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This research examines the importance of proximity and the role of distance within the life science sector of the economy for the interacting metropolitan regions of Denver and Boulder, Colorado and Triad and Triangle, North Carolina. This sector is characterized by high technology employment, research and development, and knowledge spillovers. The thesis of this research is that synergies among sectors within the life science industry exist between proximate places to build a regional economic growth engine. Denver/Boulder, CO and Triad/Triangle, NC are complementary regions which share benefits of interactions within the growing life science sector of the economy because of proximity, strong commuting ties, a solid university system, and adequate research funding. Statistics and data regarding labor sources and employment, commuting patterns, and funding come from the Bureau of Labor Statistics, ReferenceUSA Employment database, Census Transportation Planning Package, and the National Institute of Health. Employment figures are classified by selected life science sectors within the North American Industry Classification System (NAICS). Analysis of these statistics will demonstrate the clustering of life science employment, ease of mobility within the regions, and strength of research and development within the study areas. Conclusions demonstrate that proximate places in Colorado and North Carolina possess the attributes necessary to maintain a successful economic environment for the life science industry to develop.

LIFE SCIENCE INDUSTRY REGIONAL CLUSTERS: SPATIAL CONCENTRATIONS IN DENVER/BOULDER, COLORADO and TRIAD/TRIANGLE, NORTH CAROLINA

by

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APPROVAL PAGE

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CHAPTER I

INTRODUCTION

Metropolitan areas seek to attract clusters of firms related to the life science industry since this sector tends to be highly profitable. A major question remains as to why some groups of cities are more successful at nurturing firms in certain components of this industry than are other urban areas. A region can be measured at various scales but is defined here as a group of proximate Metropolitan Statistical Areas (MSAs) or Combined Statistical Areas (CSAs). The MSAs chosen for analysis are grouped into CSAs, which are defined by the U.S. Census Bureau as an aggregate of adjacent MSAs that are linked by commuting ties (U.S. Census Bureau 2008). Some metropolitan locations attract successful, high-technology clusters while others are less able to do so. The role of place is an important consideration in the location of life science activities. Why do companies choose one place over another?

The thesis of this research is that synergies among sectors within the life science industry exist between proximate places that can build a regional economic growth engine. It is hypothesized that each MSA in this group selected tends to develop its own specialization within the life science industry. Even with specializations that are unique to each MSA, firms within life sciences tend to cluster in a proximate sense. Life science industry clusters and specializations by MSA will be demonstrated through the use of Bureau of Labor Statistics (BLS) and ReferenceUSA company database information. Another part of the hypothesis of this research is that life science firms establish their locations in regional clusters and develop strategies for innovation and collaboration to benefit from synergies and regional growth. This will be demonstrated through the use of company surveys.

This research examines the importance of proximity and the role of distance within the life science sector of the economy using case studies of CSAs in Colorado and North Carolina. In Colorado, the proximate MSAs of Boulder, Denver, and Greeley are studied. In North Carolina, the proximate CSAs of Greensboro - Winston-Salem - High Point (known as the Triad) and Raleigh – Durham – Cary (known as the Triangle) are studied. The Triad CSA contains three MSAs and the Triangle consists of two. The MSA and CSA definitions for the year 2006 are used. They change according to population patterns and decisions made by the U.S. Census Bureau and Office of Management and Budget. Some of the data presented uses previous MSA definitions. The Research Design section articulates the reason for choosing these MSAs as study regions and their rankings in terms of employment within selected life science sectors.

It is asserted that the regions of Denver/Boulder, CO and Triad/Triangle, NC are each complementary regions which share the benefits of interactions within the growing life science sector of the economy because of the location of employment clusters, strong commuting ties between the proximate MSAs and CSAs, and highly ranked research institutions in terms of grant funding. These regions benefit economically from the development of biopharmaceutical industry clusters. They are highly connected with their local university systems, thus attracting high-technology firms and employment and providing a highly skilled and highly educated workforce. There is a sense of communication relationships which result in knowledge flows and spillovers. The industry is experiencing high rates of growth in these economically vibrant regions because corporations, businesses, and universities learn from each other.

The life sciences industry is important to study since their R&D branches apply biological knowledge and techniques related to molecular, cellular, and genetic processes to develop products and services, generating high revenues for their harboring locales. Biotechnology remains a fairly new industry with approximately 40% of existing firms less than 15 years old (Hall and Bagchi-Sen 2007). The industry consists of firms which establish themselves to develop this knowledge and involves the creation of new ideas through research and development of new products and processes (Cortwright and Mayer 2002). This new and rapidly changing industry has a great impact on the health, quality of life, and life span of the human race. One significant achievement is recombinant DNA technology which has resulted in proteins that are already used as therapeutics. Antibodies for cancer, arthritis and tissue transplant, growth hormones, and clot-busting enzymes have been also been discovered by top scientists and researchers within the industry (DeVol et al. 1994).

Funding and support are available in the form of National Institute of Health (NIH) grant funding, private sector investments, venture capitalists, and research and development (R&D) contracts. NIH funding data will be used as a proxy to represent all of these sources of support. The literature review in the next section includes a discussion of collaboration, alliances, and innovation within the biopharmaceutical industry, strategies for cluster development, knowledge flows, funding sources, and research facilities. The data presented in the Findings section will show that the important characteristics of life science clusters exist and aid in regional economic growth in key metropolitan clusters in both Colorado and North Carolina.

CHAPTER II

REVIEW OF LITERATURE

2.1 Synergies Among Sectors Within the Same Industry

High-technology related businesses generally locate in a place so they can benefit from the synergies created through human interaction and easy access to a university's researchers, students, facilities, programs, and equipment (Rosenblum 2004). Core high technology areas are characterised by a synergistic combination of growth in employment, product and process innovation, and high rates of local business formation, all operating to obtain high levels of agglomerative advantage (Lyons 1995). Firms containing higher levels of R&D are presented with more opportunities for collaboration (Hall and Bagchi-Sen 2007).

Regional hot spots help to create new jobs and business ventures from technological discovery and inventions that are important for an innovation infrastructure. One survey of biotech firms suggests that access to highly-skilled labor is a critical factor for activities that involve R&D (St. John and Pouder 2006). Biopharmaceutical is a field where high-technology professional employment, ability to license technology, and access to venture capital are important. Low R&D intensity firms place more importance on proximity to major customers because they may be actively involved or interested in new product development. Innovation performance is most often a function of firm-level characteristics wherein technology is integrated throughout the innovation process (Hall and Bagchi-Sen 2007). Firms need carefully planned and executed strategies for research, product development, manufacturing, marketing, and distribution in order to achieve competitive advantage

A firm's commitment to R&D expenditure is critical to innovation performance. The general definition of R&D intensity is the percentage of firm revenues spent on R&D. This is considered an incurred expense so research could sometimes have a negative effect on innovation measurements. R&D productivity is better measured by research-based rather than production-based innovation. Data suggest that high levels of R&D intensity are associated with high levels of domestic patent applications, international patent applications, domestic patent approvals, and international patent approvals (Hall and Bagchi-Sen 2007). In the case of many firms, there could be a significant lag time between investment in research and eventual growth in business performance. High R&D intensity firms place higher levels of importance on access to universities, other biopharmaceutical firms, and firms in related industries.

2.1.1 Collaboration and Alliances

Several important innovation strategies seek to ensure success in biopharmaceutical firms including university alliances, licensing agreements, export-import connections to alliances for R&D, product development, and marketing. The strength of an area's local science base is closely correlated with new firm formation, especially in the therapeutics and diagnostics sectors (Bagchi-Sen 2007). One strategic consideration presented includes increasing the number of university and industry candidates in which firms can associate with investors and collaborators. Another strategy is to license-in technologies from other firms and use their expertise. There are many good reasons for considering inter-firm strategic alliances: accessibility of funds, reduction of risk, quality control in R&D, product development and manufacturing for large scale trials, and getting attention of third party investors. A mutual benefit is apparent, where large firms benefit from alliances with smaller firms and vice versa (Bagchi-Sen 2007). Smaller firms often seek assistance from larger firms for clinical trials, manufacturing, sales, and marketing which help maintain a continuous revenue stream. Over 50% of all respondents in a recent study of life biopharmaceutical firms in the U.S. noted the critical importance of developing alliances with large non-biopharmaceutical companies. Firms with high R&D intensity levels earn over 60% of their revenues from royalty and/or licensing agreements or contracts. The primary focus is on production and commercialization if a firm earns a greater amount of revenue from product sales. Younger firms tend to concentrate resources on research, product development, licensing technology, and collaborating to innovate (Hall and Bagchi-Sen 2007). The Data and Methodology section includes statistics from a survey conducted in North Carolina related to innovation strategies.

2.1.2 Innovation Systems

A regional innovation system (RIS) differs from a cluster in that it can span several different sectors and clusters rather than being composed of a concentration of organizations within the same or similar industrial sector. A sectoral innovation system (SIS) focuses more on the impact of specific knowledge bases and innovation processes and is defined as a group of firms working to develop and make a sector's product and utilize its technologies. They tend to be more concerned with the impact of different technological regimes on innovation processes than an RIS would be (Coenen, et al. 2006). A regional perspective is important for analyzing innovation interaction and inter-organizational learning processes because it emphasizes the importance of personal relationships and networks for economic activities. This research defines regions as proximate, inter-related combinations of cities which encompass urban areas.

A decline in the R&D power of large corporations is occurring along with the increase of specialist research firms (Cooke 2004). Many government agencies are interested in developing policies to network regional innovation systems. The mode of knowledge production shifted because of the rise in research. Many dedicated biotechnology firms (DBFs) are initiating leading-edge research in clusters where large pharmaceutical firms are linked to research institutes and other DBFs. Many DBFs are heavily involved in knowledge generation but still need large pharmaceutical firms to assist in funding. Research DBFs are able to bring together skilled researchers and technologists to target specific areas (Cooke 2004). Several large companies developed and released drugs due to research conducted by university and private research scientists (i.e. Novartis, and Glivec). Knowledge production is strongly regionalized in many clusters because of the importance of university and research institute laboratories to clusters of DBFs and the support of venture capitalists and other business services.

2.2 Proximate Places

Several studies found that companies with similar interests and business like to cluster in close proximity. Industry clusters are part of a popular development practice useful for policy-makers, community leaders, and everyday citizens to better understand regional economies. Regional clusters may form because of trading relationships and/or to share markets and knowledge resources (Feser and Luger 2003). Clusters can have a significant, positive impact on the regional economies in which they reside. The Milken Institute defines an industry cluster as "a geographic concentration of sometimes competing, sometimes collaborating firms, and their related supplier network" (DeVol et al. 1994: 1). Interrelated life science industries generate wealth within a regional economy. Important factors in the development of life science clusters include proximity to research institutions, a supportive entrepreneurial culture, risk financing, and the availability of real estate (Walcott 2002). Competitive advantage is maintained when companies cooperate in a shared place. Government officials advertise a variety of regional features that may be appealing to high technology firms, including research universities, generous financial institutions, and political support.

On the global scale, "places of high skill, high wage labor such as involved in research and development activities will attract businesses in the most developed countries, while lower paying and less skill-demanding jobs will cluster in less developed countries" (Walcott 2001). This is known as the new international division of labor which plays a large role in the location of biotechnology activities. Walcott (2001) used core (United States) and semi-periphery (China) areas to categorize R&D and manufacturing sites of high tech activities. R&D occurs in core regions and while manufacturing and product packaging, processing, and handling occur in the semi-periphery. Regional and urban land planners are increasingly looking toward the biotechnology industry for long term economic growth opportunities. Knowledge flows through professional associations and informal relationships between individuals can result in knowledge spillovers being created within a cluster (Phene and Tallman 2002). The Marshall-Arrow-Romer (MAR) externality predicts that industries cluster geographically to absorb knowledge that spills over from other firms. Part of the prediction is that the industry grows faster because neighboring firms learn from each other. The data and analysis presented in this research demonstrate the existence of clusters within these sectors in the Colorado and North Carolina study areas. This demonstrates the benefits of life science industry cluster formation within regions.

2.2.1 Spatial Concentrations: Cluster Development Strategy

Almost every state has a cluster development strategy as part of its economic development plan. The Brookings Institute reported in 2002 that 41 communities were pursuing a life science cluster strategy even though 75% of the largest biopharmaceutical firms are located in only nine regions of the United States (St.John and Pouder 2006). Firms within certain sectors of the life science industry are often very successful when spatially concentrated. A firms' specific industry classification affects what type of interactions are created within clusters. Biopharmaceutical industry clusters are characterized by an analytical and science-based knowledge base related to natural sciences like biology, chemistry, and medicine (Coenen et al. 2006). The agro – food industry is more synthetic and engineering-based involving food technology, agriculture, and basic knowledge transfer between agro-food companies and large public research institutes. The pharmaceutical sector is the largest niche in terms of amount of sales, accounting for over 70% of all sales in life sciences. The biopharmaceutical industry is based on R&D trade among universities, research institutes, pharmaceutical companies, and small life science firms.

Biopharmaceutical businesses in the United States thrive in geographic clusters, attracting capital investment and facilitating technology transfer. Highly skilled labor tends to be more concentrated in some MAs than others. A major factor in the development of a cluster is a nearby research university, which is necessary because of the need to remain competitive and have access to the latest technological innovations in this knowledge-based industry (Walcott 2002). Life science firms tend to concentrate geographically around research universities and health centers. Marshall developed the notion of "industrial districts" as aggolmerations of firms operating in one industry sector in a well-defined and relatively small geographic area (St. John and Pouder 2006). Other innovative models include innovative milieus and technology districts. Cluster formation and evolultion could be the result of various factors including start-up firms evolving or just proximity to a large customer base or market.

Some of the numerous advantages of firms in clusters include cost savings, increased market power, availability of specialized labor facilities, sharing of information, proximity to suppliers or markets, learning, innovation, and increased specialization (Feser and Luger 2003). Clusters have been used by policy-makers, community leaders, and citizens to understand the complexity of regional economies. Biotechnology is considered a "hot cluster" along with the fields of bioinformatics and information technology. Policy-makers are generally more interested in emerging and potential high-tech clusters because they provide good jobs and are beneficial for regional economic analysis. Although cluster studies are useful, they must have clearly laid-out goals, objectives, defenitions, indicators, weghts, data sources, and models. Biases should also be discussed up front (Feser and Luger 2003). These types of analyses can help with disagreements between local officials and the public regarding a region's future and economic prospects. Successful development of a high-technology cluster depends on several factors such as a strong scientific base, government support, a highly educated workforce, and a good quality of life, just to name a few. This study examines whether these factors exist in the metropolitan areas of the Triad/Triangle, NC and Denver/Boulder, CO.

2.2.2 Knowledge Flows

R&D spillovers have a significant effect on high technology employment. Communication can be improved with an increase in informal relationships and more frequent face to face contact. A concentration of an industry in a city can result in knowledge spillovers between firms and a growth of the industry (Acs, FitzRoy, and Smith 2002). Knowledge spillovers are 'knowledge externalities bounded in space', which allows companies located nearby important knowledge sources to introduce innovations at a faster rate than rival firms located elsewhere. Firms may seek external knowledge indirectly and informally by localized knowledge spilling across organizational boundaries (Breschi and Lisson 2001).

Location is key in increasing exposure to potential knowledge spillovers. Location decisions often made by firms to maximize the effect of knowledge spillovers and to enhance their competitive position (Alcacer and Chung 2007). Many firms strategically choose locations in order to more easily gain knowledge from others but also to reduce leakage of their own knowledge. Generally, public sources like academia and government provide basic knowledge while private industry sources provide less basic, more appropriable knowledge. Firms can serve as potential knowledge sources while also receiving knowledge spillovers. Some locations have greater amounts of knowledge-generating activity than others. Localized spillovers from academic institutions impact the birth of biopharmaceutical companies in the United States (Zucker et al. 1988).

2.3 Building a Regional Economic Growth Engine

Employment in biopharmaceutical is expected to grow faster than employment in the rest of the economy through at least 2012, according to the Bureau of Labor Statistics. Some regions are "hubs for organizational creation" due to a diversity of organizations, a well-established knowledge base (university system), law firms specializing in intellectual property, public research institutes, consultants, and venture capitalists (Powell, Koput and Smith-Doerr 2002). Private sector investment in product development is a critical factor in the development of firms within the biopharmaceutical industry. Recently, public and private investment surged in bio-related firms. Firms spend large amounts of money on R&D for many years, thus usually operating at a loss. They generally have low odds of success and developing regulatory approval for commercial products takes a long time. Drugs require Federal Drug Administration (FDA) approval, which requires a great deal of time and money. Venture capitalists and other investors often seek to recoup their investment by having the firm issue stock in an "initial public offering" (IPO) once promising products are developed (Cortwright and Mayer 2002). Other sources of funding include R&D contracts and funding arrangements with pharmaceutical companies.

Biopharmaceuticals is a field where firms are dependent on venture financing. A large percentage of firms receive such funding from local sources. Monitoring, advising, and managing are easier if the young firm is located nearby (Powell, Koput and Smith-Doerr 2002). Venture capitalists may play a different role in an early-stage company versus one that has already undergone its first round of financing. Companies that sought only non-local finance were, on average, larger, older, and had more collaborations with diverse types of organizations. Findings also concluded that firms at the pre-initial public offering (IPO) stage with only local backing were the smallest in terms of number of employees but had the largest percentage of staff with PhDs and/or MDs. Locally–backed firms are generally stronger scientifically suggesting a strong research base. Older, more experienced venture capital firms located in technology-rich areas can be more flexible in where they invest. As they become more established and mature, they are more willing to work with high-risk local start-ups (Powell, Koput and Smith-Doerr 2002).

2.3.1 Funding

The founding of new biopharmaceutical firms in the 1970s and 1980s occurred in areas with high "intellectual capital" (Powell, Koput and Smith-Doerr 2002). "Star scientists" who had direct roles as founders and advisors resulted in closer links being established. A major source of funding for small biopharmaceutical firms is a R&D contract or equity funding arrangement with a major company. The dollar amount of research agreements has increased from $846 million prior to 1990 to $5.2 billion since 1996. As stated by Cortwright and Mayer (2002: 23) "The flow of research contracts from pharmaceutical funds to biotechnology firms is a strong indicator of the location of commercially promising research activities" .

The availability of capital is a major factor in the development of firms within the biopharmaceutical industry. Start-up firms depend heavily on venture capital investment for initial costs and organized venture capital is the most important source of start-up capital. An example of this is a private investment made by a professional fund manager. Venture capitalists may invest in several biopharmaceutical firms while firms may obtain funding from several venture sources. Venture capital firms and capitalists themselves tend to be highly concetrated regionally. These investments are needed to sustain biopharmaceutical firms from inception through years of research and product development. Technology-based startups with a high potential for growth are more likely to be sought after by venture capital firms. In the case of biopharmaceutical, venture capitalists may play more of a role in a financed company possiby even helping run the company. This is another reason for clustering and close proximity. The Colorado and North Carolina sections of the literature review describe sources of funding for start-up businesses and several initiatives taking place in both states to assist in growth of the industry.

2.3.2 Research and Educational Facilities

The life science sector of the economy is very research-oriented and innovative. Examining the location of research institutions and universities is the first step in understanding the geography of biotechnology (Cortwright and Mayer 2002). Levels of commitment to R&D vary among individual firms. State governments tend to invest funds in developing biopharmaceutical around public research universities. There is difficulty in the long-term survival of small firms without strong relationships with universities or other large biopharmaceutical (pharmaceutical and other) companies. Universities are generally good sources of knowledge, funds, and credibility of a firm's reputation. Most large public and private universities have invested in technology transfer in the biomedical sciences industry (Bagchi-Sen 2007). Universities are used for assisting in advancing research-based innovation and are important in terms of technology resources and access to physical resources. Detailed information on the life science fields of study offered at the various research institutions within Colorado and North Carolina are described in this study.

Research parks normally utilize a partnership of government, academia, and industry and consist of master planned land and buildings which are designed for public and private research (Rosenblum 2004). A variety of activities are able to take place simultaneously including applied research, technology transfer and corporate research and development. Space is provided for start-up firms to become established businesses and some parks provide incubator facilities.

University technology transfer programs are found to be a good source of business startups and an interface between academic research and industry. Regional and state governments view research parks as great economic development tools. Universities generally seek business opportunities for students, training, and increased technology transfer while private industry attempts to develop clusters of like-mined businesses.

CHAPTER III

RESEARCH DESIGN

This research will demonstrate the economic strength of the life science industry in the selected metropolitan regions in Colorado and North Carolina. It will also show the different specializations existent in each proximate place, and location factors of individual firms. The important factors of proximity, commuting ties, industry clusters, and funding will be examined by utilizing data from various sources. Research funding and grant statistics are obtained from the National Institute of Health (NIH) to show the amount received by the top universities within the study areas. Commuting pattern statistics are obtained from the U.S. Census Bureau, Census Transportation Planning Package (CTPP) to demonstrate the amount of workers traveling daily between the selected MSAs and CSAs. This will emphasize the importance of geographic proximity in maintaining a region's economic strength. Industry clusters are determined by computing the number of employees from the Bureau of Labor Statistics (BLS) and ReferenceUSA Company database to visualize total number of employees and employment concentration within select industry classifications.

The nature of the industrial employment clusters and location of research-intensive universities will prove that the key proximate metropolitan areas are complementary regions. The analysis presented will show how proximate places are able to benefit from each other and work together in building a strong regional economy. It contributes to the idea that the biopharmaceutical industry is highly sought after as a tool for regional economic strength and has the ability to unify metropolitan regions.

3.1 Study Area

Colorado and North Carolina contain metropolitan regions in which spatial concentrations of sectors within the biopharmaceutical industry thrive. Life science sector firms are very profitable and have a beneficial impact on the regions in which they are located. This research asserts that metropolitan areas within close proximity of each other are able to share the benefits of economic development within this sector. Both states contain two proximate, complimentary regions which share benefits of interactions within the life science sector. Remember that a region is defined here as an MSA or CSA. In Colorado, the proximate MSAs of Boulder and Denver are examined. The Greeley MSA will also be included since it is part of the same CSA. The North Carolina study area is different from Colorado in that two proximate CSAs are examined: Greensboro – Winston-Salem – High Point (referred to as the Triad), and Raleigh – Durham – Cary (referred to as the Triangle). The Colorado study area is shown in Figure 3.1 and North Carolina's in Figure 3.2. Compiled data include research grant funding, commuting patterns within each region, total available employment figures, and opinions expressed through individual company surveys.

Figure 3.1

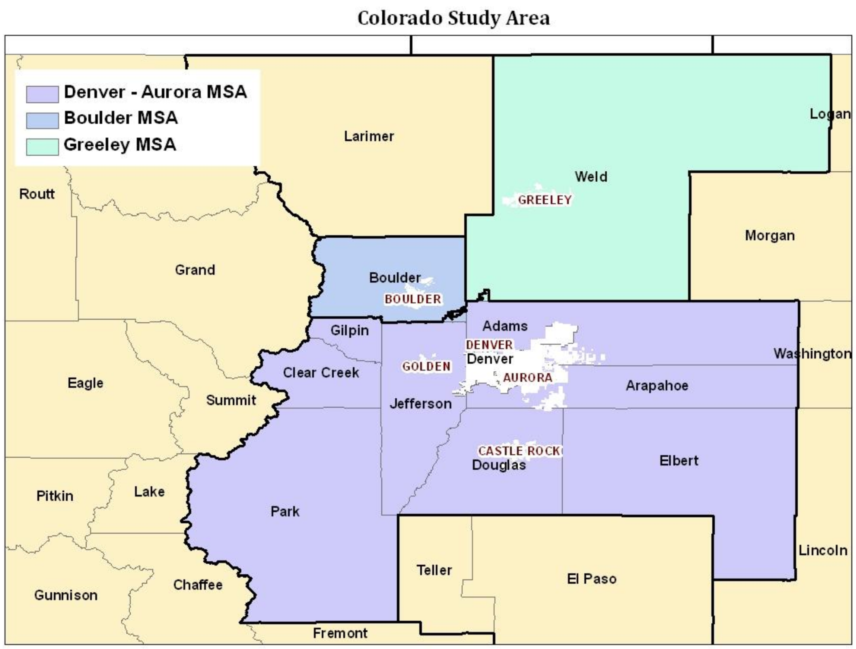
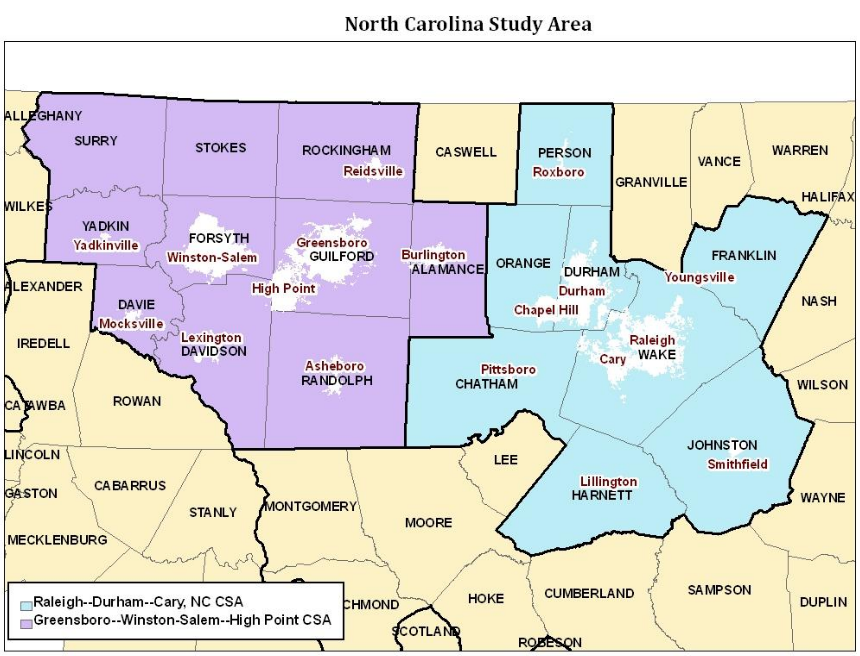


Figure 3.2



These study regions were chosen because of their high ranking in terms of life science employment. The Brookings Institution classifies the Raleigh – Durham – Chapel Hill MSA as a biotechnology center, meaning it has an above average level of research activity and commercialization. The Denver – Boulder – Greeley and Greensboro – Winston-Salem – High Point MSAs are classified as median metropolitan areas (Cortwright and Mayer 2002). This study used 1997 MSA definitions. According to 2003 BLS data, the Boulder MSA ranked number one in terms of its location quotient (LQ) statistic which measures employment concentration within the research and development and pharmaceutical and medicine manufacturing sectors. The Raleigh – Durham – Chapel Hill MSA ranked 3rd, Denver - Aurora 27th, and Greensboro – Winston-Salem, High Point 34th (Debbage and Nuyda 2005). These are based on a study of 40 MSAs using 1999 definitions. Each study region contains one highly ranked region adjacent to one which is ranked lower, in terms of life science employment. It is believed that metropolitan areas within close proximity of each other are able to share the benefits of economic development within a particular economic sector.

3.2 Research Facilities and Funding

The largest single source of funding for research and training related to medicine, health, and biopharmaceutical is the National Institute of Health (NIH). To demonstrate the strength of the life science research base in the study areas, the amount of research grant funding and the national ranking of the major universities are presented in the Analysis section. NIH data were obtained from the U.S. Department of Health and Human Services, Office of Extramural Research. General information on academic programs related to life sciences is also presented, along with maps showing university locations.

3.3 Commuting Between Proximate Places

Commuting pattern statistics were compiled from the Journey to Work and Place of Work section of the U.S. Census Bureau Transportation Planning Package. Although the data represent all workers, not just life science employees, the statistics show the amount of commuting taking place between the MAs and CSAs to demonstrate the general traits of a regional growth engine and the connection between proximate places. Even though CSAs are defined by the U.S. Census Bureau as an aggregate of adjacent MSAs that are linked by commuting ties, it is beneficial to look at commuting statistics, especially noting the amount of commuting taking place between the selected proximate regions (U.S. Census Bureau 2008). Data were collected as "Residence to Workplace", showing the number of daily commuters from one county to another. This was done for each county to each other county in the study regions. The total number of daily commuters between the proximate MSAs and CSAs was then calculated.

3.4 Life Science Sectors and Employment

The North American Industry Classification System (NAICS) is defined by the Office of Management and Budget of the federal government and classifies industry nationwide (Cortwright and Mayer 2002). According to the Brookings Institution (2002), most life science firms fall into either of two industry categories: 54171 – Research and Development in Physical, Engineering, and Life Sciences or 32541 – Pharmaceutical and Medicine Manufacturing, but there is no one generally accepted definition of biotechnology (Debbage and Nuyda 2005). This report will define the life science sector by the following nine NAICS codes as defined by the Census, to cover the broad range of related activities that take place within the sector:

a) 325411: Medicinal and Botanical Manufacturing
b) 325412: Pharmaceutical Preparation Manufacturing
c) 325413: In-Vitro Diagnostic Substance Manufacturing
d) 325414: Biological Product (except Diagnostic) Manufacturing
e) 334510: Electro medical and Electrotherapeutic Apparatus Manufacturing
f) 334517: Irradiation Apparatus Manufacturing
g) 339111: Laboratory Apparatus and Furniture Manufacturing
h) 339112: Surgical and Medical Instrument Manufacturing
i) 541710: Research and Development in Physical, Engineering, and Life Sciences

These codes encompass a variety of life science drug and pharmaceuticals and manufacturing activities that take place along with research and development. Batelle (2006) includes these NAICS codes in his analysis. Since defining life sciences is difficult, he identified four major subsectors: Agricultural Feedstock and Chemicals, Drugs and Pharmaceuticals, Medical Devices and Equipment, and Research, Testing, and Medical Laboratories. This study will not include analysis of Agricultural Feedstock and Chemicals. The nine codes chosen here fall into one of the latter three categories. The selected study regions in both Colorado and North Carolina contain a great number of firms within these categories.

Employment data were compiled from the U.S. Department of Labor – Bureau of Labor Statistics (BLS) and the ReferenceUSA business database for the years 2006 and 2007. The BLS proved useful for total number of employees for the study areas. This statistic was used in the equation for location quotients (LQ), described later in this section. Total employment within each sector was calculated using the available individual company information downloaded from the ReferenceUSA database. An identification and password is required and was accessed through the University of North Carolina – Greensboro online library system. Data provided through the database is updated monthly. This research utilized August 2007 data. The selection criteria used was NAICS code within the counties located within the specified MSAs. Data were downloaded from two business databases: U.S. Businesses, and Corp Tech. The U.S. Business database includes a broad range of sectors of employment while the Corp Tech database lists companies specializing in biopharmaceutical, computer hardware/software, and pharmaceuticals. One important difference between the two databases is that the U.S. Business database provides latitude and longitude information while the Corp Tech database does not provide this information.

The Analysis section of this research will show maps of company locations by NAICS code, using the U.S. Business list, while the Corp Tech companies are in a list. Available data includes the total number of employees and NAICS code for each company listed. Companies within the selected life science NAICS codes were selected and grouped for analysis, although data were not available for a small number of the companies. This data provides evidence of different patterns of industrial concentrations.

The employment statistics, along with calculated LQs for each county within the study areas, provide evidence of the different specializations prominent in the different MSAs. LQs are beneficial for visualizing the location of labor markets by county or region with a higher or lower proportion of their employment base in life sciences relative to a national norm (Debbage and Nuyda 2005). The equation is a ratio defined as:

$$\frac{\text{(County/Regional Biotech Employment/U.S. Biotech Employment)}}{\text{(County/Regional Total Employment/U.S. Total Employment)}}$$

A LQ greater than one indicates an area with a higher percentage of biotech employment than the percentage of total jobs relative to a national share while an LQ less than one indicates a lower percentage.

3.5 Company Surveys

Surveys were mailed to life science companies within the North Carolina study regions to gain a better understanding of local and nonlocal connections of companies and location factors that increase competitiveness. The survey was created by Dr. Susan Walcott and Dr. Sharmistha Bagchi-Sen for another life science related study for companies in New York and North Carolina. The companies chosen to answer surveys were based on the North Carolina list of 414 obtained from the ReferenceUSA database. The first section of the survey contained questions related to company background. The respondents were asked to choose from *Diagnostic*, *Therapeutic*, *Agri-Bio*, *Environment*, or *Other* as the firm's main area of business. Other background information obtained includes whether the company is a subsidiary of a larger firm or a university spin off, public or private, year established, total revenue, percent of revenue assigned to R&D, and how much exporting is taking place. The second section of the survey pertains to location factors. Respondents were asked top reasons for choosing their location, the most important forms of local/state government assistance received, and status of labor supply in the location. The third section presents questions related to collaborative efforts. They were used to determine how much R & D activity is performed in-house and where, if any, university and industry collaborators are located. The next section of questions helped gather information related to where, if any, company manufacturing activities take place. The last section of the survey deals with innovation. Respondents were asked to rank the importance of various innovation strategies. The survey is presented in Appendix A.

CHAPTER IV

FINDINGS

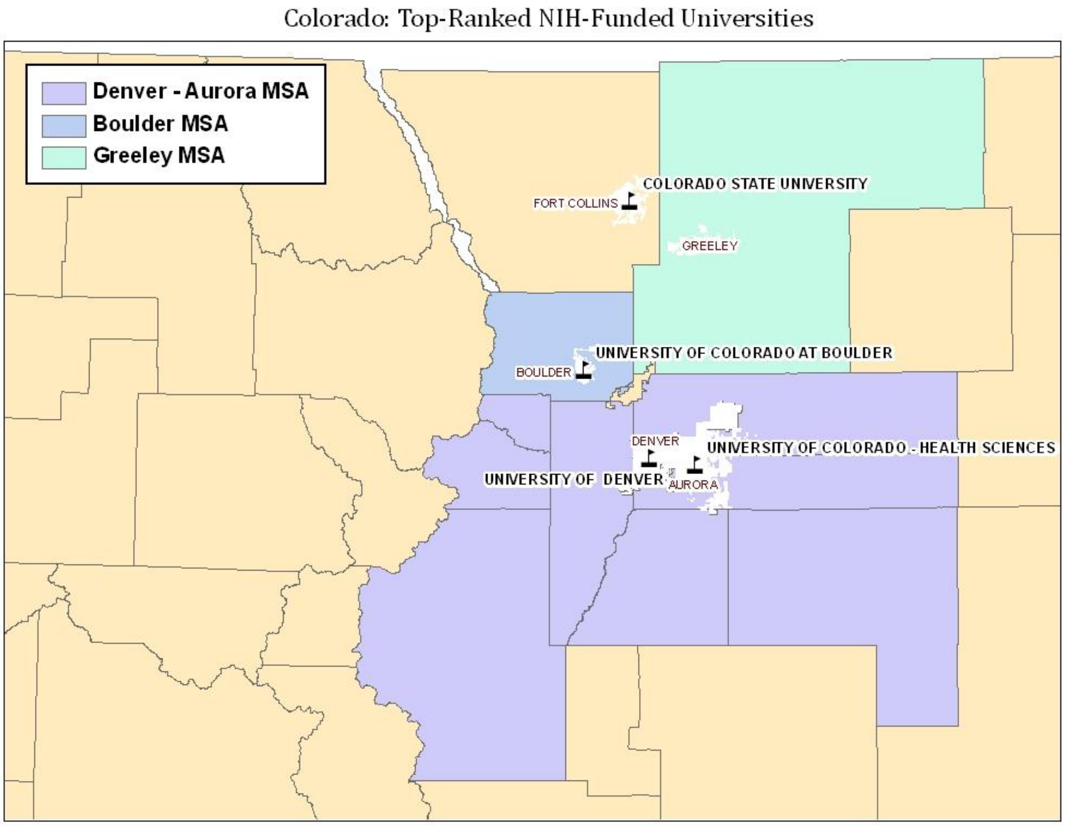
4.1 Education and Research

This section will demonstrate the strength of the research base in Colorado and North Carolina, contributing to the first thesis hypothesis that synergies among sectors within the life science industry exist between proximate places to build a regional economic growth engine. Since the life science sector of the economy is very research-oriented and innovative, examining the location of research institutions and universities is the first step in understanding the geography of biopharmaceuticals. The quality of medical research and education available affects economic development of the life science industry (Cortwright and Mayer 2002). Universities are generally good sources of knowledge, funds, and credibility of a firm’s reputation. This section of the findings will provide a general description of the universities in the study areas and how much NIH funding is made available.

4.1.1 Colorado Universities and Research Facilities

The Denver/Boulder area is a ‘stand-alone’ profit center with product related R & D activities employing skilled and semi-skilled workers (Lyons 1995). The National Science Foundation reported 52 life science PhDs issued in 1999 by universities in the Denver-Boulder-Greeley Metropolitan Statistical Area (MSA). Colorado maintains a healthy link between academia and the private sector. The University of Colorado system contains substantial research centers which support the life science industry. The Colorado Alliance for Bioengineering is responsible for the coordination of biopharmaceutical activities among faculty in all universities throughout the state (Colorado Bioscience Association). The University of Colorado at Denver and Health Services Center offer a Ph.D in Health and Behavioral Sciences, an M.S. in Health Administration, an M.S. in Biology, and in Chemistry. The University of Denver offers an M.S. and Ph.D in Biological Sciences and PhDs in Biochemistry and Chemistry. The University of Colorado at Boulder offers several PhDs including Biological Sciences (Ecology, Evolutionary, Molecular, Cellular, and Developmental), Chemical and Biological Engineering, and Biochemistry. Other advanced degrees in Environmental Engineering and Neuroscience are also available. Bio-technician training is offered at the Community College of Aurora where students can emphasize in R&D or biotechnology manufacturing. The Institute for Bio-Energetics was created by the University of Colorado – Colorado Springs to study cellular metabolism and communication to help treat and/or cure serious diseases. Figure 4.1 shows the Colorado universities which ranked highly in research grant funding received from the NIH.

Figure 4.1



4.1.2 North Carolina Universities and Research Facilities

4.1.2a Triad

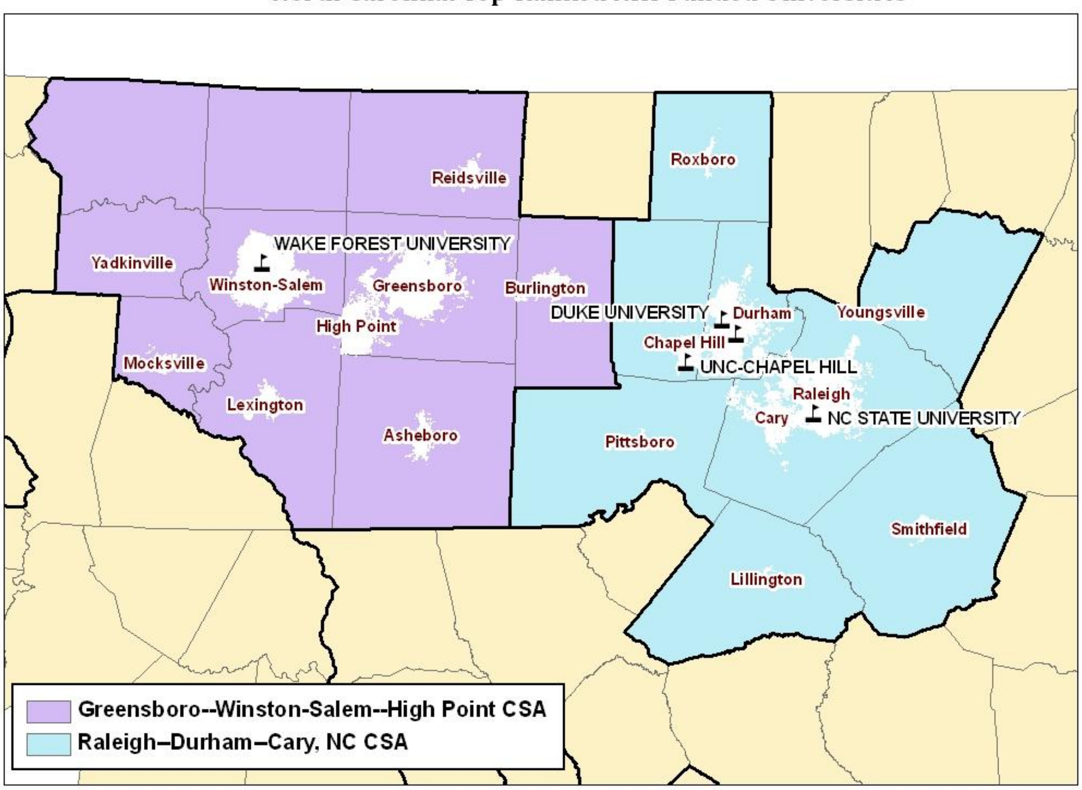
The Triad region includes the cities of Greensboro, Winston-Salem, and High Point and is home to several research institutions offering degrees related to life sciences. UNC-Greensboro offers M.S. degrees in Chemistry and Biochemistry Information, Genetic Counseling, and Biology. Ph.D degrees are available in Nutrition and Public Health. NC A&T State University offers an M.S. degree in Biology, a Ph.D in Energy and Environmental Studies, and an undergraduate degree in Chemistry. Both of these universities are in the process of developing a joint graduate program in nanoscience and nanoengineering to be housed at the new Nanotechnology School and Gateway University Research Park. The Joint School of Nanoscience and Nanoengineering (JSNN) will enroll Masters and Doctorate students focusing in nanotechnology research. High Point University offers undergraduate degrees in biology, chemistry, and medical technology. Another major Triad university is Wake Forest (and the Bowman Gray School of Medicine) located in Winston-Salem. Along with advanced degrees in the field of medicine, they offer PhD's in Biochemistry, Structural Biology, Biomedical Engineering, Cancer Biology, Chemistry, Neuroscience, Physiology, and Pharmacology. Wake Forest is also home to various health science departments, the Institute for Regenerative Medicine, and the Center for Nanotechnology and Molecular Materials.

4.1.2b Triangle

The Triangle region includes the cities of Raleigh, Durham, Chapel Hill, and Cary. Universities in this region have a great deal to offer in terms of advanced degrees in medicine and life science-related fields of study. NC State University in Raleigh offers several degrees and certificates directly related to life sciences. These include minor studies in Biotechnology and Life Science Ethics, Masters degrees in Microbial Biotechnology and Comparative Biomedical Sciences, and a Ph.D degree in Biomedical Engineering. Others include PhD's in Biochemistry, Bioinformatics, Microbiology, and Biological and Agricultural Engineering. UNC-Chapel Hill is home to one of the Triangle's medical schools. Some of the advanced degrees are Biochemistry and Biophysics, Biological and Biomedical Sciences, Cell and Developmental Biology, Neurobiology, and Pharmaceutical Sciences. Duke University in Durham houses the other medical school in the Triangle. It offers certificates in Biomolecular and Tissue Engineering and Nanoscience, along with Ph.D. degrees in branches of Biology and Chemistry. Figure 4.2 shows the North Carolina universities which ranked highly in grant funding from the NIH. A higher education bond approved in North Carolina in the year 2000 included bioscience research buildings like the College of Veterinary Research Building on NC State's Centennial Biomedical Campus. Bond funding has also been approved for a new research and clinical facility at the UNC Chapel Hill Cancer Center budgeted at $180 million (Batelle 2006). The Centennial Campus of NC State is being developed as a dual-use research park including university resources in genomics and bio-informatics.

Figure 4.2

North Carolina: Top-Ranked NIH-Funded Universities



4.1.3 Research Funding

In 2000, NIH disbursed a total of $13.3 billion for research activities. The Denver-Boulder-Greeley MSA was allocated $208,884,942, a 1.8% share of the total funding to the top 100 cities. The share of NIH research funding for medical schools and research institutions increased by 0.5% between 1985 and 2000 – from $29,698,000 to $134,378,000 (more than quadrupled). This type of funding comprises the largest share of NIH funding. Total federal research funding for medical schools in all the metropolitan areas more than tripled in 15 years from $2.4 billion in 1985 to $7.6 billion in 2000 (Cortwright and Mayer 2002). Research institutions provide highly trained and skilled scientists, many of which are financed by NIH grant funding. Several institutions within the Colorado and North Carolina study areas ranked highly in the amount of funding awarded. For the fiscal year 2005, 3419 institutions received awards. Table 4.1 provides a listing of the major universities with their respective rankings, number of awards and amounts from the top 500 list.

Table 4.1 Top-ranked NIH-funded Universities within the Colorado and North Carolina Study Areas

		All Awards	
National Rank	**Organization**	**Number**	**Amount**
6	DUKE UNIVERSITY (NC)	795	$391,196,272
16	UNIVERSITY OF NORTH CAROLINA CHAPEL HILL (NC)	782	$296,566,365
30	UNIVERSITY OF COLORADO DENVER/HSC AURORA (CO)	466	$181,939,144
51	WAKE FOREST UNIVERSITY (NC)	271	$125,545,373
97	COLORADO STATE UNIVERSITY-FORT COLLINS (CO)	118	$53,307,839
116	UNIVERSITY OF COLORADO AT BOULDER (CO)	167	$41,539,275
210	NORTH CAROLINA STATE UNIVERSITY RALEIGH (NC)	65	$16,341,526
392	NORTH CAROLINA CENTRAL UNIVERSITY (NC)	14	$5,121,112
451	UNIVERSITY OF DENVER (CO)	19	$3,914,976

Source: U.S. Department of Health and Human Services, Office of Extramural Research – NIH

Among these universities, the total amount of funding for North Carolina universities is $834,770,648 while those in Colorado received a total of $280,701,234. Duke in Durham, NC, ranked sixth, is the highest ranking among the universities in both study areas. This is followed by UNC-Chapel Hill (16th) and UC-Denver (30th). The University of Denver ranked 451st, receiving the lowest amount among those on this list. Nearly each major city within the study clusters houses a major university ranked highly in NIH funding. In Colorado, a university from the list is located in Denver, Aurora, Boulder, and Fort Collins. In North Carolina, they are located in the Triad city of Winston-Salem and the Triangle cities of Raleigh, Durham (two universities), and Chapel Hill. The locations of these universities and the high amount of health-related research funding provide evidence of the strength of research activities within the study regions.

4.2 Business and Technological Development

4.2.1 Colorado

Four bills introduced in the 2006 legislative session would benefit Colorado's bioscience industry. The Bioscience Net Operating Loss Bill gives permission to the Colorado Economic Development Commission to purchase the right to gain a future tax benefit from net operating losses from bioscience companies. It establishes criteria for a company to be able to sell the future tax benefit to the commission. A second bill concerns the advancement of new bioscience discoveries at Colorado research institutions. It provides for matching funds to support the development of life science technologies come from new discoveries within institutions. A third bill subsidizes the indirect cost portion of contract for core laboratory services at research institutions by Colorado bioscience companies. Companies would gain incentives to contract for services with research institutions and the research institutions would likewise be provided incentives to provide business-friendly services. The fourth piece of legislation would provide a performance-based incentive to employers who create a certain number of new full-time jobs. The Office of Economic Development and International Trade works with Colorado businesses, associations, and universities to encourage growth and development of life science companies. The Advance Colorado Center (ACC) provides a common headquarters and support for non-profit organizations. The organizations, in turn, provide a variety of services and programs to companies and entrepreneurs to enhance job growth. The ACC is a partnership between the Colorado Economic Development Commission, the Office of Economic Development and International Trade, and the University of Colorado at Denver Health Sciences Center (Batelle 2006).

An Action Plan to Grow Colorado's Bioscience Cluster was developed in 2003 by the Colorado Office of Innovation and Technology, industry, university, and government representatives. The idea behind the plan is that the state nurture local businesses and focus heavily on excelling in bioscience research. The Action Plan is updated yearly and has resulted in a great deal of concentration in the northern part of the state. The medical campus at Fitzsimons is home to many relocated facilities including the University of Colorado Health Science Center (UCHSC), the University of Colorado Hospital (UCH), and the Children's Hospital. Approximately $53 million has been appropriated by Congress for the relocation of Denver's Veterans Affairs Hospital. The initial phase of the full campus move is estimated to cost $1.3 billion. The new location will increase from 2.7 million square feet on 46 acres to 3.4 million square feet on 210 acres at the new location. Another 1.5 million square feet for research activities is planned after the initial phase. A total capital investment of around $4 billion will be required to complete the entire Fitzsimons building program. Other projects that have been completed since 2004 or are under construction include two research complexes, Barbara Davis Center for Childhood Diabetes, Denison Library, 3 education facilities, an academic office, and a common area including a residential and commercial complex (Batelle 2006).

The U.S. Department of Labor gave the Denver metropolitan region a five - year, $15 million Workforce Innovations in Regional Economic Development (WIRED) grant for workforce development and the biosciences are one of the targeted industries. The Fitzsimons BioBusiness Incubator helps promote the growth and success of the bioscience businesses in Colorado, with an emphasis on forming a cluster at Fitzsimons. Services include business planning, management, intellectual property protection, scientific resources, access to laboratory space, and capital formation (Batelle 2006). The Colorado Economic Development Commission, Aurora Economic Development Council, Fitzsimons Redevelopment Authority, University of Colorado, and the Metro Denver Economic Development Corporation are some of the contributors. The Colorado Venture Capital Authority (VCA) was created in March 2004 because of legislation signed by the Governor. The legislation requires that the funds be used to provide capital in early stages of company development.

The Colorado Bioscience Park Aurora is being developed as a part of the Fitzsimons Redevelopment Project. The park is affiliated with the University of Colorado and is expected to contain 3 million square feet of space and 4000 employees. Research-oriented biomedical, biotechnology, and pharmaceutical facilities will be a large part of the park's development process. The Bioscience Park Center opened in 2000 and currently houses 18 bioscience companies taking advantage of specialized equipment and facilities (Batelle 2006). Denver Bioscience Center at Stapleton is under development at the former Stapleton Airport and will consist of a 200-acre biomanufacturing park. It will provide space for small spin-offs to expand their manufacturing operations and is in close proximity to the Colorado Bioscience Park at Fitzsimons.

The Fitzsimons Redevelopment Authority in Aurora is a $ 4.3 billion life sciences complex that has become the focus of the biopharmaceutical industry in the Rocky Mountain region (Krizner 2005). It lies on the site of a former U.S. Army medical base, which has assumed control of 332 acres, while the University of Colorado controls the rest. Currently, 5000 people are employed there, and that is expected to grow to 19,000 by 2010. Funding has been approved by the Colorado state legislature for the university to build a Health Sciences Center on a 217-acre site by 2008. The complex will include the university's education and research buildings and a medical library. One hundred sixty acres is designated as the Colorado Bioscience Park – Aurora which including an incubator. Companies need three qualifications to join the incubator program: 1) research needs to be in life sciences, 2) science has to be peer-reviewed, and 3) there needs to be a compelling reason to be in the incubator program. Officials at Fitzsimons will consider whether a technology has the opportunity to grow a company (Krizner 2005).

According to PriceWaterhouseCoopers Moneytree and IPO.com, 16 venture capital investments were made in the Denver-Boulder-Greeley CMSA between 1995 and 2001, totaling $156,162,000 or a 1.6% share of the total venture capital investments made during this time in the United States. The Commercial Opportunity Fund was created by Colorado State University to support early feasibility studies and analyses of technologies that may emerge from its faculty. The fund's purpose is to provide monetary support to increase the likelihood of commercial success of the technologies. Criteria used by the Colorado State University Research Foundation (CSURF) to grant awards include commercial viability, proximity to completion, market research, and adequacy (Batelle 2006). The Proof of Concept (POC) Fund, created by the University of Colorado, is similar to Commercial Opportunity Fund but uses a competitive application process managed by the Technology Transfer Office. Recombinant Capital is a private analyst of the biopharmaceutical industry and reports the dollar value of R&D. The total value for Denver-Boulder-Greeley between 1990 and 2001 was $169 million which increased from $19 million prior to 1980 to $133 million between 1996 and 2001 (Cortwright and Mayer 2002).

4.2.2 North Carolina

Many regions across America are developing strategies to create and grow clusters of biopharmaceutical companies, and many are cultivating in the Triangle and Piedmont Triad (Batelle 2006). These regions are working to replace jobs in older, declining, and manufacturing industries with life sciences since it is a field that can compete in national and international markets. Clusters and concentrations of businesses are an important requirement for the success of the industry in these two metropolitan areas. Many regional policy-makers invest in R&D infrastructure to help sustain university-industry connections. Alliances and access to knowledge may not necessarily be bound by geography but spatial proximity promotes vital knowledge spillovers. North Carolina experienced a decline in the textile, apparel, furniture, and tobacco industries because the state lacked a strong R&D base. This prompted an effort to shift policy from traditional manufacturing to high-tech businesses. Government leaders and policy-makers believe that the state should nurture the identified existing clusters of high-growth and R&D-intensive activity. Stressing the development of these clusters will help achieve and maintain a competitive advantage (Feser and Luger 2003).

Strategies implemented to expand the industry throughout the state include the *New Jobs Across North Carolina* policy developed in 2004 by the North Carolina Biotechnology Center. The nonprofit Golden LEAF Foundation contributed to the $60 million Biomanufacturing and Pharmaceutical Training Consortium, a network created through NC State University, Central University in Durham, and the NC Community College System. This fund also contributed a great deal to a bioscience venture fund. The Biotechnology Center offers institutional development and multidisciplinary research grants or bioscience research at North Carolina universities. The Center, along with the UNC system, provides a trust fund and other sources for assistance in faculty recruitment. Collaborative funding grants are offered by the Biotechnology Center and the Kenan Institute for Engineering, Technology and Science at NC State to match university and industry contributions to joint research projects (Batelle 2006).

The North Carolina Small Business and Technology Development Center offers grants for universities participating in applied research that are matched by in-state companies. The Council for Entrepreneurial Development is a non-profit organization that mentors and prepares entrepreneurs in the Research Triangle area for raising venture capital. The Biotechnology Center also makes loans to companies for product development, proof-of-concept research and business planning (Batelle 2006). There are several bioscience incubators available in North Carolina including a 14,000-square-foot one at the First Flight Venture Center in RTP, RTP BioVenture Center, and the NC State Technology Incubator. Research Triangle Park (RTP) has grown since its development in the 1950s with the goal of attracting R&D labs in biosciences, including agricultural (Batelle 2006). It now encompasses over 15 million square feet of office space on over 7000 acres. The Piedmont-Triad Research Park in Winston-Salem currently houses 14 bioscience companies and uses resources from Bowman Gray School of Medicine at Wake Forest University.

Parks provide “a nurturing environment in which to work” as a full-fledged stand-alone business (Krizner 2005: 16). The biggest challenge to startup a company is often the transition from the academic world to the business world. Biopharmaceutical economic development projects grew tremendously during the past few years. The industry is constantly finding new products and vaccines while maintaining job growth.

4.3 Commuting Patterns

CSAs are defined by the U.S. Census Bureau as an aggregate of adjacent MSAs that are linked by commuting ties (U.S. Census Bureau 2008). Included in this research are the commuting statistics, especially to note the amount of commuting taking place between the selected proximate regions (MSAs or CSAs). Tables 4.2 and 4.3 show the number of commuters traveling daily between the counties of the Colorado and North Carolina study regions.

Table 4.2 Total Number of Daily Commuters: Colorado Study Area

		DESTINATION COUNTY												
		Boulder MSA	Denver-Aurora MSA										Greeley MSA	
		Boulder	Adams	Arapahoe	Clear Creek	Denver	Douglas	El Paso	Elbert	Gilpin	Jefferson	Park	Weld	Total Out-bound
	Boulder	127,692	6,137	2,496	4	10,783	277	124		59	6,619	11	2,419	28,929
	Adams	17,009	70,244	13,884	27	49,339	2,106	198	49	575	21,028	29	1,917	159,396
ORIGIN	Arapahoe	2,333	13,901	130,435		84,795	12,281	586	100	187	12,240	48	369	254,942
	Clear Creek	47	140	223	2,425	890	39	3		278	1,262	7	2	5,269
COUNTY	Denver	5,395	14,948	47,190	67	176,750	6,107	553	28	605	23,176	62	799	270,285
	Douglas	711	2,111	32,217		20,901	30,157	1,377	293	34	6,589	14	84	93,777
	El Paso	184	493	1,851		2,149	1,155	251,105			484	3	59	257,299
	Elbert	46	347	2,389		1,500	2,180	379	3,006	9	390	2	2	10,204
	Gilpin	690	89	76	25	279	23			1,219	520	3	13	2,247
	Jefferson	12,867	19,496	30,482	448	73,727	5,438	282	10	2,032	137,126	305	743	270,089
	Park	90	220	580	4	805	111	214		15	1,552	2,788		6,289
	Weld	7,771	4,716	991		3,702	209	41			1,336	8	57,777	68,780
Total In-bound		47,143	126,705	260,318	2,996	414,837	59,806	254,738	3,486	4,954	205,703	3,269	61,765	1,398,577

Source: U.S. Census Bureau, Census Transportation Planning Package

Table 4.3 Total Number of Daily Commuters: North Carolina Study Area

		DESTINATION COUNTY																		
		Greensboro -- Winston-Salem -- High Point CSA											Raleigh -- Durham -- Cary CSA							
		Alamance	Davidson	Davie	Forsyth	Franklin	Guilford	Randolph	Rockingham	Stokes	Surry	Yadkin	Chatham	Durham	Harnett	Johnston	Orange	Person	Wake	Total Out-bound
	Alamance	47,734	129	19	418		6,443	301	271				346	2,387	8	60	3,589	58	847	62,610
	Davidson	323	40,621	314	11,062		14,668	2,540	177	63	10	39	2	22			18		45	69,904
	Davie	25	521	7,710	5,242		410	53	28	30	69	327					15		58	14,488
	Chatham	349	21		54	21	589	884	11	6			11,018	2,739	26	71	4,206	8	2,743	22,746
ORIGIN	Durham	385	25		29	211	303	23	20		15		349	84,262		409	9,262	270	13,929	109,492
COUNTY	Forsyth	287	4,136	902	119,233	8	16,515	392	358	1,165	560	663	20	84		15	33	2	262	144,635
	Franklin	25			2		27						47	951	28	282	54	29	10,347	11,792
	Guilford	4,050	2,982	67	7,636	17	187,150	3,984	1,720	68	10	45	192	450		5	362	53	597	209,388
	Harnett	17			21	24	34	24	7				248	547	15,916	1,521	84		8,841	27,284
	Johnston	41	33		77	92	51	11		8			124	1,645	1,399	26,971	246	8	23,628	54,334
	Orange	2,038			83	83	526	47					792	16,470	9	105	35,053	142	4,212	59,560
	Person	312			5	8	76		36				43	3,939		17	671	9,609	614	15,330
	Randolph	578	2,607	11	694		20,278	38,637	143	10	12		832	39		29	55		157	64,082
	Rockingham	503	96	24	870		11,960	73	25,523	511	21			36			17	5	122	39,761
	Stokes	15	252	58	10,259		1,620	20	1,360	6,330	1,167	66					17		54	21,218
	Surry	13	101	73	4,316		500	14	79	512	24,821	1,146		2	11		21	9	89	31,707
	Wake	274	39	23	153	2,430	353	23	10	7	15	60	873	43,351	916	4,050	3,552	166	272,432	328,727
	Yadkin	11	134	541	5,504		323	19	14	72	1,678	7,572							27	15,895
Total In-bound		56,980	51,697	9,742	165,658	2,894	261,826	47,045	29,757	8,782	28,378	9,918	14,886	156,924	18,313	33,535	57,255	10,359	339,004	1,302,953

Source: U.S. Census Bureau, Census Transportation Planning Package

From these figures, the following number of commuters between proximate regions was determined:

Location	Number of Commuters
Boulder MSA to Denver-Aurora MSA	26,386
Boulder MSA to Greeley MSA	2,419
Denver Aurora MSA to Boulder MSA	39,118
Denver-Aurora MSA to Greeley MSA	2,209
Greeley MSA to Boulder MSA	7,771
Greeley MSA to Denver-Aurora MSA	10,962
Greensboro – Winston-Salem – High Point CSA to Raleigh – Durham – Cary CSA	11,052
Raleigh – Durham – Cary CSA to Greensboro – Winston-Salem – High Point CSA	7,177

This data helps demonstrate the interaction between the proximate places in each state and contributes to the hypothesis that synergies exist.

4.4 Employment

Tables 4.4 and 4.5 show the numbers of employees and LQs by NAICS code for the counties in the Colorado and North Carolina study areas. After data were collected from the ReferenceUSA database, very few employees from both study areas were listed for NAICS 334517 (Irradiation Apparatus Manufacturing), so it was left out of the LQ calculation. LQ is used in this analysis as an indicator of the strength of the employment bases of the specified life science sectors. Table 4.4 shows that Boulder County (also its own MSA) has the highest LQ in biological product manufacturing, surgical and medical instrument manufacturing, and research and development. Denver County shows the highest in surgical and medical instrument manufacturing, and the same is true for all the counties combined. Table 4.5 shows that Durham County is similar to Boulder, in that the LQ is high for surgical and medical instrument manufacturing and research and development. Biological product manufacturing returns the highest LQ for all counties in the North Carolina study region. Later in this section, the LQs for all sectors are presented for all MSAs covered in this study (Table 4.8 and 4.9).

Table 4.4 Number of Employees and LQs for Colorado Counties

Colorado Study Area Counties										
Number of Employees and Location Quotients by NAICS Code (According to ReferenceUSA Database)										
	Adams		Arapahoe		Boulder		Denver			
	Employees	LQ	Employees	LQ	Employees	LQ	Employees	LQ		
Medicinal and Botanical Manufacturing (325411)			125	2.78						
Pharmaceutical Preparation Manufacturing (325412)	69	0.31	39	0.09	439	1.94	117	0.17		
In-Vitro Diagnostic Substance Manufacturing (325413)	35	2.22								
Biological Product (except Diagnostic) Manufacturing (325414)	58	2.25			448	17.40				
Electromedical and Electrotherapeutic Apparatus Manufacturing (334510)	6	0.10			14	0.24	31	0.18		
Laboratory Apparatus and Furniture Manufacturing (339111)					18	1.24	20	0.46		
Surgical and Medical Instrument Manufacturing (339112)	319	2.95	1529	7.08	5028	46.50	584	1.80		
Research and Development in Life Sciences (541710)	250	0.47	563	0.53	1147	2.14	825	0.51		
ALL NAICS	737	0.72	2256	1.11	7094	6.97	1577	0.52		
	Douglas		Elbert		Jefferson		Weld		All Counties	
	Employees	LQ	Employees	LQ	Employees	LQ	Employees	LQ	Employees	LQ
Medicinal and Botanical Manufacturing (325411)									125	0.56
Pharmaceutical Preparation Manufacturing (325412)	166	1.23			207	0.46			1037	0.51
In-Vitro Diagnostic Substance Manufacturing (325413)					15	0.48			50	0.32
Biological Product (except Diagnostic) Manufacturing (325414)			2	3.22	7	0.14			515	1.99
Electromedical and Electrotherapeutic Apparatus Manufacturing (334510)					3	0.03			54	0.39
Laboratory Apparatus and Furniture Manufacturing (339111)									38	0.26
Surgical and Medical Instrument Manufacturing (339112)	149	2.30	20	7.67	2771	12.80	19	0.09	10419	12.60
Research and Development in Life Sciences (541710)	114	0.36			840	0.78	67	0.06	3806	0.73
ALL NAICS	429	0.70	22	0.90	3843	1.89	86	0.04	16044	1.92

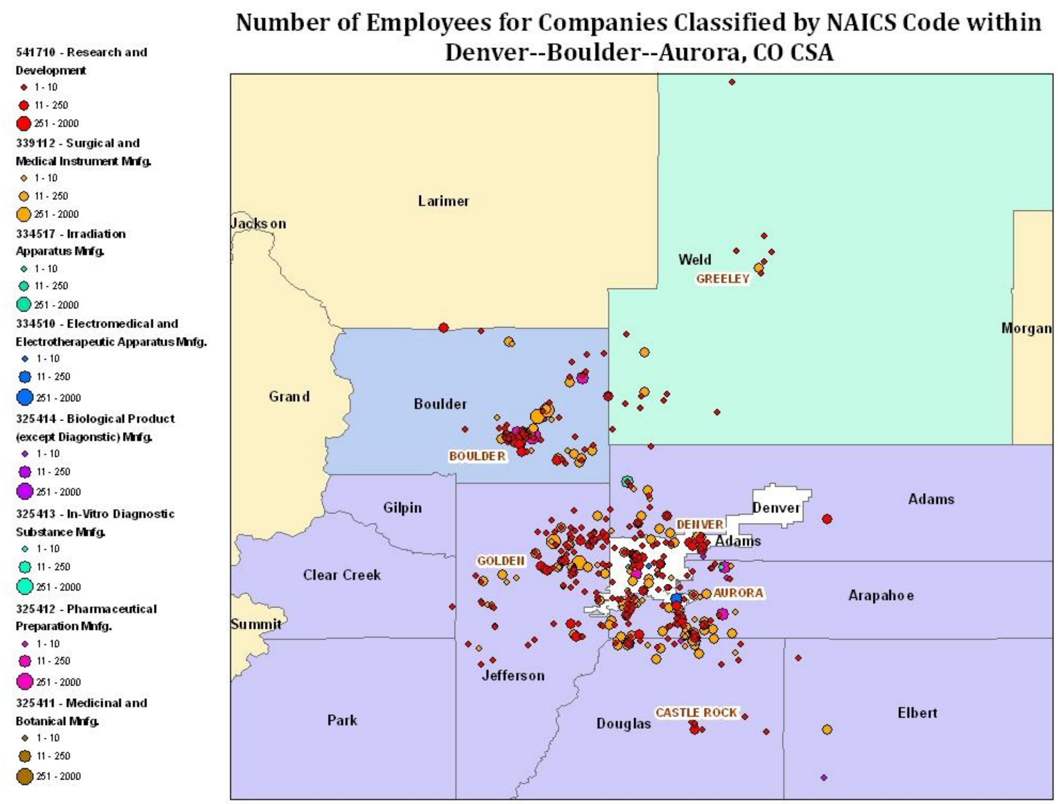
Table 4.5 Number of Employees and LQs for North Carolina Counties

North Carolina Study Area Counties										
Number of Employees and Location Quotients by NAICS Code (According to ReferenceUSA Database)										
	Alamance		Chatham		Davidson		Davie		Durham	
	Employees	LQ	Employees	LQ	Employees	LQ	Employees	LQ	Employees	LQ
Medicinal and Botanical Manufacturing (325411)										
Pharmaceutical Preparation Manufacturing (325412)	2	0.02							929	4.00
In-Vitro Diagnostic Substance Manufacturing (325413)										
Biological Product (except Diagnostic) Manufacturing (325414)	4	0.31	80	30.00					20	0.78
Electromedical and Electrotherapeutic Apparatus Manufacturing (334510)									73	1.24
Laboratory Apparatus and Furniture Manufacturing (339111)										
Surgical and Medical Instrument Manufacturing (339112)	324	5.99			15	0.41	15	1.66	6308	58.30
Research and Development in Life Sciences (541710)	100	0.37	2	0.37					5662	10.50
ALL NAICS	430	0.96	82	1.46	15	0.04	15	0.18	12992	17.30
	Forsyth		Guilford		Harnett		Johnston		Orange	
	Employees	LQ	Employees	LQ	Employees	LQ	Employees	LQ	Employees	LQ
Medicinal and Botanical Manufacturing (325411)										
Pharmaceutical Preparation Manufacturing (325412)	10	0.04	1091	2.42	16	0.43			2	0.03
In-Vitro Diagnostic Substance Manufacturing (325413)										
Biological Product (except Diagnostic) Manufacturing (325414)	3	0.12	1494	29.00			1204	156.00	10	1.30
Electromedical and Electrotherapeutic Apparatus Manufacturing (334510)	511	8.68								
Laboratory Apparatus and Furniture Manufacturing (339111)			200	6.86						
Surgical and Medical Instrument Manufacturing (339112)	191	1.77	202	0.94			40	1.23	174	5.37
Research and Development in Life Sciences (541710)	116	0.22	182	0.17			10	0.00	120	0.75
ALL NAICS	831	0.87	3169	1.56	16	0.09	1254	4.10	306	1.00
	Randolph		Stokes		Wake		Yadkin		All Counties	
	Employees	LQ	Employees	LQ	Employees	LQ	Employees	LQ	Employees	LQ
Medicinal and Botanical Manufacturing (325411)					130	1.93			0	0.58
Pharmaceutical Preparation Manufacturing (325412)					3389	5.00			5439	2.40
In-Vitro Diagnostic Substance Manufacturing (325413)					195	4.13			195	0.00
Biological Product (except Diagnostic) Manufacturing (325414)					44	0.57			2859	11.10
Electromedical and Electrotherapeutic Apparatus Manufacturing (334510)					140	0.79			724	1.23
Laboratory Apparatus and Furniture Manufacturing (339111)					262	5.99			462	3.17
Surgical and Medical Instrument Manufacturing (339112)	240	5.55	8	1.52	1374	4.24	122	14.40	9013	8.19
Research and Development in Life Sciences (541710)					4055	2.52			10247	1.91
ALL NAICS	240	0.59	8	0.16	9589	3.14	122	1.54	28939	2.85

Source: ReferenceUSA Database

Figures 4.3 and 4.4 show the number of employees and locations of individual companies classified by NAICS code. The point features for the companies are displayed in a geographic information system based on coordinates. These maps present the companies obtained from the ReferenceUSA Business database, containing latitude and longitude information. Tables 4.6 and 4.7 list the companies from the ReferenceUSA Corp Tech database, since they contained no latitude and longitude information. The maps and Corp Tech lists begin to show a general pattern of different sectors and employee size of individual companies within the study areas. Figure 4.3 shows larger companies within Surgical and Medical Instrument Manufacturing (NAICS 339112) in all three MSAs with more located in the Denver-Aurora MSA. A dense concentration of R&D (NAICS 541710) companies is found in the Boulder MSA and many in this sector are scattered throughout Denver-Aurora. Figures 4.4 and 4.5 show a similar pattern for North Carolina. Large companies within Surgical and Medical Instrument Manufacturing are found in both CSAs while R&D is concentrated more in the Triangle. The Triangle is also home to several large Pharmaceutical Preparation Manufacturing (NAICS 325412) companies as shown in Figure 4.5.

Figure 4.3



Source: ReferenceUSA Business Database

Figure 4.4

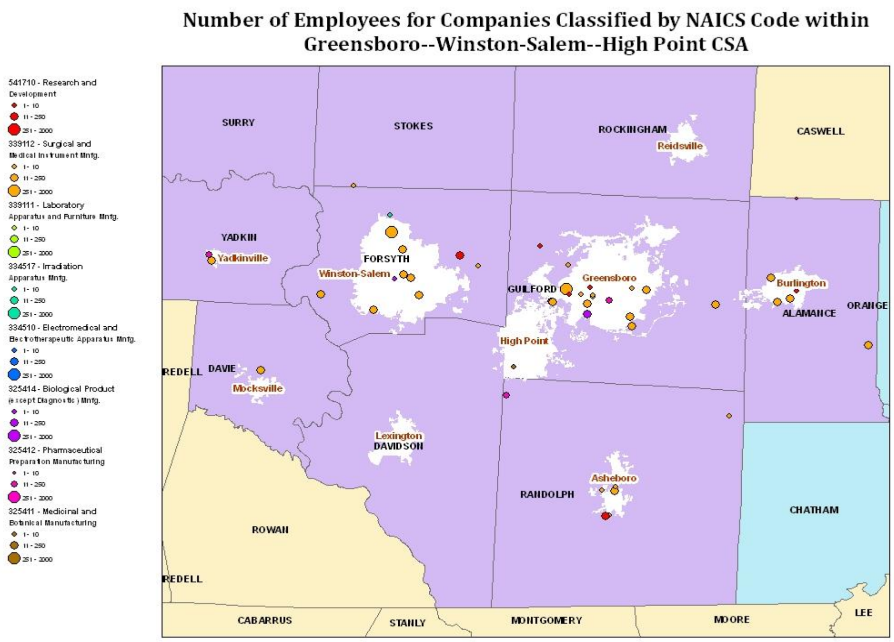
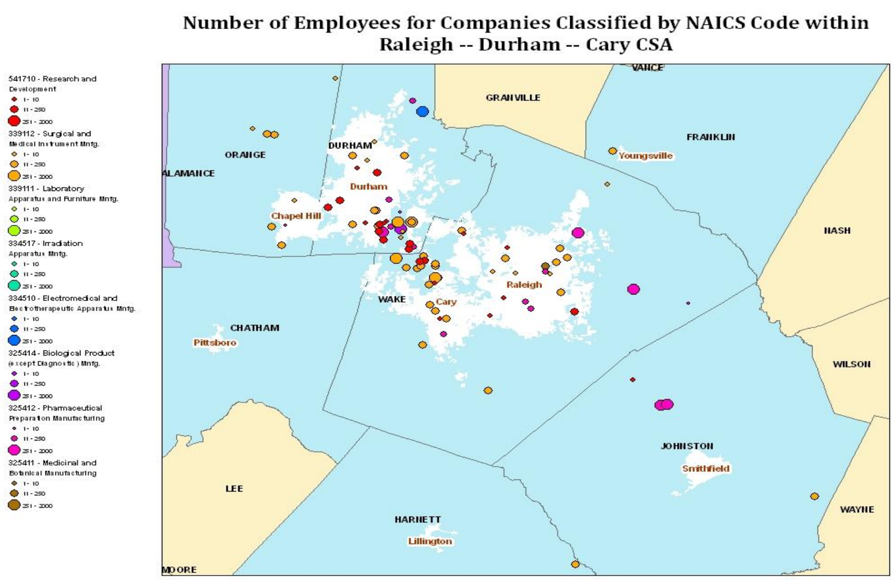


Figure 4.5



Source: ReferenceUSA Business Database

Table 4.6 Colorado Corp Tech Companies

Company Name	City	ST	NAICS1	Primary Industry Code	Num of Employees	Company Type
Isonics Corp.	Golden	CO	325411	Advanced Materials	16	Public
Animark, Inc.	Aurora	CO	325412	Medical	4	Private
Roche Colorado Corporation	Boulder	CO	325412	Pharmaceuticals	325	Subsidiary
Sirna Therapeutics	Boulder	CO	325412	Pharmaceuticals	77	Public
Shippert Medical Technologies Corp.	Centennial	CO	325412	Medical	15	Private
The Chemins Company, Inc.	Colorado Springs	CO	325412	Pharmaceuticals	110	Private
EAS, Inc.	Golden	CO	325412	Pharmaceuticals	200	Private
GTC Nutrition, LLC	Golden	CO	325412	Pharmaceuticals	3	Private
Ora Labs Inc	Parker	CO	325412	Pharmaceuticals	153	Subsidiary
Myogen, Inc.	Westminster	CO	325412	Pharmaceuticals	53	Public
Affinity Bioreagents, Inc.	Golden	CO	325413	Biotechnology	15	Private
Martek Biosciences Boulder Corporation	Boulder	CO	325414	Biotechnology	30	Subsidiary
Pharmion Corporation	Boulder	CO	325414	Pharmaceuticals	50	Public
Proligo LLC	Boulder	CO	325414	Biotechnology	331	Subsidiary
SomaLogic, Inc.	Boulder	CO	325414	Biotechnology	40	Private
AspenBio, Inc.	Castle Rock	CO	325414	Biotechnology	11	Public
Evolutionary Genomics, LLC	Lafayette	CO	325414	Biotechnology	13	Private
Geobiotics, LLC	Lakewood	CO	325414	Biotechnology	7	Private
GlobeImmune, Inc.	Louisville	CO	325414	Biotechnology	34	Private
Allos Therapeutics, Inc.	Westminster	CO	325414	Pharmaceuticals	57	Public
CardioOptics, Inc.	Boulder	CO	334510	Medical	12	Private
Encision, Inc.	Boulder	CO	334510	Medical	35	Public
Conmed Electrosurgery	Centennial	CO	334510	Medical	331	Subsidiary
Williams-Associates Inc	Commerce City	CO	334510	Medical	6	Unknown
Denver Instrument Co	Denver	CO	334510	Environmental	12	Public
VIASYS Healthcare Inc. Nicolet Vascular Inc.	Golden	CO	334510	Medical	3	Subsidiary
Gambro Healthcare	Lakewood	CO	334510	Medical	500	Subsidiary
Mesa Laboratories, Inc. Medical Division	Lakewood	CO	334510	Medical	32	Division
Medivance, Inc.	Louisville	CO	334510	Medical	35	Private
Mountain X Ray & Equipment Inc	Denver	CO	334517	Medical	5	Private
Sienco, Inc.	Arvada	CO	339111	Medical	3	Private
Scientech, Inc.	Boulder	CO	339111	Test & Measurement	18	Private
Vitraform Inc	Denver	CO	339111	Test & Measurement	20	Private
Accellent Cardiology Arvada	Arvada	CO	339112	Medical	140	Division
Therapeutic Recreation Systems, Inc.	Boulder	CO	339112	Medical	5	Private
Tyco Healthcare Group LP Valleylab Division	Boulder	CO	339112	Medical	664	Division
Valleylab	Boulder	CO	339112	Medical	1201	Division
Endo Pharmaceuticals Colorado	Boulder	CO	339112	Medical	21	Subsidiary
Pare Surgical Inc	Centennial	CO	339112	Medical	1	Private
Preferred Medical Products, Inc.	Centennial	CO	339112	Medical	35	Private
Certol International, LLC Cottrell	Commerce City	CO	339112	Medical	30	Private
Genesee BioMedical, Inc.	Denver	CO	339112	Medical	17	Private
Baxa Corporation	Englewood	CO	339112	Medical	185	Private
Denver Biomedical, Inc.	Golden	CO	339112	Medical	50	Private
Employee Information Services, Inc.	Lakewood	CO	339112	Medical	65	Private
Ferraris Medical, Inc.	Louisville	CO	339112	Medical	40	Subsidiary
Inverness Medical BioStar, Inc.	Louisville	CO	339112	Medical	300	Division
Sound Surgical Technologies LLC	Louisville	CO	339112	Medical	58	Private
Mc Kinley Medical LLC	Wheat Ridge	CO	339112	Medical	24	Private

Source: ReferenceUSA Corp Tech Database

Table 4.7 North Carolina Corp Tech Companies

Company Name	City	ST	NAICS1	Primary Industry Code	Num of Employees	Company Type
Aeolus Pharmaceuticals Inc.	Research Triangle Park	NC	325412	Pharmaceuticals	5	Public
Apex Bioscience, Inc.	Durham	NC	325412	Pharmaceuticals	10	Subsidiary
Ardent Pharmaceuticals, Inc.	Durham	NC	325412	Pharmaceuticals	16	Private
DarPharma, Inc.	Chapel Hill	NC	325412	Pharmaceuticals	13	Private
EISAI Inc	Research Triangle Park	NC	325412	Pharmaceuticals	230	Private
Eli Lilly and Co. Sphinx Laboratories	Durham	NC	325412	Pharmaceuticals	148	Division
Gentris Corp.	Morrisville	NC	325412	Pharmaceuticals	15	Private
Gilead Sciences, Inc.	Durham	NC	325412	Pharmaceuticals	180	Division
IDEXX Pharmaceuticals, Inc.	Greensboro	NC	325412	Pharmaceuticals	40	Private
Inspire Pharmaceuticals, Inc.	Durham	NC	325412	Pharmaceuticals	165	Public
Krenitsky Pharmaceuticals Inc.	Durham	NC	325412	Pharmaceuticals	6	Private
Kucera Pharmaceutical Co., Inc.	Winston Salem	NC	325412	Biotechnology	5	Private
MoliChem Medicines Inc.	Chapel Hill	NC	325412	Pharmaceuticals	4	Private
Novo Nordisk Pharmaceutical	Clayton	NC	325412	Pharmaceuticals	365	Unknown
Pozen, Inc.	Chapel Hill	NC	325412	Pharmaceuticals	38	Public
Salix Pharmaceuticals, Ltd.	Raleigh	NC	325412	Pharmaceuticals	83	Public
TEAMM Pharmaceuticals, Inc.	Morrisville	NC	325412	Pharmaceuticals	85	Subsidiary
Targacept Inc.	Winston Salem	NC	325412	Pharmaceuticals	72	Private
Tranzyme, Inc.	Research Triangle Park	NC	325412	Pharmaceuticals	32	Private
Trimeris, Inc.	Durham	NC	325412	Biotechnology	100	Public
Tyco Healthcare Mallinckrodt	Raleigh	NC	325412	Pharmaceuticals	280	Division
Hybrizyme Corp.	Raleigh	NC	325413	Biotechnology	7	Private
Icoria, Inc.	Morrisville	NC	325413	Biotechnology	188	Public
Ajinomoto AminoScience, LLC	Raleigh	NC	325414	Biotechnology	130	Private
AlphaVax Human Vaccines, Inc.	Research Triangle Park	NC	325414	Pharmaceuticals	60	Private
Argos Therapeutics, Inc.	Durham	NC	325414	Pharmaceuticals	65	Private
Athenix Corp.	Durham	NC	325414	Biotechnology	38	Private
Biogaia Biologics, Inc.	Raleigh	NC	325414	Biotechnology	3	Subsidiary
Biolex, Inc.	Pittsboro	NC	325414	Biotechnology	80	Private
Carolina By-Products Co.	Greensboro	NC	325414	Biotechnology	1494	Private
EMD Pharmaceuticals, Inc.	Durham	NC	325414	Pharmaceuticals	166	Subsidiary
Piedmont Research Ctr	Morrisville	NC	325414	Biotechnology	40	Private
Serenex	Durham	NC	325414	Biotechnology	25	Private
Talecris Biotherapeutics, Inc.	Research Triangle Park	NC	325414	Biotechnology	1700	Private
Vesta Therapeutics, Inc.	Durham	NC	325414	Biotechnology	7	Private
Zen-Bio, Inc.	Research Triangle Park	NC	325414	Biotechnology	9	Private
BMG LabTechnologies, Inc.	Durham	NC	334510	Biotechnology	50	Private
BioStratum Inc.	Durham	NC	334510	Medical	23	Private
Carolina Medical, Inc.	King	NC	334510	Medical	11	Subsidiary
Diagnostic Healthcare Systems	Raleigh	NC	334510	Medical	20	Private
LipoScience, Inc.	Raleigh	NC	334510	Medical	120	Private
MED-EL Corporation North America	Durham	NC	334510	Medical	0	Subsidiary
Aeroglide Corporation	Cary	NC	339111	Test & Measurement	145	Private
Flexcell International Corp.	Hillsborough	NC	339111	Biotechnology	10	Private
Purolator Facet Inc	Greensboro	NC	339111	ubassemblies & Component	200	Public
Bespak, Inc.	Cary	NC	339112	Medical	85	Public
Hospira, Inc. Clayton	Clayton	NC	339112	Medical	60	Division
Innovative Devices, LLC	Raleigh	NC	339112	Medical	2	Partnership
MEDTOX Diagnostics, Inc.	Burlington	NC	339112	Medical	65	Subsidiary

Medi USA	Whitsett	NC	339112	Medical	32	Unknown
Nobex Corporation	Durham	NC	339112	Medical	42	Private
Owens & Minor	Raleigh	NC	339112	Medical	57	Unknown
Ribonomics, Inc.	Durham	NC	339112	Biotechnology	5	Private
STEMCO Biomedical, Inc.	Durham	NC	339112	Medical	26	Private
SunTech Medical, Inc.	Morrisville	NC	339112	Medical	70	Private
TriPath Oncology, Inc.	Durham	NC	339112	Medical	70	Subsidiary
Triangle Biomedical Sciences, Inc.	Durham	NC	339112	Medical	30	Private
bioMerieux, Inc.	Durham	NC	339112	Biotechnology	3850	Subsidiary
AAIPharma Inc. Analytical Services Inc.	Chapel Hill	NC	541710	Pharmaceuticals	58	Division
Alpha-Gamma Technologies, Inc. Research and Engineering Division	Raleigh	NC	541710	Environmental	0	Division
Amphora Discovery Corp.	Durham	NC	541710	Pharmaceuticals	56	Private
Bayer Environmental Science	Clayton	NC	541710	Biotechnology	22	Unknown
CaroTech, LLC	Durham	NC	541710	Pharmaceuticals	3	Private
Cato Research Ltd	Durham	NC	541710	Biotechnology	300	Subsidiary
Charles River Clinical Services	Cary	NC	541710	Test & Measurement	2827	Division
Chathamborough Research Group	Pittsboro	NC	541710	Pharmaceuticals	2	Private
Chemical Technologies, LLC	Graham	NC	541710	Chemicals	70	Private
Constella Group Inc.	Durham	NC	541710	Computer Software	170	Private
Eastern Technical Associates	Raleigh	NC	541710	Environmental	20	Private
Embrex, Inc.	Durham	NC	541710	Biotechnology	309	Public
Fortron Bio Science, Inc.	Morrisville	NC	541710	Biotechnology	7	Private
Health Decisions, Inc.	Chapel Hill	NC	541710	Biotechnology	43	Private
Honda R & D Americas Inc	Haw River	NC	541710	Factory Automation	30	Public
HumanCentric Technologies, Inc.	Cary	NC	541710	Computer Hardware	40	Private
Integrated Laboratory Systems, Inc.	Durham	NC	541710	Environmental	120	Private
King Pharmaceuticals Inc	Cary	NC	541710	Pharmaceuticals	65	Unknown
Laboratory Corporation of America	Research Triangle Park	NC	541710	Pharmaceuticals	700	Division
Lineberry Research Associates, LLC	Research Triangle Park	NC	541710	Pharmaceuticals	75	Private
MediaSpan Group, Inc.	Durham	NC	541710	elecommunications & Intern	200	Private
Metabolon Inc	Durham	NC	541710	Factory Automation	34	Private
National Institute of Environmental Health Sciences	Research Triangle Park	NC	541710	Medical	1000	Subsidiary
National Institute-Environmntl Hlth Sciences	Research Triangle Park	NC	541710	Environmental	875	Non-profit
Norak Biosciences, Inc.	Morrisville	NC	541710	Biotechnology	29	Private
Novozymes North America, Inc.	Franklinton	NC	541710	Biotechnology	400	Subsidiary
Nuada Pharmaceuticals, Inc.	Durham	NC	541710	Pharmaceuticals	30	Private
PPD Discovery	Morrisville	NC	541710	Biotechnology	43	Subsidiary
PharmaLinkFHI, Inc.	Research Triangle Park	NC	541710	Pharmaceuticals	0	Private
SCYNEXIS Chemistry and Automation, Inc.	Research Triangle Park	NC	541710	Biotechnology	80	Private
Scientific Services Program	Chapel Hill	NC	541710	Biotechnology	5	Non-profit
Synthon Parmaceuticals	Research Triangle Park	NC	541710	Factory Automation	35	Unknown
TransTech Pharma Inc.	High Point	NC	541710	Biotechnology	70	Private
Valspar Corp	High Point	NC	541710	Advanced Materials	100	Public
inGenium research, inc.	Cary	NC	541710	Biotechnology	30	Private
nTouch Research Corp.	Raleigh	NC	541710	Pharmaceuticals	90	Private

Source: ReferenceUSA Corp Tech Database

Each MSA's specialization in life sciences is more apparent in Tables 4.8 and 4.9. These show the calculated LQ's by NAICS code for each MSA. Table 4.8 shows that surgical and medical instrument manufacturing is the most dominant in both Boulder and Denver-Aurora, but far higher in Boulder at 46.5. This sector is considered the specialization for both of these MSAs.

These LQs conclude that the Boulder MSA is the hub of life science and manufacturing activities. The Greeley MSA does not have a significant life science industry base.

The hypothesis that each MSA develops its own specialization is more applicable to the North Carolina study area. This is evident from the LQs shown in Table 4.9. It shows that biological product manufacturing is the specialization in the Triad (LQ of 11.67) while it is surgical and medical instrument manufacturing in the Triangle (LQ of 12.18). The Triangle specializes more in R&D than the Triad. The Triad has a higher LQ for all the other manufacturing activities than the Triangle, except for pharmaceutical preparation manufacturing and laboratory apparatus and furniture manufacturing.

Table 4.8 Colorado MSA LQs

Boulder/Denver, CO - Location Quotients			
	MSA		
	Denver-Aurora	Boulder	Greeley
Medicinal and Botanical Manufacturing (325411)	0.62		
Pharmaceutical Preparation Manufacturing (325412)	0.29	1.94	
In-Vitro Diagnostic Substance Manufacturing (325413)	0.35		
Biological Product (except Diagnostic) Manufacturing (325414)	0.29	17.40	
Electromedical and Electrotherapeutic Apparatus Manufacturing (334510)	0.08	0.24	
Laboratory Apparatus and Furniture Manufacturing (339111)	0.15	1.24	
Surgical and Medical Instrument Manufacturing (339112)	5.52	46.50	0.09
Research and Development in Life Sciences (541710)	0.54	2.14	0.06
All NAICS	0.97	6.97	0.04

Table 4.9 North Carolina MSA LQs

Triad/Triangle, NC - Location Quotients		
	CSA	
	Triad	Triangle
Medicinal and Botanical Manufacturing (325411)		0.97
Pharmaceutical Preparation Manufacturing (325412)	0.98	3.20
In-Vitro Diagnostic Substance Manufacturing (325413)		2.06
Biological Product (except Diagnostic) Manufacturing (325414)	11.67	8.80
Electromedical and Electrotherapeutic Apparatus Manufacturing (334510)	1.74	0.60
Laboratory Apparatus and Furniture Manufacturing (339111)	2.75	3.00
Surgical and Medical Instrument Manufacturing (339112)	2.07	12.18
Research and Development in Life Sciences (541710)	0.15	3.06
All NAICS	0.95	4.76

Source: ReferenceUSA Database

4.5 Surveys

The companies chosen to answer surveys were based on the North Carolina list of 414 firms obtained from the ReferenceUSA database. The response rate for the individual company surveys was low at 4% (18 respondents), but the answers provide insight into specific location factors of life science firms in North Carolina. Just under one-half of the companies that disclosed their name and location are in the Triad (Greensboro, Winston-Salem, Burlington, and Haw

River) while the remaining are located in the Triangle (Raleigh, Durham, and, Chapel Hill, and RTP). Eleven percent of the companies are classified as diagnostic, 45 percent therapeutic, 11 percent agri-bio, and 33 percent classified themselves in the "other" category (i.e. biodiesel and manufacturing). Company names are anonymous. These results are shown in Table 4.10.

Table 4.10 Company Background Information from Surveys

Company	CSA	Main Area of Business	Company Type	Year Established	Number of Employees
1	Triangle	Other (biofuels)	Other (company)	2003	24
2	Triad	Other (biologic, scaffolding)	Other	1989	8
3	Triangle	Therapeutic	A spin off from a university	2000	7
4	Triangle	Therapeutic	Other (privately held)	2003	10
5	###	Therapeutic		2001	10
6	Triangle	Therapeutic	A spin off from a university	2005	4
7	###	Therapeutic	Other	2002	11
8	###	Agri-Bio		1994	5
9	###	Therapeutic	Other (private LLC)	2001	3
10	###	Therapeutic	Other	1999	100
11	Triad	Diagnostic	A subsidiary of a large firm	2002	4
12	Triad	Agri-Bio	Other (independent)	2006	2
13	Triangle	Diagnostic	Other	2001	5
14	Triangle	Diagnostic	Other (started after retiring from university)	2002	5
15	Triad	Other (service)	Other (small business)	1989	3
16	Triad	Therapeutic	Other (corporate HQ)	1955	120
17	###	Therapeutic	Other	2004	12
18	Triangle	Other (Bioanalytical)	Other (Type "S" Corp)	1993	55

Source: Survey created by Dr. Susan Walcott and Dr. Sharmistha Bagchi-Sen

The oldest firm is a corporate headquarter therapeutic firm established in 1955. This company also happens to have the highest number of employees (120). The youngest firm is an independent agri-bio firm established in 2006, which happens to contain the lowest number of employees (2). The second largest employer is a therapeutic firm with 100 employees while a majority of the remaining companies employ less than ten. All of the companies reported revenue earnings under $10 million with two-thirds reporting under $1 million. The average percentage of total revenue assigned by a company to R&D activity is 46.5%. Two companies (one therapeutic and one agri-bio) reported an assigned 100 percent of their revenue toward R&D

activity, although the independent agri-bio firm spent only an estimated $20,000 on R&D in the past 5 years. The largest amount spent on R&D is $20 million (75% of its revenue) by a therapeutic company with 100 employees. Four of the companies reported regular exporting activities and 13 of them do not export at all. Table 4.11 shows these results.

Table 4.11 Company Background Information from Surveys: Revenue

Company	CSA	Main Area of Business	Total Revenue	% Revenue for R&D	Estimate $ spent on R&D (past 5 yrs.)	Export	If Yes, Revenue from Export, %
1	Triangle	Other (biofuels)	$1 - $10 million	15	750,000	no	
2	Triad	Other (biologic, scaffolding)	$1 - $10 million	20	4,000,000	yes, regularly	30
3	Triangle	Therapeutic	< $1 million	75	6,000,000	no	
4	Triangle	Therapeutic	< $1 million	40	3,000,000	no	
5	###	Therapeutic	< $1 million	100		yes, periodically	1
6	Triangle	Therapeutic	< $1 million	80	250,000	no	
7	###	Therapeutic	< $1 million	70		no	
8	###	Agri-Bio	< $1 million	20	350,000	no	
9	###	Therapeutic	< $1 million	50	100,000	no	
10	###	Therapeutic	$1 - $10 million	75	20,000,000	no	
11	Triad	Diagnostic	$1 - $10 million	0		yes, regularly	5
12	Triad	Agri-Bio	< $1 million	100	20,000	no	
13	Triangle	Diagnostic	< $1 million	75	2,250,000	yes, regularly	15
14	Triangle	Diagnostic	< $1 million	90	500,000	no	
15	Triad	Other (service)	< $1 million	0	0	no	
16	Triad	Therapeutic	$1 - $10 million	10	1,000,000	yes, regularly	30
17	###	Therapeutic	< $1 million	15	750,000	no	
18	Triangle	Other (Bioanalytical)	$1 - $10 million	3	400,000	no	

Source: Survey created by Dr. Susan Walcott and Dr. Sharmistha Bagchi-Sen

Various reasons were given for the locations being chosen for establishment. Several respondents noted proximity to local universities (i.e. NC State, Duke, UNC-Chapel Hill), RTP, Piedmont Triad Research Park, medical facilities, farms, and other firms within the industry. A few personal reasons were listed such as family establishment, lifestyle, existing residence in the area, and new structure's color coordination. A majority of the answers indicate a strong presence of universities, talented labor, and other biopharmaceutical firms. It is of interest that two known Triad companies stated proximity to RTP as a reason for location. This signifies the synergy that exists between the Triad and Triangle. Another respondent mentioned synergies as a reason. Table 4.12 lists the specific reasons given.

Table 4.12 Company Location Information from Surveys

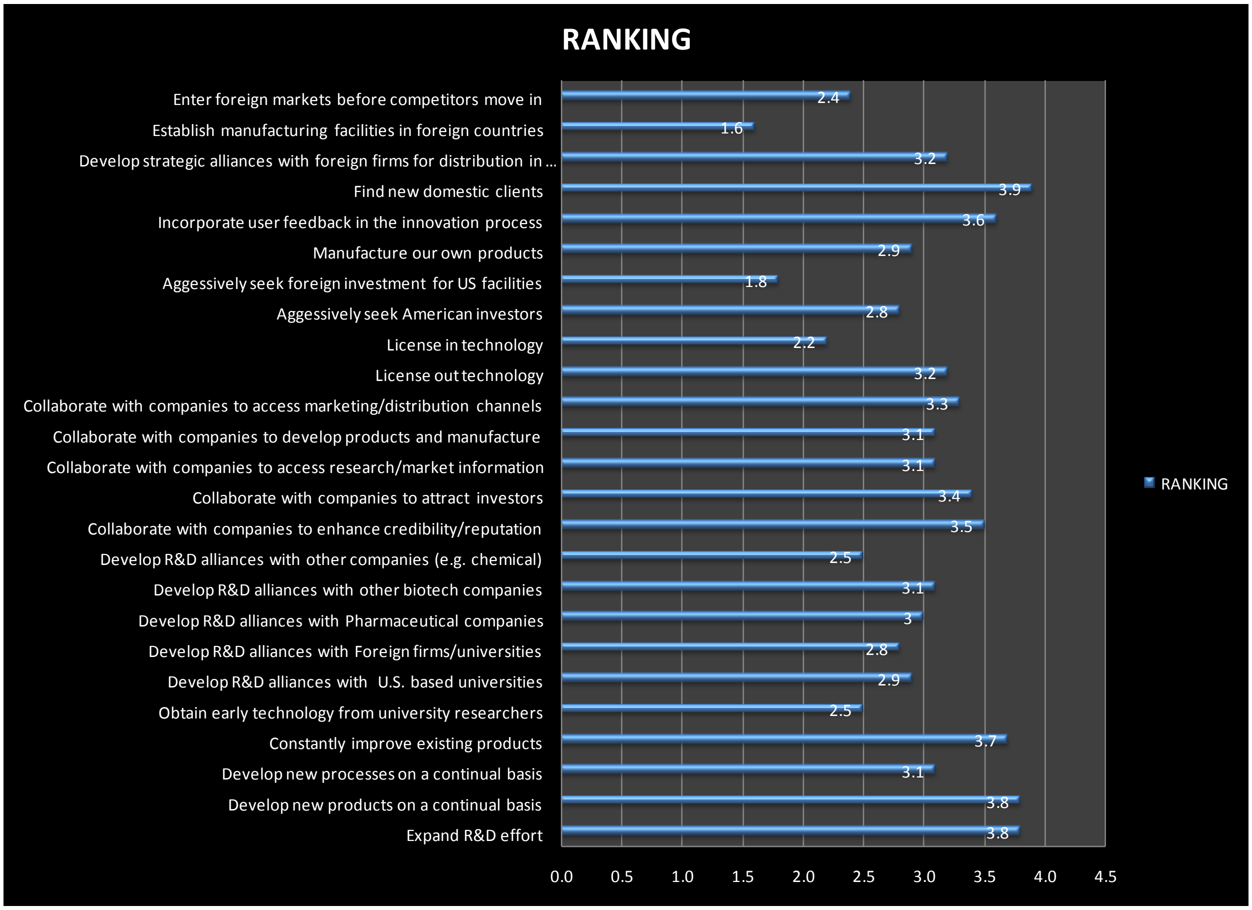
Company	CSA	Main Area of Business	LOCATION	
			Reason # 1	Reason # 2
1	Triangle	Other (biofuels)	Good deal on buildings and land	Mezzanine painted in corporate colors
2	Triad	Other (biologic, scaffolding)	Was already living here	New opportunities have materialized in the last 3 years
3	Triangle	Therapeutic	Access to talented labor pool (scientists)	Quality of life in RTP
4	Triangle	Therapeutic	talent in the area	general industry player in the area
5	###	Therapeutic	town zoning	convenience for customers
6	Triangle	Therapeutic	Close to N.C. State	Cost per square foot
7	###	Therapeutic	biotech hub	skilled worker pool
8	###	Agri-Bio	proximity to markets	costs
9	###	Therapeutic	close to home	close to Research Triangle
10	###	Therapeutic	quality of life	proximity to life science companies
11	Triad	Diagnostic	close proximity to RTP and other research groups	lifestyle
12	Triad	Agri-Bio	close to farmers, farms	close to university; industry
13	Triangle	Diagnostic	close to Duke and RTP	important contacts in the area
14	Triangle	Diagnostic	established family (wife and children)	in RTP area (Duke, UNC-Chapel Hill, NC State)
15	Triad	Other (service)	Location, near medical facilities	cost factor
16	Triad	Therapeutic	labor costs	proximity to RTP
17	###	Therapeutic	already resided here	research park (Piedmont Triad Research Park), synergies
18	Triangle	Other (Bioanalytical)	It is where I lived prior to founding the business	need for labs by local industries

Source: Survey created by Dr. Susan Walcott and Dr. Sharmistha Bagchi-Sen

Eleven out of the eighteen respondents answered “No” when asked if there is a shortage of labor supply. Four respondents indicated a shortage of labor supply including companies specializing in biofuels, therapeutic, diagnostic, and bioanalytical services. They indicated the need for scientifically educated sales personnel, entrepreneurial managers, and administrative assistants.

A majority of the companies do not perform R&D in-house. All but two of the companies have seen an increased or the same amount of R&D collaboration with universities and industries in the past five years. Less than 30% of the firms have one or more strategic alliances for manufacturing. Some of the facilities are not suitable for manufacturing. A majority of the companies reported developing new products and processes in the past ten years. The average number of new products is approximately seven and the average number of new processes is three. Most of them had only a few domestic patent approvals within this time period, but one company had 200. The last section of the survey asked respondents to rank the importance of various innovation strategies on a scale of 1 to 5 (1 = not important, 2 = minor importance, 3 = moderate importance, 4 = very important, and 5 = critically important). The average score was calculated for each strategy since a wide range of scores was reported (Figure 4.6).

Figure 4.6 Survey Ranking Scores of Various Firm Innovation Strategies



Source: Survey created by Dr. Susan Walcott and Dr. Sharmistha Bagchi-Sen

The strategies of overall highest importance are to find new domestic clients, develop new products on a continuous basis, and expand R&D effort. The lowest rankings were with the strategies of establishing manufacturing facilities in foreign countries, aggressively seeking foreign investment for U.S. facilities and licensing-in technology. The remaining strategies are generally at least moderately important. All but two of the companies have seen an increased or the same amount of R&D collaboration with universities and industries in the past five years. This tells us that firms within the region are working closely with the local universities and research facilities for R&D activities. Also, a majority of the companies would like to increase this effort, along with finding new local clients. This is more important to them than seeking foreign investment. The overall conclusion from these survey findings is that many companies are likely to seek resources from within their local region. The results contribute to the hypothesis that life science firms establish their locations in regional clusters and develop strategies for innovation and collaboration to benefit from synergies and regional growth.

CHAPTER V

CONCLUSION

Both Colorado and North Carolina contain comparable regional clusters of companies in the life science industry. A sectoral complementarity exists between Boulder and Denver, Colorado, and the Triad and Triangle, North Carolina where the proximate places benefit economically from the development of industry clusters. Employment clusters were found here by collecting data from the BLS and ReferenceUSA company database for nine specified sectors covering R&D and various manufacturing activities. These data, including latitude and longitude information for individual companies, helps visualize where firms of specified life science sectors are located. The company location maps conclude that larger companies within Surgical and Medical Instrument Manufacturing are located in all three study MSAs in Colorado with more located in Denver-Aurora. A dense concentration of R&D companies is found in the Boulder MSA and many in this sector are scattered throughout Denver-Aurora. The pattern is similar for North Carolina where Surgical and Medical Instrument Manufacturing firms are found in both CSAs while R&D is concentrated more in the Triangle. The Triangle is also home to several Pharmaceutical Preparation Manufacturing firms.

Each MSA's specialization in life sciences is more apparent when looking at calculated LQ's by NAICS code for each MSA. Surgical and medical instrument manufacturing is the most dominant industry for both Boulder and Denver-Aurora, but the LQ is far higher in Boulder. This sector is considered the specialization for both of these MSAs. The LQ calculations also conclude that the Boulder MSA is the hub of life science and manufacturing activities in Colorado. The Greeley MSA does not have a significant life science industry base. The hypothesis that each MSA develops its own specialization is more applicable to the North Carolina study area. The LQs conclude that biological product manufacturing is the specialization in the Triad while it is surgical and medical instrument manufacturing in the Triangle (LQ of 12.18). The Triangle specializes more in R&D than the Triad. The Triad has a higher LQ for all the other manufacturing activities than the Triangle, except for pharmaceutical preparation manufacturing and laboratory apparatus and furniture manufacturing.

Commuting pattern statistics were compiled from the U.S. Census Bureau Transportation Planning Package to show a connection between the proximate regions of each study area and to demonstrate the general traits of a regional economic growth engine. Small portions of all commuters were found to be traveling daily to work in the other proximate MSA or CSA in their region. The strength of the research base of both study areas is demonstrated through the use of data from the NIH, including the highest-ranked institutions in terms of research grant funding. These research institutions provide highly trained and skilled scientists. Nine universities from these regions are ranked in the top 500. This is an indicator of the high quality of medical research and well educated labor force. Four universities receiving a total of $280,701,234 in grants are located in the Colorado study area. Five receiving a total of $834,770,648 are in North Carolina. Several schools in both study areas provide advanced degrees in life science fields.

Data were collected from surveys conducted for North Carolina companies. Several survey respondents noted proximity to local universities as the reason for their location decision. A majority of them also indicated an increase in R&D collaboration with universities. Findings conclude that many companies are likely to seek resources from within their local region and contribute to the hypothesis that life science firms establish their locations in regional clusters and develop strategies for innovation and collaboration to benefit from synergies and regional growth. Findings from these data sources indicate that characteristics of both states allow them to house proximate, complimentary regions where life science firms can become successful. Synergies in both states exist between the proximate places to build regional economic growth engines.

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APPENDIX A: SURVEY: INNOVATION AND COLLABORATION IN LIFE SCIENCE FIRMS

Background:

1. Main area of business (*check all that apply*):
   □ Diagnostic □ Therapeutic □ Agri-Bio □ Environment □ Other ___________

2. Is the company:
   □ a subsidiary of a large firm □ a spin off from a university □ Other_____________________

3. Is the company: □ public □ private

4. When was the company established? _______

5. The total number of employees is *(please estimate)*: __________

6. The **total revenue** for the most recent fiscal year is (*check only one box*.):

   □ < $1 million □ $1-10 million □ $10.1-25 million □ $25.1-50 million □ > $50 million

7. What **%** of your company's total revenue is assigned to research and development (R&D) activity? ____%

   If possible, please estimate the total dollars spent per year on R&D over the past 5 years: $_______________

8. Do you export? □ No □ Yes, regularly □ Yes, periodically □ Plan to export in the future

   If yes, what percentage of revenue comes from exports? __%

Location:

9. Please list the top two reasons for locating your establishment where you are:

Reason #1: ____

Reason #2: ____

10. Please list the most important form of local/state government assistance that benefits your operations:

Local: ____

State: ____

11. What is the most essential type of government assistance that is missing and would be beneficial to your operations?

Local: ____

State: ____

12. Is there a shortage of labor supply in the area? □ No □ Yes

If yes, in which occupational groups (please describe):

Group 1: ____

Group 2: ____

Others: ____

Collaborative Efforts:

Collaboration is defined as formal partnerships in R&D, which include substantial contributions of time, capital, technology, or other assets. Please answer the following questions as they relate to your company's experience with collaboration:

13. Is all R&D performed in-house? ☐No ☐Yes If no, please answer the following:

In the past 5 years, **university** R&D collaboration has ☐increased ☐decreased ☐remained the same

In the past 5 years, **industry R&D** collaboration has ☐increased ☐decreased ☐remained the same

14. Roughly what percentage of your **R&D collaborators** comes from the following geographic areas?

(*Here, we are trying to assess the importance of local versus non-local R&D connections*)

Location of R&D collaborators	**University (percentage share of collaborators)**	**Industry (percentage share of collaborators)**
Local	%	%
State	%	%
Elsewhere in the US	%	%
International	%	%
Total	100%	100%

15. What is the main foreign country from where you have **University** collaborators? ______________________

16. What is the main foreign country from where you have **Industry** collaborators? ______________________

Manufacturing and Sales:

17. Does this firm operate with strategic alliances for manufacturing?. ☐ Yes ☐ No If yes, how many? ___

Please indicate the location of manufacturing facilities:

Location of manufacturing facility	% of manufacturing
Local city region	%
Same state	%
Elsewhere in the US	%
International	%
Total	**100%**

18. If you have operations outside of the same city or region, please provide the main reasons:

#1: ____

#2: ____

19. What are the difficulties in having a manufacturing operation or a partner in the same city or region?

In-house difficulty: ____

Same city or region difficulty: ____

Innovation:
20. Please indicate the approximate **total number** of innovations your company has achieved over the past 10 years (or the period from company inception to present, if less than 10 years).

New products _______ New processes _______ Domestic patent approvals _______

21. Please indicate the % of products in 3rd stage clinical trial: ____%

22. Indicate the importance of the following **strategies** to your company (*check one box per strategy from scale)*

1=not important 2=minor importance 3=moderate importance 4=very important 5=critically important

	1	2	3	4	5
a. Expand our research and development (R&D) effort	☐	☐	☐	☐	☐
b. Develop new products on a continual basis	☐	☐	☐	☐	☐
c. Develop new processes on a continual basis	☐	☐	☐	☐	☐
d. Constantly improve our existing products	☐	☐	☐	☐	☐
e. Obtain “early” technology from university researchers.......	☐	☐	☐	☐	☐
f. Develop R&D alliances with: U.S. based universities........	☐	☐	☐	☐	☐
i. Foreign firms/universities	☐	☐	☐	☐	☐
Pharmaceutical companies	☐	☐	☐	☐	☐
ii. Other biotech companies .	☐	☐	☐	☐	☐
iii. Other companies (eg, chemical)	☐	☐	☐	☐	☐
g. Collaborate with established pharma or chemical companies to:					
i. enhance credibility/reputation	☐	☐	☐	☐	☐
ii. attract investors	☐	☐	☐	☐	☐
iii. access research/market information.......................	☐	☐	☐	☐	☐
iv. develop products and manufacture	☐	☐	☐	☐	☐
v. access marketing/distribution channels	☐	☐	☐	☐	☐
h. License out technology	☐	☐	☐	☐	☐
i. License in technology	☐	☐	☐	☐	☐
j. Aggressively seek American investors	☐	☐	☐	☐	☐
k. Aggressively seek foreign investment for US facilities.......	☐	☐	☐	☐	☐
l. Manufacture our own products	☐	☐	☐	☐	☐
m. Incorporate user feedback in the innovation process	☐	☐	☐	☐	☐
n. Find new domestic clients	☐	☐	☐	☐	☐
o. Develop strategic alliances with foreign firms for distribution in foreign markets	☐	☐	☐	☐	☐
p. Establish manufacturing facilities in foreign countries........	☐	☐	☐	☐	☐
q. Enter foreign markets before competitors move in.............	☐	☐	☐	☐	☐

THANK YOU FOR TAKING THE TIME TO COMPLETE THIS SURVEY

YOUR ASSISTANCE IS GREATLY APPRECIATED

A summary of this survey will be available in February 2008. The results will show overall trends only (no individuals or firms will be identified). If you wish to receive a copy of the summary report, please attach your business card to this form or complete the mailing address section below.

Can we call or e-mail you for clarification of a specific answer?

☐ yes, call or e-mail ☐ yes, I would like a copy of the completed report