<td>0.495</td>
</tr>
<tr>
<td>Log Services employment</td>
<td>9268.799</td>
<td>1914.269</td>
<td>4.842</td>
<td>0.000</td>
</tr>
<tr>
<td>Log Number of Proprietors</td>
<td>-4494.544</td>
<td>2056.357</td>
<td>-2.186</td>
<td>0.030</td>
</tr>
<tr>
<td>Log College enrollment undergraduate</td>
<td>-1757.765</td>
<td>713.667</td>
<td>-2.463</td>
<td>0.015</td>
</tr>
<tr>
<td>Population Change, 1990 to 2000</td>
<td>0.000</td>
<td>0.003</td>
<td>-0.070</td>
<td>0.944</td>
</tr>
<tr>
<td>Crime Index Rate</td>
<td>-0.555</td>
<td>0.295</td>
<td>-1.88</td>
<td>0.062</td>
</tr>
<tr>
<td>Log COLI</td>
<td>11976.318</td>
<td>4625.98</td>
<td>2.589</td>
<td>0.010</td>
</tr>
<tr>
<td>Log Pop</td>
<td>-1027.587</td>
<td>706.608</td>
<td>-1.454</td>
<td>0.147</td>
</tr>
</tbody>
</table>

Dependent Variable: Per Capita GDP
Total degree of freedom: 219
R: .709
R square: .503
Adjusted R square: .477
F= 19.125
Significance: .000

Unemployment

The second set of null hypotheses examines the relationship between unemployment and industrial research funding and science & engineering graduates.

NH2a: Industrial research funding is not correlated to unemployment in a region.

H2a: Industrial research funding is negatively correlated to unemployment in a region.

NH2b: The number of science and engineering graduates is not correlated to unemployment in a region.
H2b: The number of science and engineering graduates is negatively correlated to unemployment in a region.

The analyses in Table 20 provide the statistical summary for the dependent variable unemployment. The results indicate that the set of independent variables significantly predict unemployment rate (F=4.45, Sig=.000). The adjusted $R^2$ indicates that 43.7 percent of the variation in unemployment rates is explained by the independent variables. The results from the analysis show that both the independent variables industrial research funding and science and engineering graduates are not significant.

Thus, neither of the null hypotheses are rejected and there is no statistical support for H2a or H2b.

Table 20

*Unemployment Analysis for the Combined Model*

<table>
<thead>
<tr>
<th>Model 1</th>
<th>B</th>
<th>Std. Error</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>0.676</td>
<td>1.022</td>
<td>0.662</td>
<td>0.509</td>
</tr>
<tr>
<td>IRF</td>
<td>-3.25E-07</td>
<td>0.000</td>
<td>0.094</td>
<td>0.925</td>
</tr>
<tr>
<td>S&amp;E Graduates</td>
<td>-2.14E-05</td>
<td>0.000</td>
<td>-1.432</td>
<td>0.154</td>
</tr>
<tr>
<td>Patents</td>
<td>4.21E-05</td>
<td>0.000</td>
<td>0.501</td>
<td>0.617</td>
</tr>
<tr>
<td>Log Manufacturing Employment</td>
<td>0.034</td>
<td>0.033</td>
<td>1.052</td>
<td>0.294</td>
</tr>
<tr>
<td>Log Services Employment</td>
<td>-0.361</td>
<td>0.088</td>
<td>-4.096</td>
<td>0.000</td>
</tr>
<tr>
<td>Log Number of Proprietors</td>
<td>0.204</td>
<td>0.095</td>
<td>2.151</td>
<td>0.033</td>
</tr>
<tr>
<td>Log College enrollment undergraduate</td>
<td>-0.019</td>
<td>0.033</td>
<td>-0.572</td>
<td>0.568</td>
</tr>
<tr>
<td>Population Change, 1990 to 2000</td>
<td>3.18E-07</td>
<td>0.000</td>
<td>2.020</td>
<td>0.028</td>
</tr>
<tr>
<td>Crime Index Rate</td>
<td>5.51E-05</td>
<td>0.000</td>
<td>4.046</td>
<td>0.000</td>
</tr>
<tr>
<td>Log COLI</td>
<td>0.182</td>
<td>0.213</td>
<td>0.856</td>
<td>0.393</td>
</tr>
<tr>
<td>Log Pop</td>
<td>0.113</td>
<td>0.033</td>
<td>3.47</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Dependent Variable: Log Unemployment
Total degree of freedom: 219
R: .437  
R square: .191
Adjusted R square: .148
F= 4.454  
Significance: .000
New Firm Births

The third set of null hypotheses examines the relationship between new firm births and industrial research funding and science & engineering graduates.

NH3a: Industrial research funding is not correlated to new firm births in a region.

H3a: Industrial research funding is positively correlated to new firm births in a region.

NH3b: The number of science and engineering graduates is not correlated to new firm births in a region.

H3b: The number of science and engineering graduates is positively correlated to new firm births in a region.

The Table 21 provides the statistical summary for new firm births in the MSAs. The results from the analysis show that the set of independent variables significantly predicts new firm births (F=261, Sig=.000). The adjusted R^2 indicates that 92.9 percent of the variation in new firm births is explained by the independent variables. IRF is negatively related to new firm births, thus the increase in IRF does not positively affect new firm births in the MSAs as the results show no statistical support for H3a.

The coefficient for number of science and engineering graduates is not significant. Thus neither of the null hypotheses is rejected and the results do not support statistically H3a and H3b.
Table 21

*New Firm Births Analysis for the Combined Model*

<table>
<thead>
<tr>
<th>Model 1</th>
<th>B</th>
<th>Std.Error</th>
<th>t</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>-2.286</td>
<td>1.13</td>
<td>-2.024</td>
<td>0.044</td>
</tr>
<tr>
<td>IRF</td>
<td>-9.41E-06</td>
<td>0.000</td>
<td>-2.464</td>
<td>0.015</td>
</tr>
<tr>
<td>S&amp;E Graduates</td>
<td>4.66E-06</td>
<td>0.000</td>
<td>0.282</td>
<td>0.778</td>
</tr>
<tr>
<td>Patents</td>
<td>0.000</td>
<td>0.000</td>
<td>2.515</td>
<td>0.013</td>
</tr>
<tr>
<td>Log Manufacturing Employment</td>
<td>-0.103</td>
<td>0.036</td>
<td>-2.843</td>
<td>0.005</td>
</tr>
<tr>
<td>Log Services Employment</td>
<td>0.552</td>
<td>0.098</td>
<td>5.664</td>
<td>0.000</td>
</tr>
<tr>
<td>Log Number of Proprietors</td>
<td>0.256</td>
<td>0.105</td>
<td>2.445</td>
<td>0.015</td>
</tr>
<tr>
<td>Log College enrollment undergraduate</td>
<td>0.107</td>
<td>0.036</td>
<td>2.930</td>
<td>0.004</td>
</tr>
<tr>
<td>Population Change, 1990 to 2000</td>
<td>5.32E-08</td>
<td>0.000</td>
<td>0.335</td>
<td>0.738</td>
</tr>
<tr>
<td>Crime Index</td>
<td>1.99E-05</td>
<td>0.000</td>
<td>1.323</td>
<td>0.187</td>
</tr>
<tr>
<td>log COLI</td>
<td>-0.304</td>
<td>0.236</td>
<td>-1.292</td>
<td>0.198</td>
</tr>
<tr>
<td>Log Pop</td>
<td>0.126</td>
<td>0.036</td>
<td>3.486</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Dependent Variable: Log New Firm Births
Total degree of freedom: 219
R: .966
R square: .933
Adjusted R square: .929
F= 261.609
Significance: .000
Analysis for the Partitioned Model

The second model partitioned the MSAs by the sizes in terms of populations as small, medium and large. The results of the partitioned model are analyzed below. The same sets of hypotheses are tested for this model as for the combined model.

Small Sized MSAs

The first group of MSAs is with less than 250,000 populations. The hypotheses are tested for the small sized MSAs.

Per capita GDP in Small Sized MSAs

The first set of hypotheses as explained earlier focus on the relationship between per capita GDP and IRF and SEG in small sized MSAs.

NH1ₐ: Industrial research funding is not correlated to per capita GDP in a region.

H₁ₐ: Industrial research funding is positively correlated to per capita GDP in a region.

NH1ₐ: The number of science and engineering graduates is not correlated to per capita GDP in a region.

H₁ₐ: The number of science and engineering graduates is positively correlated to per capita GDP in a region.

The Table 2 provides the statistical summary for per capita GDP for the small sized MSAs. The results indicate that the set of independent variables significantly predict per capita GDP (F=4.344, Sig=.000). The adjusted $R^2$ indicates that 27.5 percent of the variation in per capita GDP is explained by the independent variables. The results suggest that IRF and SEG are not significant. Thus neither of the null hypotheses is rejected showing no statistical support for H₁ₐ and H₁ₐ in small sized MSAs.
Table 22

*Per Capita GDP Analysis for Small sized MSAs*

<table>
<thead>
<tr>
<th>Model 2</th>
<th>B</th>
<th>Std. Error</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>954.498</td>
<td>49333.915</td>
<td>0.019</td>
<td>0.085</td>
</tr>
<tr>
<td>IRF</td>
<td>-9.00E-03</td>
<td>0.529</td>
<td>-0.017</td>
<td>0.987</td>
</tr>
<tr>
<td>S&amp; E Graduates</td>
<td>4.88E-01</td>
<td>2.608</td>
<td>0.187</td>
<td>0.852</td>
</tr>
<tr>
<td>Patents</td>
<td>2.65E+01</td>
<td>16.523</td>
<td>1.604</td>
<td>0.112</td>
</tr>
<tr>
<td>Log Manufacturing Employment</td>
<td>704.708</td>
<td>875.599</td>
<td>0.805</td>
<td>0.423</td>
</tr>
<tr>
<td>Log Services Employment</td>
<td>10126.304</td>
<td>2971.529</td>
<td>3.408</td>
<td>0.001</td>
</tr>
<tr>
<td>Log Number of Proprietors</td>
<td>-3123.371</td>
<td>2991.366</td>
<td>-1.044</td>
<td>0.299</td>
</tr>
<tr>
<td>Log College Enrollment undergraduate</td>
<td>-571.464</td>
<td>1047.595</td>
<td>-0.546</td>
<td>0.587</td>
</tr>
<tr>
<td>Population Change, 1990 to 2000</td>
<td>7.00E-03</td>
<td>0.047</td>
<td>0.158</td>
<td>0.875</td>
</tr>
<tr>
<td>Crime Index Rate</td>
<td>-3.71E-01</td>
<td>0.394</td>
<td>-0.942</td>
<td>0.349</td>
</tr>
<tr>
<td>Log COLI</td>
<td>7174.059</td>
<td>8110.601</td>
<td>0.885</td>
<td>0.379</td>
</tr>
<tr>
<td>Log Pop</td>
<td>-6691.733</td>
<td>2620.711</td>
<td>-2.553</td>
<td>0.012</td>
</tr>
</tbody>
</table>

Dependent Variable: Per Capita GDP
Total degree of freedom: 97
R: .598
R square: .357
Adjusted R square: .275
F= 4.344
Significance: .000

*Unemployment in Small Sizes MSAs*

The second set of null hypotheses examines the relationship between unemployment and industrial research funding and science & engineering graduates in small sized MSAs.

**NH2a**: Industrial research funding is not correlated to unemployment in a region.

**H2a**: Industrial research funding is negatively correlated to unemployment in a region.

**NH2b**: The number of science and engineering graduates is not correlated to unemployment in a region.

**H2b**: The number of science and engineering graduates is negatively correlated to unemployment in a region.
The Table 23 provides the statistical analysis for unemployment rates in small sized MSAs. The results indicate that the set of independent variables significantly predict unemployment rate (F=8.71, Sig=.000). The adjusted R square value explains that 46.7 percent variation in the unemployment rate is explained by the independent variables. The results from the analysis do not show significant results for IRF. The results for SEG are significant but negatively correlated. Thus, neither of the null hypotheses is rejected and there is no statistical support for H2a or H2b.

Table 23

**Unemployment Analysis for Small Sized MSAs**

<table>
<thead>
<tr>
<th>Model 2</th>
<th>B</th>
<th>Std. Error</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>-1.27</td>
<td>2.148</td>
<td>-0.591</td>
<td>0.556</td>
</tr>
<tr>
<td>IRF</td>
<td>-4.69E-06</td>
<td>0.000</td>
<td>-0.203</td>
<td>0.839</td>
</tr>
<tr>
<td>S&amp; E Graduates</td>
<td>0.00E+00</td>
<td>0.000</td>
<td>-1.863</td>
<td>0.066</td>
</tr>
<tr>
<td>Patents</td>
<td>-1.00E-03</td>
<td>0.001</td>
<td>-1.233</td>
<td>0.221</td>
</tr>
<tr>
<td>Log Manufacturing Employment</td>
<td>0.045</td>
<td>0.038</td>
<td>1.186</td>
<td>0.239</td>
</tr>
<tr>
<td>Log Services Employment</td>
<td>-0.545</td>
<td>0.129</td>
<td>-4.213</td>
<td>0.000</td>
</tr>
<tr>
<td>Log Number of Proprietors</td>
<td>0.014</td>
<td>0.130</td>
<td>0.106</td>
<td>0.916</td>
</tr>
<tr>
<td>Log College Enrollment undergraduate</td>
<td>-0.021</td>
<td>0.046</td>
<td>-0.459</td>
<td>0.648</td>
</tr>
<tr>
<td>Population Change, 1990 to 2000</td>
<td>3.44E-06</td>
<td>0.000</td>
<td>1.678</td>
<td>0.097</td>
</tr>
<tr>
<td>Crime Index Rate</td>
<td>4.02E-05</td>
<td>0.000</td>
<td>2.346</td>
<td>0.021</td>
</tr>
<tr>
<td>Log COLI</td>
<td>0.343</td>
<td>0.353</td>
<td>0.972</td>
<td>0.334</td>
</tr>
<tr>
<td>Log Pop</td>
<td>0.524</td>
<td>0.114</td>
<td>4.595</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Dependent Variable: Log Unemployment
Total degree of freedom: 97
R: .726
R square: .527
Adjusted R square: .467
F= 8.716
Significance: .000

**New Firm Births in Small Sized MSAs**

The third set of null hypotheses examines the relationship between new firm births and industrial research funding and science & engineering graduates in small sized MSAs.
NH3\textsubscript{a}: Industrial research funding is not correlated to new firm births in a region.

H3\textsubscript{a}: Industrial research funding is positively correlated to new firm births in a region.

NH3\textsubscript{b}: The number of science and engineering graduates is not correlated to new firm births in a region.

H3\textsubscript{b}: The number of science and engineering graduates is positively correlated to new firm births in a region.

The statistical summary for new firm births for the small sized MSAs is shown in Table 24. The results indicate that the set of independent variables significantly predict new firm births ($F=50.22$, $\text{Sig}=0.000$). The adjusted $R^2$ indicates that 84.8 percent of the variation in new firm births is explained by the independent variables. There are no significant results for industrial research funding and science and engineering graduates in a region. Thus neither of the null hypotheses is rejected showing no statistical support for H3\textsubscript{a} and H3\textsubscript{b} in small sized MSAs.
Medium Sized MSAs

The medium sized MSAs is the second group of MSAs is with population between 250,000 - 999,999.

Per capita GDP in Medium Sized MSAs

As stated before, the first set of hypotheses focuses on the relationship between per capita GDP and industrial research funding and science and engineering graduates in the medium sized MSAs.

NH1a: Industrial research funding is not correlated to per capita GDP in a region.

H1a: Industrial research funding is positively correlated to per capita GDP in a region.

NH1b: The number of science and engineering graduates is not correlated to per capita GDP in a region.
H1b: The number of science and engineering graduates is positively correlated to per capita GDP in a region.

Table 25 provides the statistical results for per capita GDP in the medium sized MSAs. The results indicate that the set of independent variables significantly predict per capita GDP for medium sized MSAs (F=4.312, Sig=.000). The adjusted $R^2$ indicates that 30.8 percent of the variation in per capita GDP rates is explained by the independent variables. The IRF is significant at .10 level and SEG is not significant, thus the first null hypothesis is rejected, but the second null hypothesis failed to reject. The increase in IRF may affect per capita GDP positively; however there is no statistical support for H1b in medium sized MSAs.

Table 25

*Per Capita GDP analysis for Medium Sized MSAs*

<table>
<thead>
<tr>
<th>Model 2</th>
<th>B</th>
<th>Std. Error</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>62307.312</td>
<td>64228.23</td>
<td>-0.97</td>
<td>0.335</td>
</tr>
<tr>
<td>IRF</td>
<td>3.44E-01</td>
<td>0.207</td>
<td>1.665</td>
<td>0.095</td>
</tr>
<tr>
<td>S&amp; E Graduates</td>
<td>-5.33E-01</td>
<td>1.440</td>
<td>-0.37</td>
<td>0.712</td>
</tr>
<tr>
<td>Patents</td>
<td>1.84E+00</td>
<td>4.854</td>
<td>0.380</td>
<td>0.705</td>
</tr>
<tr>
<td>Log Manufacturing Employment</td>
<td>379.034</td>
<td>1523.735</td>
<td>0.249</td>
<td>0.804</td>
</tr>
<tr>
<td>Log Services Employment</td>
<td>13077.362</td>
<td>4130.443</td>
<td>3.166</td>
<td>0.002</td>
</tr>
<tr>
<td>Log Number of Proprietors</td>
<td>-7082.443</td>
<td>4407.779</td>
<td>-1.607</td>
<td>0.113</td>
</tr>
<tr>
<td>Log College enrollment undergraduate</td>
<td>-3184.425</td>
<td>2361.6</td>
<td>-1.348</td>
<td>0.182</td>
</tr>
<tr>
<td>Population Change, 1990 to 2000</td>
<td>-1.70E-02</td>
<td>0.020</td>
<td>-0.822</td>
<td>0.414</td>
</tr>
<tr>
<td>Crime Index Rate</td>
<td>-6.87E-01</td>
<td>0.603</td>
<td>-1.139</td>
<td>0.258</td>
</tr>
<tr>
<td>Log COLI</td>
<td>12668.863</td>
<td>11047.147</td>
<td>1.147</td>
<td>0.255</td>
</tr>
<tr>
<td>Log Pop</td>
<td>-463.142</td>
<td>2430.854</td>
<td>-0.191</td>
<td>0.849</td>
</tr>
</tbody>
</table>

Dependent Variable: Per Capita GDP
Total degree of freedom: 82
R: .633
R square: .400
Adjusted R square: .308
F= 4.312
Significance: .000
**Unemployment in Medium Sized MSAs**

The second set of null hypotheses examines the relationship between unemployment and industrial research funding and science & engineering graduates in medium sized MSAs.

\( NH2_a \): Industrial research funding is not correlated to unemployment in a region.

\( H2_a \): Industrial research funding is negatively correlated to unemployment in a region.

\( NH2_b \): The number of science and engineering graduates is not correlated to unemployment in a region.

\( H2_b \): The number of science and engineering graduates is negatively correlated to unemployment in a region.

The results (Table 26) indicate that the set of independent variables significantly predict unemployment rate \((F=3.177, \text{Sig}=.002)\) in the medium sized MSAs. The adjusted \( R^2 \) indicates that 22.6 percent of the variation in unemployment rates is explained by the independent variables. For the unemployment both IRF and SEG are not significant, thus neither of the null hypotheses are rejected and there is no statistical support for \( H2_a \) or \( H2_b \).
Table 26

*Unemployment Analysis for Medium Sized MSAs*

<table>
<thead>
<tr>
<th>Model 2</th>
<th>B</th>
<th>Std. Error</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>-2.001</td>
<td>2.726</td>
<td>-0.734</td>
<td>0.465</td>
</tr>
<tr>
<td>IRF</td>
<td>-3.55E-06</td>
<td>0.000</td>
<td>-0.405</td>
<td>0.687</td>
</tr>
<tr>
<td>S&amp; E Graduates</td>
<td>-6.66E-05</td>
<td>0.000</td>
<td>-1.089</td>
<td>0.280</td>
</tr>
<tr>
<td>Patents</td>
<td>7.60E-05</td>
<td>0.000</td>
<td>0.369</td>
<td>0.713</td>
</tr>
<tr>
<td>Log Manufacturing Employment</td>
<td>-0.003</td>
<td>0.065</td>
<td>-0.039</td>
<td>0.969</td>
</tr>
<tr>
<td>Log Services Employment</td>
<td>-0.455</td>
<td>0.175</td>
<td>-2.596</td>
<td>0.011</td>
</tr>
<tr>
<td>Log Number of Proprietors</td>
<td>0.271</td>
<td>0.187</td>
<td>1.450</td>
<td>0.151</td>
</tr>
<tr>
<td>Log College enrollment undergraduate</td>
<td>0.083</td>
<td>0.100</td>
<td>0.828</td>
<td>0.410</td>
</tr>
<tr>
<td>Population Change, 1990 to 2000</td>
<td>1.20E-06</td>
<td>0.000</td>
<td>1.384</td>
<td>0.171</td>
</tr>
<tr>
<td>Crime Index Rate</td>
<td>4.91E-05</td>
<td>0.000</td>
<td>1.919</td>
<td>0.059</td>
</tr>
<tr>
<td>Log COLI</td>
<td>0.439</td>
<td>0.469</td>
<td>0.937</td>
<td>0.352</td>
</tr>
<tr>
<td>Log Pop</td>
<td>0.208</td>
<td>0.103</td>
<td>2.017</td>
<td>0.048</td>
</tr>
</tbody>
</table>

Dependent Variable: log Unemployment
Total degree of freedom: 82
R: .574
R square: .330
Adjusted R square: .226
F= 3.177
Significance: .002

*New Firm Births in Medium Sized MSAs*

The third set of null hypotheses examines the relationship between new firm births and industrial research funding and science and engineering graduates.

**NH3a:** Industrial research funding is not correlated to new firm births in a region.

**H3a:** Industrial research funding is positively correlated to new firm births in a region.

**NH3b:** The number of science and engineering graduates is not correlated to new firm births in a region.

**H3b:** The number of science and engineering graduates is positively correlated to new firm births in a region.
The results indicate that the set of independent variables significantly predict new firm births ($F=37.31$, $\text{Sig}=.000$) in medium sized metropolitans. The adjusted $R^2$ indicates that 85.3 percent of the variation in new firm births is explained by the independent variables. The Table 27 shows that the industrial research funding was negative and significant and number of science & engineering graduates was positively related and significant at .05 level. The first null hypothesis is not rejected, but the second null hypothesis related to SEG is rejected showing statistical support for $H_3_b$. Thus the increase in IRF does not positively affect new firm births in the MSAs as the results show no statistical support for $H_3_a$.

Table 27

*New Firm Births Analysis for Medium Sized MSAs*

<table>
<thead>
<tr>
<th>Model 2</th>
<th>B</th>
<th>Std. Error</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>-1.854</td>
<td>2.311</td>
<td>-0.803</td>
<td>0.425</td>
</tr>
<tr>
<td>IRF</td>
<td>-3.02E-05</td>
<td>0.000</td>
<td>-4.066</td>
<td>0.000</td>
</tr>
<tr>
<td>S&amp; E Graduates</td>
<td>0.00E+00</td>
<td>0.000</td>
<td>2.399</td>
<td>0.019</td>
</tr>
<tr>
<td>Patents</td>
<td>0.00E+00</td>
<td>0.000</td>
<td>2.719</td>
<td>0.008</td>
</tr>
<tr>
<td>Log Manufacturing Employment</td>
<td>-0.088</td>
<td>0.055</td>
<td>-1.600</td>
<td>0.114</td>
</tr>
<tr>
<td>Log Services Employment</td>
<td>0.438</td>
<td>0.149</td>
<td>2.947</td>
<td>0.004</td>
</tr>
<tr>
<td>Log Number of Proprietors</td>
<td>0.107</td>
<td>0.159</td>
<td>0.678</td>
<td>0.500</td>
</tr>
<tr>
<td>Log College enrollment undergraduate</td>
<td>0.060</td>
<td>0.085</td>
<td>0.704</td>
<td>0.484</td>
</tr>
<tr>
<td>Population Change, 1990 to 2000</td>
<td>1.46E-06</td>
<td>0.000</td>
<td>1.988</td>
<td>0.051</td>
</tr>
<tr>
<td>Crime Index Rate</td>
<td>2.09E-05</td>
<td>0.000</td>
<td>0.964</td>
<td>0.338</td>
</tr>
<tr>
<td>Log COLI</td>
<td>-0.391</td>
<td>0.397</td>
<td>-0.984</td>
<td>0.329</td>
</tr>
<tr>
<td>Log Pop</td>
<td>0.362</td>
<td>0.087</td>
<td>4.136</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Dependent Variable: Log new firm births
Total degree of freedom: 82
$R^2$: .923
$R$ square: .853
Adjusted $R$ square: .830
$F=37.312$
Significance: .000
Large Sized MSAs

The third partitioned group of MSAs is with population more than 1 million populations.

*Per capita GDP in Large Sized MSAs*

The first set of hypotheses focuses on the relationship between per capita GDP and industrial research funding and science and engineering graduates in the large sized MSAs.

NH1a: Industrial research funding is not correlated to per capita GDP in a region.

H1a: Industrial research funding is positively correlated to per capita GDP in a region.

NH1b: The number of science and engineering graduates is not correlated to per capita GDP in a region.

H1b: The number of science and engineering graduates is positively correlated to per capita GDP in a region.

Table 28 provides the statistical summary for per capita GDP. The results indicate that the set of independent variables significantly predict per capita GDP for large sized MSAs (F=4.00, Sig=.001). The adjusted $R^2$ indicates that 46.5 percent of the variation in per capita GDP is explained by the independent variables. The results from the analysis show significant and positive relation for industrial research funding and negative significant for science and engineering graduates. The first null hypothesis is rejected at .10 level, showing support for the increase in IRF positively effecting per capita GDP. The second hypothesis failed to reject showing no statistical support for H1b, thus the increase in SEG does not positively effect per capita GDP in the MSAs.
Table 28

*Per Capita GDP Analysis for Large Sized MSAs*

<table>
<thead>
<tr>
<th>Model 2</th>
<th>B</th>
<th>Std. Error</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>-53702.533</td>
<td>56676.937</td>
<td>-0.948</td>
<td>0.352</td>
</tr>
<tr>
<td>IRF</td>
<td>2.12E-01</td>
<td>0.115</td>
<td>1.834</td>
<td>0.078</td>
</tr>
<tr>
<td>S&amp; E Graduates</td>
<td>-1.26E+00</td>
<td>0.605</td>
<td>-2.085</td>
<td>0.047</td>
</tr>
<tr>
<td>Patents</td>
<td>1.12E+00</td>
<td>2.643</td>
<td>0.425</td>
<td>0.675</td>
</tr>
<tr>
<td>Log Manufacturing Employment</td>
<td>2324.81</td>
<td>2503.521</td>
<td>0.929</td>
<td>0.361</td>
</tr>
<tr>
<td>Log Services Employment</td>
<td>3800.903</td>
<td>4224.894</td>
<td>0.900</td>
<td>0.376</td>
</tr>
<tr>
<td>Log Number of Proprietors</td>
<td>1720.264</td>
<td>5265.901</td>
<td>0.327</td>
<td>0.746</td>
</tr>
<tr>
<td>Log College enrollment college undergraduate</td>
<td>-5852.095</td>
<td>2000.084</td>
<td>-2.926</td>
<td>0.007</td>
</tr>
<tr>
<td>Population Change, 1990 to 2000</td>
<td>4.00E-03</td>
<td>0.005</td>
<td>0.888</td>
<td>0.382</td>
</tr>
<tr>
<td>Crime Index Rate</td>
<td>-2.62E-01</td>
<td>1.044</td>
<td>-0.251</td>
<td>0.804</td>
</tr>
<tr>
<td>Log COLI</td>
<td>15924.161</td>
<td>7784.387</td>
<td>2.046</td>
<td>0.051</td>
</tr>
<tr>
<td>Log Pop</td>
<td>-750.051</td>
<td>2015.651</td>
<td>-0.372</td>
<td>0.713</td>
</tr>
</tbody>
</table>

Dependent Variable: Per Capita GDP
Total degree of freedom: 38
R: .787
R square: .620
Adjusted R square: .465
F=4.00
Significance: .001

Unemployment in Large Sized MSAs

The second set of null hypotheses focuses on the relationship between unemployment and industrial research funding and science & engineering graduates in large sized MSAs.

NH2a: Industrial research funding is not correlated to unemployment in a region.

H2a: Industrial research funding is negatively correlated to unemployment in a region.

NH2b: The number of science and engineering graduates is not correlated to unemployment in a region.

H2b: The number of science and engineering graduates is negatively correlated to unemployment in a region.
The Table 29 below provides the statistical summary for unemployment for the large sized MSAs. The results indicate that the set of independent variables are insignificant and thus do not predict unemployment rate (F=.383, Sig=.952) in large sized MSAs. The adjusted R² value of (.217) indicates unemployment rates in the large sized MSAs do not explain the independent variables. The unemployment analysis shows that neither of the null hypotheses are rejected thus there is no statistical support for H2a or H2b.

Table 29

**Unemployment Analysis for Large Sized MSAs**

<table>
<thead>
<tr>
<th>Model 2 Variable</th>
<th>B</th>
<th>Std. Error</th>
<th>t</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>0.843</td>
<td>2.022</td>
<td>0.417</td>
<td>0.680</td>
</tr>
<tr>
<td>IRF</td>
<td>7.60E-07</td>
<td>0.000</td>
<td>0.185</td>
<td>0.855</td>
</tr>
<tr>
<td>S&amp; E Graduates</td>
<td>-1.03E-05</td>
<td>0.000</td>
<td>-0.478</td>
<td>0.636</td>
</tr>
<tr>
<td>Patents</td>
<td>-2.00E-05</td>
<td>0.000</td>
<td>-0.212</td>
<td>0.834</td>
</tr>
<tr>
<td>Log Manufacturing Employment</td>
<td>-0.016</td>
<td>0.089</td>
<td>-0.183</td>
<td>0.856</td>
</tr>
<tr>
<td>Log Services Employment</td>
<td>0.035</td>
<td>0.151</td>
<td>0.230</td>
<td>0.819</td>
</tr>
<tr>
<td>Log Number of Proprietors</td>
<td>-0.009</td>
<td>0.188</td>
<td>-0.049</td>
<td>0.961</td>
</tr>
<tr>
<td>Log College enrollment undergraduate</td>
<td>-0.024</td>
<td>0.071</td>
<td>-0.333</td>
<td>0.742</td>
</tr>
<tr>
<td>Population Change, 1990 to 2000</td>
<td>1.34E-07</td>
<td>0.000</td>
<td>0.824</td>
<td>0.417</td>
</tr>
<tr>
<td>Crime Index Rate</td>
<td>-1.71E-05</td>
<td>0.000</td>
<td>-0.460</td>
<td>0.649</td>
</tr>
<tr>
<td>Log COLI</td>
<td>-0.049</td>
<td>0.278</td>
<td>-0.177</td>
<td>0.861</td>
</tr>
<tr>
<td>Log Pop</td>
<td>0.073</td>
<td>0.072</td>
<td>1.020</td>
<td>0.317</td>
</tr>
</tbody>
</table>

Dependent Variable: Log Unemployment
Total degree of freedom: 38
R: .367
R square: .135
Adjusted R square: .217
F=.383
Significance: .952
New Firm Births in Large Sized MSAs

The third set of null hypotheses examines the relationship between new firm births and industrial research funding and science & engineering graduates in large sized MSAs.

NH3a: Industrial research funding is not correlated to new firm births in a region.

H3a: Industrial research funding is positively correlated to new firm births in a region.

NH3b: The number of science and engineering graduates is not correlated to new firm births in a region.

H3b: The number of science and engineering graduates is positively correlated to new firm births in a region.

The Table 30 provides the statistical summary for new firm births for the large sized MSAs. The results indicate that the set of independent variables significantly predict new firm births (F=14.377, Sig=.000) in large sized MSAs. The adjusted $R^2$ indicates that 79.5 percent of the variation in new firm births is explained by the independent variables. The new firm births analysis shows that neither of the null hypotheses is rejected thus there is no statistical support for H3a or H3b.
Table 30

*New Firm Births Analysis for Large Sized MSAs*

<table>
<thead>
<tr>
<th>Model 2</th>
<th>B</th>
<th>Std. Error</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>0.219</td>
<td>5.075</td>
<td>0.043</td>
<td>0.966</td>
</tr>
<tr>
<td>IRF</td>
<td>-4.00E-06</td>
<td>0.000</td>
<td>-0.387</td>
<td>0.702</td>
</tr>
<tr>
<td>S&amp; E Graduates</td>
<td>-1.15E-05</td>
<td>0.000</td>
<td>-0.212</td>
<td>0.834</td>
</tr>
<tr>
<td>Patents</td>
<td>0.00E+00</td>
<td>0.000</td>
<td>0.965</td>
<td>0.343</td>
</tr>
<tr>
<td>Log Manufacturing Employment</td>
<td>-0.218</td>
<td>0.224</td>
<td>-0.974</td>
<td>0.339</td>
</tr>
<tr>
<td>Log Services Employment</td>
<td>1.103</td>
<td>0.378</td>
<td>2.917</td>
<td>0.007</td>
</tr>
<tr>
<td>Log Number of Proprietors</td>
<td>-0.182</td>
<td>0.472</td>
<td>-0.386</td>
<td>0.702</td>
</tr>
<tr>
<td>Log College enrollment undergraduate</td>
<td>0.115</td>
<td>0.179</td>
<td>0.642</td>
<td>0.526</td>
</tr>
<tr>
<td>Population Change, 1990 to 2000</td>
<td>3.74E-07</td>
<td>0.000</td>
<td>0.914</td>
<td>0.369</td>
</tr>
<tr>
<td>Crime Index Rate</td>
<td>-7.41E-05</td>
<td>0.000</td>
<td>-0.793</td>
<td>0.435</td>
</tr>
<tr>
<td>Log COLI</td>
<td>-0.305</td>
<td>0.697</td>
<td>-0.437</td>
<td>0.665</td>
</tr>
<tr>
<td>Log Pop</td>
<td>-0.067</td>
<td>0.181</td>
<td>-0.374</td>
<td>0.712</td>
</tr>
</tbody>
</table>

Dependent Variable: log new firm births
Total degree of freedom: 38
R: .924
R square: .854
Adjusted R square: .795
F=14.377
Significance: .000

Comparison of Small, Medium and Large MSAs

The results from the second model show that the IRF does not influence per capita GDP in small sized MSAs. However, IRF positively affects per capita GDP in medium & large sized MSAs and combined MSAs. But science and engineering graduates is not positively related to per capita GDP in the combined or partitioned model.
For the null hypothesis to be rejected the regression results for unemployment rates in reference to IRF should be significant and negatively correlated. Though the IRF is negatively correlated in small, medium and total MSAs but it is not significant. This suggests that there is no influence of industrial research funding on employment rates in small, medium and large sized MSAs and the same is the case for the combined MSAs. The results for whether SEG influences unemployment rates in the MSAs also did not support our hypothesis. The results for the number of science and engineering graduates though significant but are positively correlated in small sized MSAs. The regression results for unemployment in relation to medium and large sized MSAs and the combined though negatively correlated with SEG are not significant.
Table 32

Unemployment Comparison

<table>
<thead>
<tr>
<th>Observations</th>
<th>Small 98</th>
<th>Medium 83</th>
<th>Large 39</th>
<th>Combined 220</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>-1.27</td>
<td>-2.001</td>
<td>0.843</td>
<td>0.6800</td>
</tr>
<tr>
<td>IRF</td>
<td>-4.69E-06</td>
<td>0.8390</td>
<td>7.60E-07</td>
<td>-3.25E-07</td>
</tr>
<tr>
<td>S&amp;E Graduates</td>
<td>0.00E+00</td>
<td>-6.66E-05</td>
<td>2.00E-05</td>
<td>-1.03E-05</td>
</tr>
<tr>
<td>Patents</td>
<td>1.00E-03</td>
<td>0.7130</td>
<td>2.00E-05</td>
<td>0.8340</td>
</tr>
<tr>
<td>Log Manufacturing Employment</td>
<td>0.045</td>
<td>0.9690</td>
<td>-0.016</td>
<td>0.8560</td>
</tr>
<tr>
<td>Log Services Employment</td>
<td>0.545</td>
<td>0.0101</td>
<td>0.035</td>
<td>0.8190</td>
</tr>
<tr>
<td>Log Number of Proprietors</td>
<td>0.034</td>
<td>0.1510</td>
<td>-0.009</td>
<td>0.9610</td>
</tr>
<tr>
<td>Log College enrollment undergraduate</td>
<td>-0.021</td>
<td>0.4100</td>
<td>-0.024</td>
<td>0.7420</td>
</tr>
<tr>
<td>Population Change, 1990 to 2000</td>
<td>3.44E-06</td>
<td>0.1710</td>
<td>1.34E-07</td>
<td>0.4170</td>
</tr>
<tr>
<td>Crime Index Rate</td>
<td>4.02E-06</td>
<td>0.4100</td>
<td>1.34E-07</td>
<td>0.4170</td>
</tr>
<tr>
<td>Log COLI</td>
<td>0.343</td>
<td>0.2080</td>
<td>0.073</td>
<td>0.3170</td>
</tr>
<tr>
<td>Log Population</td>
<td>0.524</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

The results for third dependent variable new birth firm shows no significant relationship between IRF and science and engineering graduates in small sized MSAs.

The relationship was similar for the large sized MSAs with IRF and the number of science and engineering graduates. However for the medium sized MSAs, the IRF and the combined are negatively related with the birth of new firms in the MSAs. The number of science and engineering graduates in medium sized MSAs influence new firm births, but combined model shows no correlation.

Table 33

New Firm Births Comparison

<table>
<thead>
<tr>
<th>Observations</th>
<th>Small 98</th>
<th>Medium 83</th>
<th>Large 39</th>
<th>Combined 220</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>-4.167</td>
<td>-1.854</td>
<td>0.219</td>
<td>-2.286</td>
</tr>
<tr>
<td>IRF</td>
<td>2.89E-07</td>
<td>-3.02E-05</td>
<td>0.0960</td>
<td>-4.66E-06</td>
</tr>
<tr>
<td>S&amp;E Graduates</td>
<td>-1.83E-05</td>
<td>0.00E+00</td>
<td>-1.15E-05</td>
<td>0.8340</td>
</tr>
<tr>
<td>Patents</td>
<td>0.00E+00</td>
<td>0.00E+00</td>
<td>0.00E+00</td>
<td>0.3430</td>
</tr>
<tr>
<td>Log Manufacturing Employment</td>
<td>-0.106</td>
<td>-0.088</td>
<td>-0.218</td>
<td>0.3390</td>
</tr>
<tr>
<td>Log Services Employment</td>
<td>0.319</td>
<td>0.438</td>
<td>1.103</td>
<td>0.0070</td>
</tr>
<tr>
<td>Log Number of Proprietors</td>
<td>0.25</td>
<td>0.107</td>
<td>-0.132</td>
<td>0.7020</td>
</tr>
<tr>
<td>Log College enrollment undergraduate</td>
<td>-0.005</td>
<td>0.06</td>
<td>0.115</td>
<td>0.5260</td>
</tr>
<tr>
<td>Population Change, 1990 to 2000</td>
<td>6.22E-06</td>
<td>0.0510</td>
<td>3.74E-07</td>
<td>0.3690</td>
</tr>
<tr>
<td>Crime Index Rate</td>
<td>1.27E-05</td>
<td>0.3380</td>
<td>-7.41E-05</td>
<td>0.4135</td>
</tr>
<tr>
<td>Log COLI</td>
<td>-0.161</td>
<td>0.362</td>
<td>-0.067</td>
<td>0.7120</td>
</tr>
<tr>
<td>Log Population</td>
<td>0.512</td>
<td>0.362</td>
<td>0.0000</td>
<td>0.126</td>
</tr>
</tbody>
</table>
CHAPTER VI
FINDINGS AND CONCLUSIONS

This study is based on the theory of innovation systems which considers innovation to be at the main focus of an economic system. A system of linkages or collaborations is formed among various institutions such as academia, government, private sectors, markets, cultural or social and political systems with innovation being at the center of all the activities among these partnerships. The interactions between the institutions lead to a new learning process and new knowledge. This results in increased regional technological capability and economic growth. The focal point of innovation systems is generally knowledge, learning and interactivity among different actors in the system whether national or regional (Lundvall 1992; Nelson 1993).

The main research question for this dissertation concerns potential increases in innovative activities resulting from collaboration between university and industry leading to economic growth in a region. Cooke and Morgan (1993) argue that industry perceives collaborating with universities leads to utilizing new innovations from the academic research for profit and other purposes. Further they suggest that collaboration benefits the community and citizens through new innovative processes and products and regions benefit from successful collaborations among economic actors. Economic development organizations encourage such collaborations as innovation has an important role in competitive advantage for a region. According to (Kaufmann and Todtling (2001) an important factor for regional economic growth is generation and creation of new ideas through research and development in a region. A main objective for university-industry collaboration has been innovation in services, products and processes.
Collaboration between university and industry is beneficial for both. However, this knowledge transfer may not always be contributing to a region. This research is an effort to explore whether the collaboration between university and the industry affects the regional patterns of growth and development.

This research considered two models to understand the relation between industrial research funding to universities in a region and its influence on the development outcomes of a region. The regions analyzed were the Metropolitan Statistical Areas (MSAs) in the United States. Two measures of university-industry collaboration were studied: Industrial research funding (IRF) to universities and science and engineering graduates (SEG). The first model studied the combined effect of the MSAs and explored the influence of IRF and SEG on per capita GDP, unemployment rates and new firm births in the MSAs. In the second model, the MSAs were partitioned in terms of population sizes into small, medium and large. This model also studied the role of IRF and SEG on per capita GDP, unemployment rates and new firm births in the small, medium and large sized MSAs.

*Per capita GDP*

The empirical results show mixed effects of university-industry collaboration in relation to per capita GDP. The first hypothesis (H1a) stated that IRF is positively correlated to per capita GDP. This hypothesis is generally supported. Regression results indicate that higher levels of IRF are associated with higher per capita GDP for medium and large sized MSAs as well as for the combined model. No statistically significant findings were found relative to IRF and per capita GDP in small MSAs. Cooke, Uranga and Extebarria (1998) argue that research and development expenditure is an input in an
innovation producing process. Thus the IRF as an input produce substantial output to create innovative resources to influence per capita GDP in a positive way in medium and large MSAs. The lack of significant findings in smaller MSAs could be due to a lack of agglomeration effects in smaller metro areas. Varga (2000) found that equal levels of research spending results in different innovative outputs depending on the agglomeration of economic activity in the large metropolitan areas compared to small metropolitan areas. Henderson, Shalizi and Venables (2001) suggests that agglomeration often explains the regional differences in income and economic activities.

The results related to science and engineering graduates were contrary to the second hypothesis related to GDP (H1b). The literature suggests that higher science and engineering would be associated with higher per capita GDP, but this research deviates from this conclusions. Science and engineering graduates in the MSAs are negatively correlated with per capita GDP in large sized MSAs as well as in the combined model. No statistically significant findings were found in small or medium sized MSAs. The innovation system approach considers growth through collaboration among economic actors in a region. Thus collaboration between university and industry through student employment was expected to lead to higher per capita GDP in a region.

There are a couple of potential explanations for this negative correlation. First, a large supply of college graduates in a region may drive down wages in that region. In broader research studying economic impact of academic institutions, Goldstein and Renault (2004) found similar results. The authors suggest that increasing the local labor market by increasing skilled manpower reduces relative earnings. Similar results were found in another study by Goldstein and Drucker (2006).
Second, college graduates tend to be ‘footloose’, moving to other regions where there may be better employment opportunities. It is easy to measure student inflows as university registration gives information on enrollment. However, outflows or students’ post-graduation information is not provided by the universities and is not easily available (Goldstein and Drucker 2007).

Any region would like to retain all of its college graduates and benefit from their skills and experience. But such a scenario is rare in any community: The reason to migrate is because of the limitations at the place of origin or perceived benefits at the migrating location. Such migration also happens when the marginal returns to human capital are more in the future location than the original location (Parsad and Gray 2005).

An important indicator of economic growth and development is the movement of families and labor force from one location to another in search of economic benefits or additional training (Sanderson and Dugoni 2002). Migration of educated and skilled manpower leads to further migration. Employment growth positively affects hourly earnings and thus migration in high employment growth areas is less (Mills and Hazarika 2001). Studies related to impact of universities on regional development have also considered influence of universities on human-capital creation and its induced effects on regional migration patterns. Regional economic development depends on the skilled and educated people remaining in the region.

People move from their native regions to better economic condition regions. The non-economic factors for migration are climate, geographical locations (Ishitani 2011). Groen (2004) found that public universities’ graduates are more likely not to migrate from their original states than private universities graduates. Students from high gross
domestic product locations and graduates from doctoral institutions are more likely to stay in their native states. However, students graduating from highly selective institutions more likely leave their original locations. Parsad and Gray (2005) examined migration patterns of science and engineering graduates and found that male science and engineering graduates were more mobile than the females. Single students with bachelor’s degree were more likely to migrate than married students. Among students and non students, full-time students are more likely to migrate than non-students, further part-time students were among the least likely to migrate.

Broader trends related to college graduate migration may be overwhelming the effects of a small group of science and engineering graduates taking skills learned in the local university to a local firm. A more specific dataset that only included locally employed science and engineering graduates may have produced a different result in this research. However, these data are not available at this time.

Unemployment

It was hypothesized that university-industry collaboration as measured by industrial research funding (H2_a) and science and engineering graduates (H2_b) would be associated with reduced unemployment rates in a region. The statistical analysis did not support these hypotheses. No statistically significant results were found relative to IRF and unemployment rates in either model. Nor was SEG significant in the combined model and medium and large sized MSAs. In small MSAs, science and engineering graduates had a positive (contrary to the hypothesis) significant result. However, the magnitude of this coefficient was very small-close to zero.
The results related to unemployment and universities are mixed in other studies. Inconsistent with the findings in this study, Gumprecht (2003) suggests that in university towns unemployment is lower and incomes of the families are high, as the local populations are highly educated. Similar to this study, Goldstein and Renault (2004) in a research studying contributions of academic institutions to regional development for the years 1969-1986 found no correlation between employment and research and development. Another factor can be that Industrial research funding generates very small employment in a region and that too may be limited to skilled workforce.

New Firm Births

The final two hypotheses were focused on new firm births. Industrial research funding was hypothesized to be positively related to new firm births (H3a). Similarly, science and engineering graduates were hypothesized to be positively related to new firm births (H3b). The findings for IRF and SEG were not supportive of the hypotheses. The IRF shows a negative correlation with new firm births in medium sized MSAs and in the combined model. SEG positively influences new firm births in medium sized MSAs, but combined model shows no relationship with SEG. Science and engineering graduates influencing new firm only in medium sized MSAs is consistent with Armington and Acs (2004) conclusions that regions that have higher level of education will have higher startups, however large sized regions have thick labor markets leaving less scope for entrepreneurship activities.

The negative relationships found related to IRF and firm births are similar to what some other researchers have found in research unrelated to universities. Reynolds, Miller and Maki (1995) studied labor market areas annual birth rate of new firms in all industrial
sectors in the US for six 2 year periods from 1976-1988. They hypothesized that “where information is readily available and innovation and creativity flourish, the formation rate of new firms is enhanced” (p 391) and found no evidence that research and development, knowledge and innovation supports new firm births. They suggest that the measures used (density of post-college adults, professional and technical employees, patents granted, or doctorates earned) may not be appropriate. Further it was found that regional economic diversity, growth in population, more personal wealth, and low unemployment rate support firm births. However, higher customer densities, suppliers or inputs, R&D facilities, production costs did not impact firm births.

Bania, Eberts and Fogarty (1993) found no evidence that a more technical human capital especially higher percent of engineers and scientists supports increase in startup rate of new firms. The industries centered in R&D activities are generally not supportive to new startups. This is explained by Mueller and Tilton (1969) that existing industries cause barriers to new startups as the existing industries are inclined towards accumulation of patents and knowhow.

There is some evidence that growth that growth in new firms is encouraged by high unemployment rate and low capital cost (Audretsch and Acs 1994). They also suggest that new firm births are influenced by macroeconomic growth. During economic contraction existing firms close or decrease employment leading to an increase in startup firms.

Lund (1986) found that growth in small firms in a region was due to better organization or business processes, and not because of higher rates of technical innovation through research and development. Carlsson and Fridh (2002) in a study of
US research institutions, hospitals and universities found that the amount of research expenditure was positively related to number of startup firms.

**Overall Results**

Universities are considered as engines of growth but they have to work in collaboration with other institutions to spur development. Acs (1990) suggested that research institutions are necessary, but certainly not sufficient for economic development in a region. The collaboration measures used in this research did not have a strong relationship with development outcomes. Goldstein and Renault (2004) suggest that regional size in terms of agglomeration economies is more effective in supporting regional development than university research activities. They also found that in smaller size regions, university research has a significant effect in regional development suggesting that universities act as alternative for agglomeration.

The economic capability of a region in the long run is influenced by generation of new knowledge through innovation and the design of the region’s innovation system (Karlsson, et al.2008). Though research at universities’ labs facilitates regional competitiveness and the universities are referred as “engines of growth” for a location, but still it has not been empirically possible to find the direct impact of universities on industrial innovation (Laursen and Salter 2004).

Doutriaux and Barker (1995) suggest that there are other local conditions that support university-industry and other collaborations for innovation-based regional growth. A region should have a strong knowledge-base, large and small high-tech industrial clusters, access to global and local environment, proximity among the institutions, supportive local, federal and government policies for university–industry
collaborations. Thus for regional growth a combination of factors should work in cooperation and support each other.

Since the study is about economic development patterns in US regions in a single year, the results in the study could also be explained by the economic status of the US economy in that period. To ensure temporal precedence, the independent variables were measured in 2000 and the dependent variables were measured in 2001. Between 2000 and 2001, the country’s longest postwar growth ended. After an increase for almost 10 years, the U.S. economy entered a period of recession in March 2001. A slump in manufacturing started in late summer of 2000 and worsened in the year 2001, due to businesses and industries reducing spending on machinery, computers, and other capital goods. Also consumer’s confidence wavered in the 4th quarter, due to both growing unemployment and psychological and economic effects of the September 11 disaster. The unemployment rate increased to 5.6 percent in 2001, which was an increase of 1.6 percent from the 30-year low of 4 percent. Total employment numbers decreased by more than 1.3 million in 2001, the first over the year decline since 1991. By late summer of 2000, U.S. automakers estimated an overall decline in new cars and light trucks demand. Thus they reduced both output and employment. In late 2000, there a huge drop in IT equipment production related sectors such as computers, semiconductors, and communications equipment lead to layoffs. Further IT manufacturers reduced their ranks by 188,000 jobs, which was 15.6 percent decline in manufacturing jobs. Metropolitan areas with a population of 1 million or more saw their unemployment rates move upward in 2001 (Langdon, McMenamin and Krolak 2002). The average unemployment rate in US metropolitans increased from 4.0 in the year 2000 to 4.8 in the year 2001. However,
there was an average increase in new firm births in the MSAs from 1745 in the year 2000 to 1903 in the year 2001. Thus, the results contrary to the hypotheses, especially those related to unemployment rates, could have been related to broader economic conditions.

Thus it can be summarized that university-industry collaboration does not always positively influence economic growth in a region. It was seen that in the broad combined results that per capita GDP is positively related to industrial research funding. However, the same was not observed with unemployment rates and new firm births.

Future Research and Limitations

*Measurement Issues*

Validity and reliability are the main issues involved in the data measurement for any research. Reliability refers to the consistency of the measure. Validity is used to determine the association between the measure and the concept it is measuring. External validity refers to how much the results obtained could be generalized across different populations, settings and time periods. Internal validity refers to the robustness with which the study was done and explains that the research procedure displayed true cause and cause and effect relationships and not manipulated (Johnson and Reynolds 2005). Shadish, Cook and Campbell (2002) suggest two threats to internal validity that may apply in this study: selection bias and history.

Selection of cases is limited due to non-availability of secondary data in several MSAs. Thus in the future research might seek to incorporate additional data sets. Events happening in the same period as treatment could cause the observed effect as the beginning of the economic recession in the years 2000/2001. This is a history threat to internal validity.
Though there are also other measures of collaboration between university and industry such as co-publications, training of graduates, patent patterns etc. due to limitations in data availability, in this study the collaboration between university and industry was measured through industrial research funding to the university and science and engineering graduates. A more specific measure of the human capital transfers from the universities to industry would improve the analysis.

Data Limitation and Future Research

Creswell (2003) suggests that limitations in a research are the difficulties or problems identified during the research process such as data unavailability. The limitation of this research was time and difficulty in obtaining data. Due to time constraint and the unavailability of the data the research was limited to one year only. A time series analysis may have made the results more conclusive. For further analysis of university–industry collaborations on the regional development a time series analysis is recommended.

Innovations generated by collaborations may generate local development, but those innovations may not be utilized locally and this could be investigated in future research. The migration of graduates and its affect on regional development can be an interesting future study.
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