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Writing sample (2016)

Biotechnology and Industrial Clusters

Conceptual Overview of Industrial Districts

The proximal localization of related industries in a group is loosely defined as an industrial district. In the classical sense, the relatedness of industries could be associated with the transfer of intermediate goods among them. In this scenario, the decline in transaction and transportation costs results in agglomeration economies (Held 1996). For the sake of relevance, the factor of relatedness will be used in the context that clusters of firms are within the same general industrial sector in which the firms may take on distinct niches or be competitors in the same market.

The British economist Alfred Marshall had the novel conception that industrial districts that reap in benefits due to clustering of firms are known as localization economies. Primarily, Marshall's analysis of industrial districts emphasizes cost savings due to pooled capital, labor and natural resources, although he does touch upon external values (Harrison 1992). Alfred Marshall found the idea of external scale economies to be appealing because the internal scale economies could not be encompassed by his framework of general equilibrium (Blaug1997).There has also been emphasis placed on industrial policy and the state as the most critical factors in promoting clustering, where the claim is that the stages of economic development for a society does not establish the strategies for industrial growth (Piore and Sable 1984). Concepts have been added to Marshall's work such as the additional emphasis of government intervention, scale economics, the role of suppliers and buyers, and control of large or small corporations, with the argument that large firms or state intervention dominate industrial districts (Markusen 1996).

Michael Porter of Harvard Business School mentions four factors that are involved in promoting the success of industrial districts: *factor conditions* such as cost and quality; *demand conditions* such as buyer concentration; *related and supported industries* that provide inputs and services for the cluster; and *firm strategy structure and rivalry* that drives for quality and efficiency (Porter 1990). It has been argued that Porter's concept of rivalry is not solely important, but so is cooperation. (Lazonick 1993). Saxenian places an emphasis on technology transfer, organizational learning and networking. She claims large firms that guard information and internalize function are inferior to a model of cooperation and flexibility between large and small firms (Saxenian 1994).

In regards to the biotechnology industrial clusters, it is critical to create, apply and transfer knowledge or information. Based on the focus on the criticality of knowledge, it is claimed to be a valuable commodity that cannot be transferred simply. A continuous and trusting relationship between seller and buyer allows for the exchange of knowledge. Firms located in small regions are more likely to network, which in turn enhances trust and informational exchange. Knowledge can be both explicit and implicit. The nature of expressing knowledge that is difficult to formalize illustrates the significance of clusters and regional learning (Nonaka and Takeuchi 1995: 8). The difficulty of communicating implicit knowledge is arguably facilitated by in-person interactions which provide a competitive advantage to those present in the region. Thus, there is a demand for individuals with common expertise to cooperate within a high-tech district to promote the development of new products.

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In regards to knowledge-intensive industrial clusters, it is no surprise that universities play a critical role. Universities are particularly important in the advancement of regional human capital. In regards to biotechnology industries, universities are known for creating technologies that are normally adopted and commercialized by regional firms (Beek et al 1995). In regards to industries that involve high risk ventures, a firm's location in an industrial district could be critical from a sociological perspective. Knowledge intensive and risky industries tend to succeed when they attract key employees in STEM fields and funding from venture capital firms. Both the attraction of employees and venture capital necessitate the cultivation of personal relationships to foster trust between them and the firm. Industrial clusters provide the perfect environment to initiate risky ventures and establish an abundance of personal relationships.

Brief History of Biotechnology and Its Emergence in Massachusetts

Biotechnology is broadly defined as any technique that utilizes living organisms or its substances to make or modify a product. Biotechnology could be used to design microorganisms for a particular use and also improve animals or plants. Historically, biotechnology can be categorized into three phases. The initial phase includes the historic human domestication of plants and animals and fermentation processes of food or beverages that include yogurt, cheese, beer and bread. The second phase involves the emergence of classical biotechnology which involves Louis Pasteur's discovery of fermentation via microorganisms and the discoveries of vaccines via the understanding of viruses. The third phase is the emergence of modern biotechnology due to a series of breakthroughs in the field of molecular biology (Acharya 1999). A critical breakthrough was the discovery of DNA structure in 1953 by James Watson and Francis Crick whom later received the Nobel Prize for their work. Following this breakthrough, the development of monoclonal antibodies transformed diagnostic techniques in the therapeutic industry. In 1973, Stanford University first developed recombinant DNA by cutting and rejoining fragments of DNA. This technique is known as cloning which paved the way of genetic engineering and revolutionized modern biotechnology.

During the 1990s, the state of Massachusetts experienced a rapid growth in the biotechnology industry based on the membership of firms in the Massachusetts Biotechnology Council which later lead to the establishment of 275 biotechnology firms by 2002 whom employed over 26,000 individuals. The dominant sector in the biotechnology industry is related to the medical sciences which place emphasis on human diagnostic and therapeutic technologies. The Boston area is renowned for their medical sciences and its impact on their economy. The area includes the prestigious Harvard Medical School and Massachusetts General Hospital, the oldest hospital in the United States. Other world-renowned medical institutions include Dana Farber and Boston Children's Hospital who are leading experts in cancer and pediatric medicine respectively. These are just a few examples of medical establishments in the area who have a long history of revolutionary medical discoveries. The Boston Metropolitan Area has a high cluster of biotechnology firms where the city of Cambridge dominates by accounting for 60% of biotechnology employment and 30% of the firms (Breznitz 2005). The strength of employment in the Cambridge area is most likely due to the localization of larger firms in the Kendall Square region which encompasses MIT, where there is even a higher rate of biotechnology. The map of Kendall Square is shown below:

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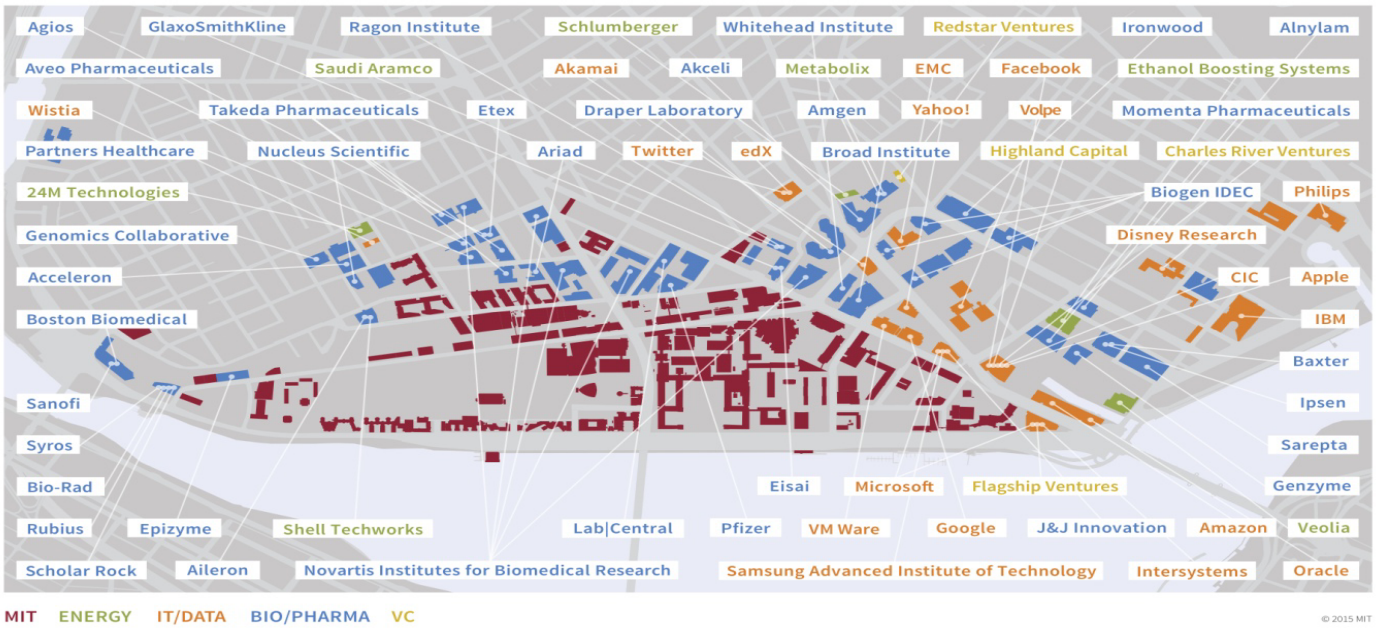

Figure 1 (kendallsquare.org)

Contributing Factors to Industrial Clusters

Shiri Breznitz from the University of Cambridge conducted a survey in the Boston/Cambridge area in order to assess factors that influenced firms in deciding where to locate themselves. Based on the ratings from the survey, it is suggestive that a pool of skilled labor force is the most essential factor followed by university research labs and other biotechnology companies, with tax incentives being the least important factor. In regards to the rating scale, 1 is the most important and 5 is the least. I will focus on the role of universities and skilled labor in the clustering of biotechnology firms due to its unique function in this industrial district of biotechnology. The table is shown below:

Factors Affecting the Location Decision

Factor	Average Rating
Other biotechnology companies	3.25
Pool of skilled labor force	2.29
Venture capital	3.80
Research labs (not university)	3.22
University research labs	2.54
Hospitals (for clinical trials)	3.89
Tax Incentives	4.23
Rent	3.39
Recombinant DNA ordinance	3.59
Suppliers	4.27
Others	2.86

Figure 2 (Breznitz 2005)

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The Role of Universities and Skilled Labor in Biotechnology

Proximal research labs and universities make several contributions that benefit biotechnology clusters such as producing specialized laborers with high levels of skill, founders or chief scientists, and providing innovative technologies to the cluster. Research universities produce a wealth of graduate students and postdoctoral fellows whose technical knowledge and skill set are critical to biotechnology firms. Biotechnology firms seem to attract a skilled labor force where "skilled" generally means having an advanced scientific degree such as a PhD or masters degree. The Boston/Cambridge area is a serious producer of skilled individuals from world class graduate programs in molecular biology and engineering from Harvard and MIT. It comes by no surprise that a large portion of technologies are created and commercialized from university labs, making a formal education critical in the labor pool. In addition, biotechnology research conducted at universities requires a unique infrastructure because of specific capital requirements such as specialized lab space and faculties with special ventilation, plumbing and electrical set-ups used to manage biological agents.

Studies have shown that the region embodies a characteristic lifestyle and culture that retains the community of skilled people (Eaton 2000). Boston's academic and cultural atmosphere appears to be one of most critical assets where local academic institutions are the main sources of labor. It is common for many of the founders of biotechnology companies to originate from the faculty of nearby universities and there is a strong correlation factor that indicates the location of the firm to be established near the residence of the founder. In comparison to other cities in the U.S., it has been found that scientists in the Boston/Cambridge area tend to remain in area (Audretsch and Stephan1996).

In 1980, the establishment of the Bayh-Dole Act allowed universities to commercialize and patent technologies created with government funds from the NSF and NIH. The ability for research universities to license technologies has become a source of income where institutions such as Harvard or MIT in the area have specific offices whose role is to manage the licensing and transfer of novel technologies. The close proximity within the cluster is advantageous to enhance firm-university communications in regards to the exchange of information and patented technologies (Saxenian 1994). It is evident that there is frequent cross-talk and coordination between biotechnology firms and universities in the region. The biotechnology industry is notorious for having high risk and high reward, where many venture capital firms will have no return on their investments. Universities are critical due to their pure approach to basic research where they can identify biological agents during the "discovery phase", with no concerns of financial returns. In addition to the facilities and highly skilled individuals from universities, successful industrial clusters in biotechnology tend to gravitate towards top institutions due to the high concentration of extremely prolific scientists known as star scientists.

"Star" Scientists

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Star scientists in the realm of biotechnology are considered to be one of the most productive and possess intellectual human capital with high economic and scientific potential. They are characterized by high frequency and quality publications. Intellectual capital is defined as the possession of specialized knowledge which earns exceeding returns compared to the cost of obtaining the knowledge. The value of star scientists lies in their ownership of scarce scientific knowledge and novel research techniques that allows them to create transformative and valuable scientific knowledge. Star scientists appear to behave by being protective of their early discoveries and limiting their collaborative efforts to their home institution in order to slow the transfer of knowledge. Evident ties between star scientists and biotechnology firms are necessary for commercialization of scientific breakthroughs. The timing and location of star scientists actively publishing has been shown to be a strong predictor of the timing and location of when new biotech firms arise and adopt a novel technology. Another strong predictor of a firm's success is the degree of its collaboration with a star scientist. On average, when a firm and star scientist coauthor 5 articles, 3.5 more products are on the market, 5 more products are in development and they have 860 more employees. In addition, the coauthored articles between the firm and star scientist tend to have higher citation rates by just the star scientist alone. The results indicate the efficacy of firms collaborating with star scientists in fostering and commercializing biotechnologies (Zucker 1994). A correlative map between star scientists and biotechnology clusters is shown below:

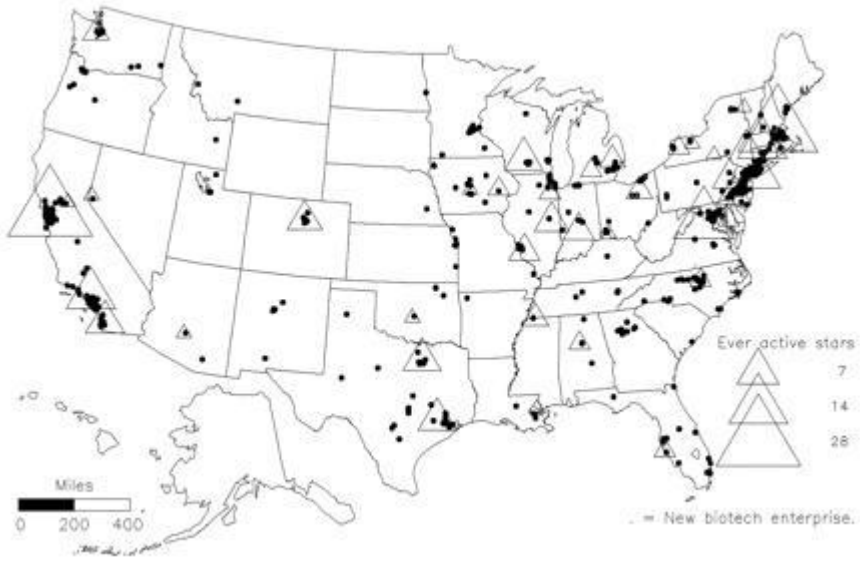

Figure 3 (Zucker 1996)

The map supports the idea that placing emphasis on understanding star scientists and their behaviors is critical in understanding technology commercialization and transfer in emerging biotechnology firms. The star scientists originate from a university setting and either collaborate or move to a firm to meet the demands of a breakthrough. When considering discoverers of a revolutionary method that is valuable for commercial research, it is likely to result in intellectual property that could lead to the emergence of a biotechnology firm. Licensing a novel methodology is one thing, but the ability to initially earn the high returns lies in the scientists

who actually learned first-hand how to execute the methodology. In the initial discovery phase, the novel technique may have been learned through an apprenticeship in a lab which provides excludability and can allow for publication without illustrating commercially valuable information. Scientists may decide whether to use their intellectual capital to create commercial products or pursue academic awards in attempt to accelerate their career. (Zucker and Darby 1993). It goes to show how valuable it is for firms to establish strong relationships with universities to commercialize and develop science that leads to the formation of new industries.

Conclusion

Overall, biotechnology clusters demonstrate many overlapping attributes with other economic districts. Certain factors such as labor pools in Boston are comparably found in clusters located in different regions. In addition, Boston demonstrates a unique retention of its skilled labor force. Studies have shown that individuals looking for work in biotechnology came from the region and decided to work in the vicinity due to a prevailing network of universities and biotech firms (Eaton 2000). The condition of rivalry is also critical in regards to stimulating competition amongst top-notch scientists. The sustenance and success of a biotechnology cluster requires a unique flow of knowledge between firms, the government and universities. The degree of intellectual capital and its relatedness to knowledge spillovers distinguishes the amount of innovation and dynamism of the cluster. The critical role of universities is arguably the most interesting and unique factor in biotechnology clusters. Particular individuals are responsible for creating and commercializing scientific breakthroughs. These star scientists are central in the timing, location and success of biotechnology firms based on technologies derived from scientific breakthroughs. The geographic distribution of intellectual human capital alongside the produced scientific breakthroughs is critical in influencing the geographic distribution of biotechnology clusters. The core of biotechnology clustering comes down to the idea that complex scientific discoveries or methods can only be effectively employed commercially by those scientists who created the novel knowledge.

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