The Study of the Communication Patterns of Boston-Cambridge Regional Biotech Firms to Universities

by
Nada Hashmi

M.S. Computer Science (2004)
University of Maryland, College Park

Submitted to the System Design and Management Program in Partial Fulfillment of the Requirements for the Degree of

Master of Science in Engineering and Management

at the
Massachusetts Institute of Technology

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Abstract

This paper analyzes data from a study which focused on understanding the informal scientific communication network among Biotechnology firms in the Boston-Cambridge Biotech area. A previous study (Allen, et. al., 2009) provided an overview of the network, how the firms were connected to one another and the frequency of the communications. The analysis for this study focuses on the firms and their communication patterns to the universities – to better understand the potentially continuing role of the universities. The goal of the study is to analyze the factors that influenced communication patterns. The following factors were studied: size, age, type of firm and degrees of centrality. In conclusion, the study finds the universities are tightly integrated into the biotech network. Some firms chose to communicate only with the universities. In addition, we find size and age to have the greatest influence on this. Finally, degrees of centrality also play a significant role in the tendency of research scientists within firms to communicate with universities.

Thesis Supervisor: Thomas Allen
Title: Margaret MacVicar Faculty Fellow
Howard W. Johnson Professor of Management Emeritus
Professor of Engineering Systems Emeritus

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It is difficult to overstate my gratitude to my thesis supervisor, Dr. Thomas Allen. Throughout my research time, he provided encouragement, sound advice, good teaching, good company, and lots of good ideas. I am truly in-depth to him!

I would like to thank Peter Gloor for helping me to understand the data and the previous study. Without his help, the data would have meant gibberish to me. I would like to thank Joanne McHugh for her continuous support with the administrative tasks. She is truly an invaluable source. I would like to thank Ornit Raz for allowing me to use the data from her study. In addition, I would like to thank Pat Hale for his support for my work and helping to make my experience at SDM a very pleasant and enjoyable one.

I would like to express my deep appreciation to all of my sisters for their support, encouragement and love. Lastly, and most importantly, I wish to thank my parents, Dr. Nasim Hashmi and Aisha Hashmi. It is their upbringing and continuous support that has helped me to reach this far.

Table of Contents

Table of Figures

Table of Tables

Chapter 1: Introduction

Entrepreneurs, small to medium businesses, and even large established firms, invest a considerable amount of thought into where they locate in order to maximize and benefit from the environment around them. There is no doubt, however, as to the benefits of the 'geographic clustering' of firms in a similar industry – the exchange and development of new ideas and innovations, attraction of scientific talent to that particular region, other businesses in the supply chain relocating to the region with confidence, a multiplicity of new venture firms is likely to attract venture capital into region, etc. Therefore, is it enough to physically move into the area and expect to reap the benefits?

Researchers as early as the 1800s, through the work of Alfred Marshall's *Principles of Economics* (1890/1920), noted the tendency of firms in similar industries to co-locate and built theories upon that. Paul Krugman (1991), AnnaLee Saxenian (1994), and Michael Porter (1998a, 1998b, 2000) all analyzed clusters and various ways the firms were 'connected' to the clusters. Patenting, Co-authorship, formal collaborative efforts were just some of the methods to quantitatively analyze and measure the connectivity of a firm to the cluster. Saxenian also has emphasized the role universities in particular play on the development and growth of a cluster and high connectivity attributes to success of the cluster and the firms. The most notable clusters with the university presence include the Silicon Valley, Route 128 in Massachusetts, and the Boston-Cambridge Biotech Cluster (also in Massachusetts).

Our study focuses on the Boson-Cambridge Biotech cluster and connectivity of the universities to this cluster. According to the data from the Massachusetts Biotechnology Council, the Massachusetts Biotech cluster accounts for nearly 20 percent of the biotechnology companies in the USA; that is, over 280 companies. In addition, they employ close to 30,000 people. There are an additional 220 medical device companies which employee 25,000 people. This highly technical and intense region also houses an unusually high number of world class universities and institutes; including MIT, Harvard, The Broad Institute, Massachusetts General Hospital, Brigham and Women's Hospital and many others. This region receives nearly 10% of all of total NIH national funding.

Nelsen attributed much of the success of the Boston-Cambridge Biotech Cluster to the key role MIT played as well as government funding to the key institutes that in turn brought innovation to the region (Nelsen 2005). In particular, she noted, MIT helped foster a culture that supplied to the region highly talented human capital, research that enables knowledge transfer, and MIT's highly entrepreneurial environment that helped its students to start their own companies. The entrepreneurial activities of MIT are notable in all aspects of the Massachusetts economy and not limited to just the Biotech cluster. A study by BankBoston in 1997 regarding the influence of MIT on the Massachusetts economy showed that 42% of the companies formed by MIT alumni are in Massachusetts alone – positively impacting the economy.

MIT's highly entrepreneurial environment comes as no surprise. MIT has worked hard to sustain an innovative and creative environment and attracts/accepts those students that come in with the necessary skills to take risks. In addition to its selective admissions process, in particular for undergraduate students, it aims at accepting those students who demonstrate excellent leadership qualities in addition to high grades. It introduces to the students through classes and events successful entrepreneurs and role models to follow. Competitions such as the one granting $100K for the best business plan further provide students the opportunity to flex their abilities as entrepreneurs.

In addition, MIT sustains strong ties with local industry. Formally, MIT sustains ties with the industry through research grants given to groups and departments at MIT. Furthermore, degree programs such as the Systems Design and Management Program allow professionals to work part-time and study part-time. Companies in Silicon Valley also boast of strong ties with the local universities while the local universities, such as Stanford, proudly stake claim to their integral role in successful development of the Silicon Valley. Researchers have spent considerable time in proving how formal relations have gone a long way in the strong relations between Stanford and the Silicon Valley. Some of these relations include an Honors Cooperative Program, a part-time degree program for engineers at nearby companies that offers the same classes and faculty that full-time on-campus students get. A Stanford Research Park, one of the world's first industrial parks, established in 1951 was another formal method to attract and establish links with industry. The industry on the other hand has seeped into the university through professorial endowments (Yahoo! Professorship), classrooms (Mitsubishi and Toshiba classrooms) and buildings (William Gates Computer Science Building).

These formal relationships between Universities and Industries are important, but there is more to it than that. An economist at the University of California at Berkeley, Anna Lee Saxenian, stated it best: "Stanford is part of the broader Silicon Valley culture. Much of what goes on between the university and industry has to do with people starting out as faculty or students. They keep in touch. People go back and forth from academia to industry. Much of this is informal."

It is this informal relation that our study aims to explore. Raz and Gloor noted in their study on startup companies in Israel, the companies with larger informal networks had survived the dotcom crash (Raz, Gloor 2007). Therefore, it is not enough to simply move to a cluster and sustain formal collaborations – a social informal network of communication is important and integral for survival. The communication network, whether through formal or informal channels, between industry and the university highlights the tightly or loosely knit integration of the cluster. Our study takes data from a comprehensive study of the Boston-Cambridge Biotech Communication network and zeroes in on the interaction of the Boston universities with the Biotech firms. We investigate the communication of firms with the Boston universities. In particular, we look at the following variables: physical distance from each university, size of the firm and the age of the firm. The thesis is organized as follows: the first section provides the details of the previous study – how the data were collected, what data were collected and what results were deduced. Then the next section extracts from the data set and investigates the role of universities against the variables discussed. The third section analyzes the results. In the final section, we conclude and offer suggestions for further research on this topic.

Chapter 2: The Previous Study:

In 2005, Dr. Thomas Allen and Dr. Ornit Raz began the study with a chosen target of the biotechnology cluster that developed within the Boston/ Cambridge region in Massachusetts (Figure 1). This 'cluster' of mostly newly-formed biotechnology firms has developed over the past 20 to 30 years and continues to grow. Depending on one's definition of what a biotech firm is, the number can range from 80 to over 200 firms. The Massachusetts Biotechnology Council, an industry trade association lists over 500 companies as members. Allen and Raz restricted the selection on the basis of location and the nature of the firm's principal activity to end up with just over 100 companies. From this select group of 100 companies, data was received from 40 companies. In each of the cooperating companies, a random listing of approximately ten percent[1] of their bench-level scientists was selected. The chosen scientists had either a PhD or MD level of education and were actively engaged in research. They were then asked to provide data on a series of randomly chosen days regarding the identity of firms within and outside of the cluster with which they held *scientific* communication. This sampling continued at a frequency of about once per week for a period of several months.

Research Method

The research method focused on locating firms that were solving technical problems in the biotechnology on a daily basis. There had to be a research agenda involved; that is, research scientists with a PhD had to be actively involved in the company doing scientific research. Using this as a base criterion, firms with research scientists were sought out and asked to participate based on the following criteria.

The Geographic Cluster: The Geographic cluster was defined through the use of postal zones. These were chosen on the basis of the concentration of firms shown in the MIT Sloan School of Management Entrepreneurship Center's data (Figure 1). Some of these postal zones covered part of Cambridge and others were in the City of Boston. They were generally in the vicinity of Harvard University, MIT, Boston University or Harvard Medical School[2] Organizations located outside of these regions formed the control group.

[1] In companies with fewer than 10 scientists, we sample all of those engaged in bench level research. Cooperation is, of course, voluntary and the overall research plan has been reviewed and approved by the MIT Committee on the Use of Human Experimental Subjects.
[2] The first two of these institutions are in Cambridge. The latter two are located in Boston.

Biotechnology Companies: An accurate listing of firms with the kind assistance of the Massachusetts Biotechnology Council and the MIT Sloan School of Management's Entrepreneurship Center[3] was compiled. This included a database listing of Boston's' biotechnology firms, pharmaceuticals firms, hospitals and universities. Around 90 firms and institutes are located at the core cluster (Boston and Cambridge) while another 100 firms are located in a variety of "suburbs". In order to focus attention onto those firms working on human therapeutic applications of biologically-derived pharmaceuticals, all companies that were in the agricultural, veterinary, and environmental products and services fields from the initial listings were eliminated. In addition, those with a primary focus on diagnostics as opposed to therapeutics were also eliminated. This finalized the list to be a final sample of around 70 firms of which 40 companies agreed to participate in the study. The chosen scientists must have at least a PhD or MD level of education and be actively engaged in research.

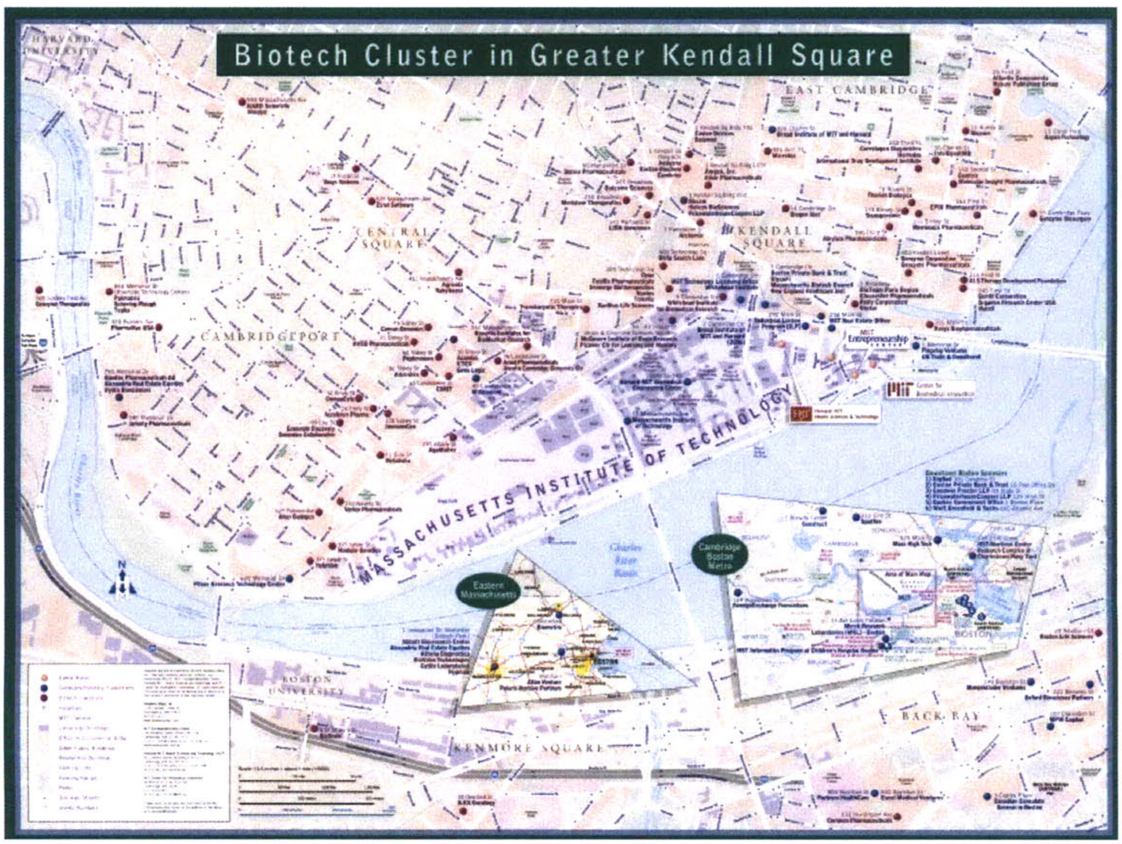

Figure 1: Biotech Cluster in Greater Kendall Square Area (source MIT Entrepreneurship Center)

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[3] In the case of the Entrepreneurship Center, we must acknowledge financial support and the encouragement of its Director, Kenneth Morse, as well. Special thanks go to Shyamala Balekuduru, who designed the Web page and helped in the preparation of the data.

Big Pharmaceutical Firms: A number of 'Big Pharma', or large broadly-based, pharmaceutical firms recently located research operations in the Cambridge/Boston area. The goal of these larger firms undoubtedly is to tap into the scientific communication network that may exist among the smaller, newly-formed firms. Their longer term goal is probably to acquire new technology and products through licensing from or acquisition of the firms owning the intellectual property. The large pharmaceutical firms were also included in their sample, to determine the degree to which they are successful in attaining this goal.

A Control Group

In addition to those firms located within the selected postal codes, scientists in a number of firms (both small and large) located within a 100 Km range of Boston but outside of the experimental region (the selected postal zones) were also selected and asked to participate. These more distant firms formed control a group that allowed comparisons on the basis of geographic proximity or separation.

Universities: There are five large research-based universities located within the selected postal codes. These were included in the study in a somewhat indirect way. Scientists in the universities were not asked to report their communications due to logistics. It would be impossible to try and find a representative sample from the universities. Instead, the firm scientists' communications to the universities were recorded and used as a basis for all analyses.

The Data Collection Web Page: A simple web page used for collecting the basic data of the study. In achieving simplicity and ease of response, a lot of information that might have been useful needed to be sacrificed[4]. The web page was designed to be completed within a maximum of 60 seconds[5]. The respondents were given the opportunity to report scientific communication with any of a total of 190 organizations. The organizations were listed alphabetically under each letter of the alphabet. The participant would select the letter the organization started with to limit the list of companies that appeared in a side window on the page. The organization could then be easily located and once all the organizations were selected, the participant would simply select 'submit'. The data was then assembled in a data base file and were available for analysis.

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[4] Achieving a simple, high response potential questionnaire is similar to achieving an uncluttered home or office. Much of what "might be useful in the future" must be eliminated

[5] Experience shows that the tradeoff between questionnaire length or complexity and response rate follows a very steep downward slope.

The Results from the Previous Work

The previous work focused on data collection and analysis at the company level. The analysis aimed to visualize the network, to analyze the key players of the network and whether distance (in or out of the cluster) played a role in the communication patterns.

The Network Visualization: With the use of social networking tool, Condor[6] the evolution of interaction patterns within the Biotech Cluster was analyzed. Furthermore, it helped visualize the environment for the visual identification and analysis of the dynamics of communication in social space [7] (Gloor, 2006). From the visualization of the interactions and connections, a 'super cluster' was identified. This super cluster represented those firms who were tightly integrated in the network (Figure 2).

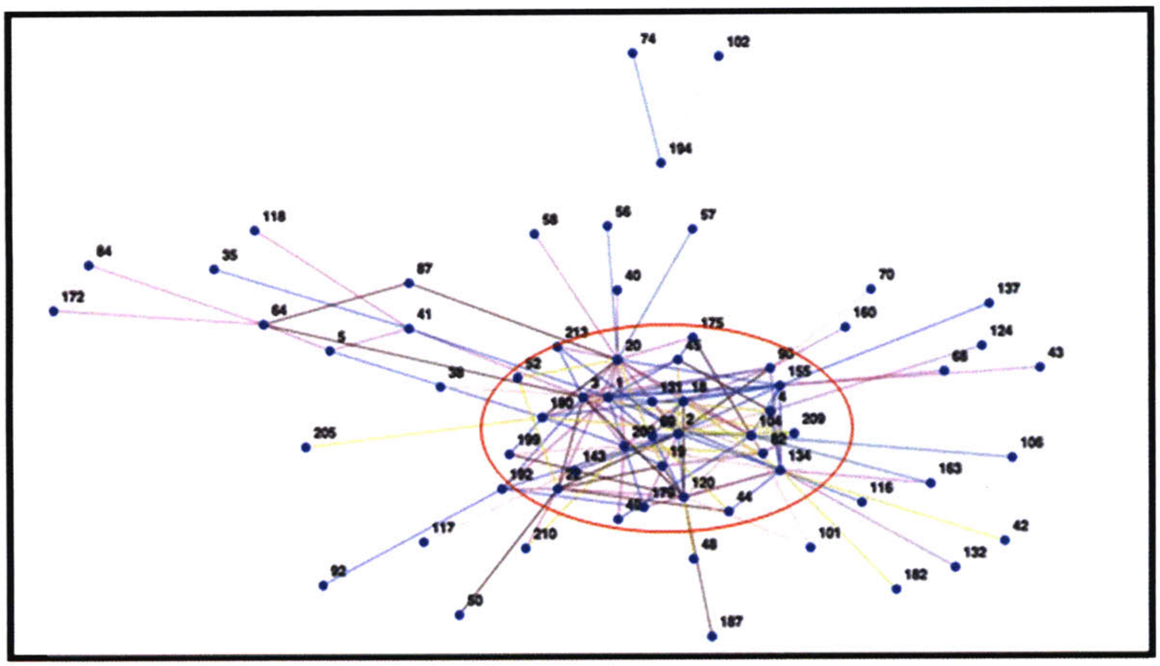

Figure 2: The Super Cluster within the Biotech Cluster. The length of connecting 'edges' between nodes (firms) is inversely proportional to the amount of scientific communication reported between those firms.

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[6] Formerly known as "TeCFlow",

[7] The framework is based on a multi-year research project on Collaborative Knowledge Networks by a global group of universities under the leadership of the MIT Center for Coordination Science and the Center for Digital Strategies at Tuck at Dartmouth (see http://www.ickn.org/ickndemo/).

By further analyzing the super cluster, it was noted that the four of the five Boston Universities (MIT, Harvard, Boston University, TUFTS, and Northeastern University), all the Big Pharmaceuticals and the Biotechnology firms were present in this network (Figure 3). This was, in particular, a significant result indicative of the importance of universities in cluster as well as possible precursors to innovation.

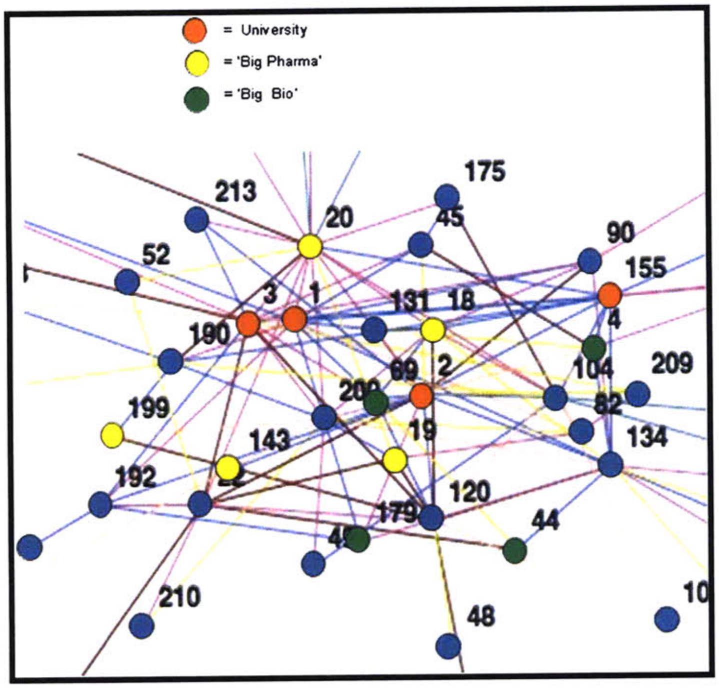


Figure 3: A Closer View of the Super Cluster and its Key Players

It was this analysis and visualization that motivated this study to further understand the importance and role of Universities in the Boston Biotech Cluster.

The Communication Network and Distance: Previous work also analyzed distance as a function of the communication network. The mean distance of a firm in relation to the network was calculated as follows. First, the distance between each firm was calculated using the great circle distance formula:

$$d = r \times \cos^{-1}[\sin Lat1 \times \sin Lat2 + \cos Lat1 \times \cos(Lon2 - Lon1)]$$

Where:

d= distance

r= radius of the earth

Lat1 =Latitude of location 1

Lat2 =Latitude of location 2

Long1=Longitude of location 1

Long2=Longitude of location 2

Once the distance of each firm to all of the othesr was determined, a mean distance was calculated by averaging all the distances together. Using the final mean distance, a scatter plot was created of the mean distances against the number of communications with All of the other organizations. The distances and radius units were in miles. Finally, the key players and their positions within the graph were highlighted. This resulted in the following figure (Figure 4):

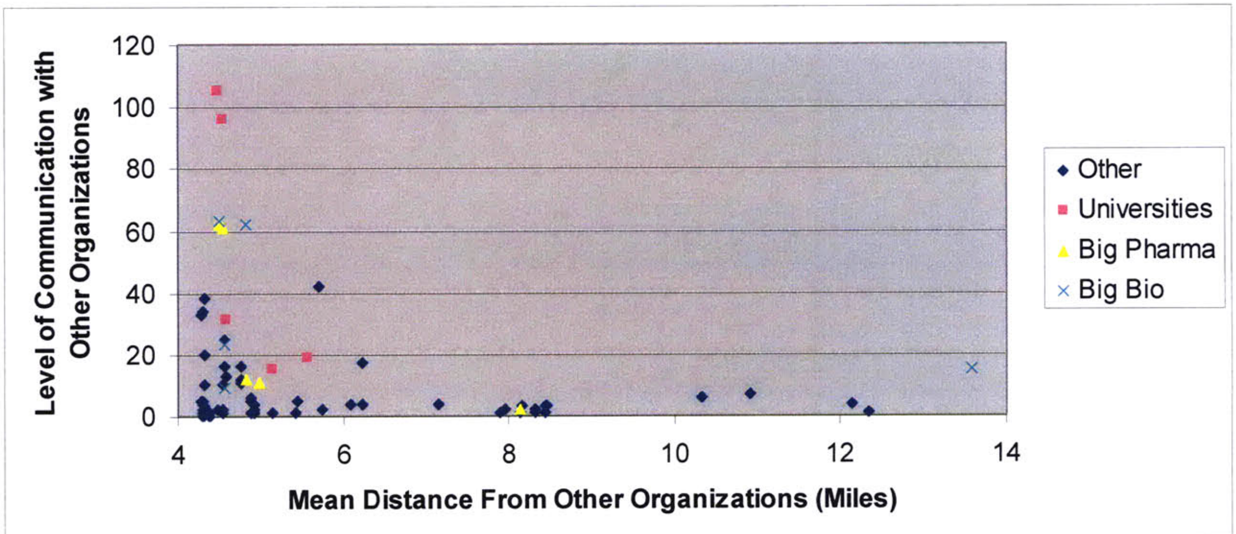


Figure 4: Distance as a function of Communication of firms

Conclusion and Limitations of Previous Study: The previous work made great strides in understanding the current network infrastructure of the Boston-Cambridge Biotech Cluster. It was able to gather the communication data to highlight and visualize where and who the key players within the cluster were. The universities were seen to be the organizations most communicated to while the big pharmaceuticals and big biotechnology firms also play a key role. It provided the motivation for this study to delve deeper into the role of universities.

However, there were a few limitations on the previous study. The main limitation in the conclusions drawn from the previous study drew from the unit of analysis. The study focused on communication per company. While this is one method of analysis, it does not take into account that each company had a different number of research scientists participating in the study.

Also, distance is a very subjective matter. While the previous study used a very solid method to quantify and calculate an average distance, it still remains difficult to try and form a correlation with the average distance. The reason is that where the communication took place was not and could not be captured. As such, it is quite possible the technical communication took place at a conference in a completely different city. Therefore, the distance calculated and correlated may in fact have little to do with the actual rate of communication. Hence, it is difficult to draw any significant conclusion using this methodology of distance against the number of communication.

Finally, the previous study still managed to draw certain conclusions. Yet it was unable to quantify the correlation or regress to hold other factors constant.

This study analysis the data using the scientist-per-communication as a unit of analysis, uses degree of centrality and further runs regression and correlation analysis to quantify the relationships.

Chapter 3: Our Study:

Nelson, Saxenian and Fleming have all noted the importance and roles of universities in helping clusters to develop and grow successfully. The visualization produced by the Condor software also highlighted how integrated the universities are in the Boston-Cambridge Biotech Cluster. This was particularly significant as there was only communication data 'to' the universities. Universities, themselves, were not sampled. That is, communication initiating out of universities into the biotech cluster was not recorded. Therefore, it is possible that a lot more communication from universities to or from biotech firms who were not participants in the study was not captured. Despite that, universities emerged with the highest counts of communications – MIT and Harvard were competing closely for the number one spot.

Given these indicators, this study took off from where the previous study stopped in regards to the roles of Universities as well as expanded the analysis scope. This study zeroed-in on the communication patterns of firms to the universities and correlated it with factors such as organizational size, degrees of centrality, type of firm and organizational age. The significance level for the mean distance was also analyzed. Finally, OLS regression analysis was used to analyze the effect of being in the cluster.

The Data

As the previous study recorded communication data from the firm to firm, we focused primarily on the participant firms. Only participant firms would be communicating to the universities. Hence, it would not make sense to include firms that were not participants as the data of them communicating or not communicating with the universities would remain unknown. It would be impossible to ascertain whether any communication resulted, as such, the data results would then not be accurate.

As such, in total, our study then focused on the 30 participant firms which included over 3500 communication data points. The five Boston Universities that were studied are: MIT, Harvard, Boston University, TUFTS and Northeastern University.

Analysis Method:

First, a general set of analysis was conducted using predictors such as communication per scientist, organizational age, organizational size, degrees of centrality and the mean distance. Descriptive statistics were taken and correlations calculated. For the OLS regression models, the dependent variable in our study was the communication per scientist in each firm. The independent variables were the organizational age, organizational size, degrees of centrality and the mean distance. We modeled the effect of being in the cluster on the communication.

Communication Per Scientist: For all our calculations, the unit of analysis will be communications per scientist per firm. That is, the total number of communications from the firm was divided the total number of research scientists who participated in the study.

Organizational Size: The organizational size of each of the firms was calculated using the current number of employees employed by the firm. This information, if not already available on their website, was obtained by contacting the firm itself. Kindly note the discussion regarding the subjectivity of the organizational size in the discussions section.

Organizational Age: The organizational age was calculated using their founding year or year of establishment for that particular branch in the Boston-Cambridge region. This information, for the most part, was readily available on all the firms' websites.

Degrees of Centrality: The degree of centrality was calculated according to the number of links incident upon the node. The node in our graph was the firm itself and the links translated to at least one communication link originating out of the node to another node. Hence, it was the number of unique firms each firm communicated to.

Hypotheses:

The study was directed at understanding the role of universities and what were the predictors for influencing the rate of communication for each scientist in the biotech cluster. The hypotheses were formulated as follows:

- H1: *Firms inside the cluster will communicate more to the universities in comparison to the firms outside the cluster.*
- H2: *Younger firms will communicate more to universities in comparison to older firms.*
- H3: *Smaller firms communicate more to universities in comparison to larger sized firms.*
- H4: *Firms with greater degrees of centrality communicate more to the universities.*

Discussion: The previous study showed firms inside the cluster communicated more than the firms outside the cluster. And given that universities were the top organizations that firms communicated with, it can be reasonable to expect that within the cluster, universities continue to be the top firms communicated with.

Regarding the younger firms hypothesis, the basis of the hypothesis arises from the notion that younger firms are spin-offs from universities. They are usually founded by professors or recent graduates from the universities and therefore, still maintain ties to the universities and the network there. Thus, the hypothesis assumes as a result, the younger firms will communicate more. situation predicament as the younger firms and, therefore, will communicate more with universities. Finally, a firm that is well embedded in a network and therefore, has a higher degree of centrality will also include universities as part of their network and be communicating more with them as well.

Results:

As mentioned previously, the universities came out as the most communicated to by the biotech firms in the Boston-Cambridge Biotech Cluster. Not only did the universities receive the highest number of communications but they also had the highest number of unique firms contact them (Figure 5).

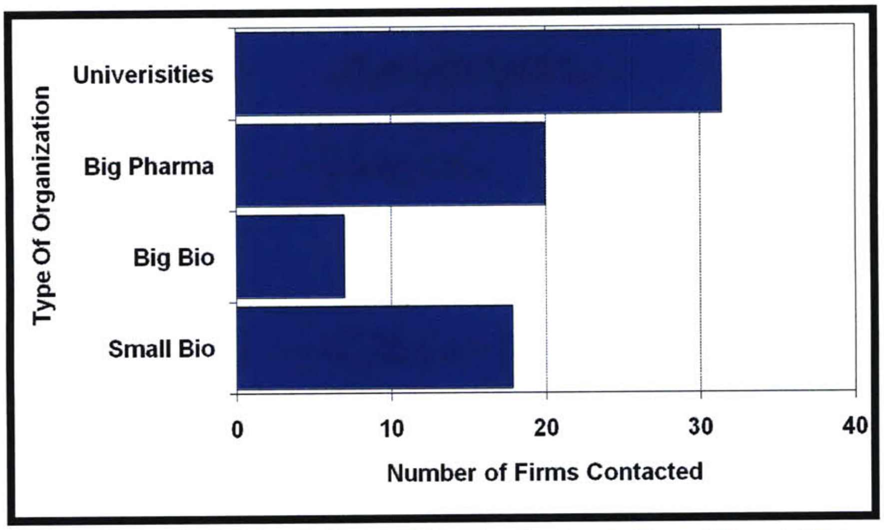


Figure 5: Number of Connections to Other Organizations by Type of Organization

Using the degree of centrality of each node within the network (reference) as a metric for breadth of communication, we can compare the two groups (Figure 6). Doing so reveals a significant difference in their centrality or embeddedness in the network. Those organizations within the geographically defined cluster region have nearly twice as many connections with other organizations (Figure 6). Since centrality indicates the number of other firms with which a given firm may be in contact but not the amount of contact, we also compare the experimental and control firms on the basis of the amount of communication reported (Figure 7). Here we find that scientists in firms that are within the geographic bounds of the cluster reported that along with distributing communication across a larger number of firms, they also simply communicated more. Physical propinquity within a cluster may or may not be the cause of greater communication but it certainly correlates very strongly with the amount of inter-organizational scientific communication and assuredly makes it easier to attain greater levels of communication.

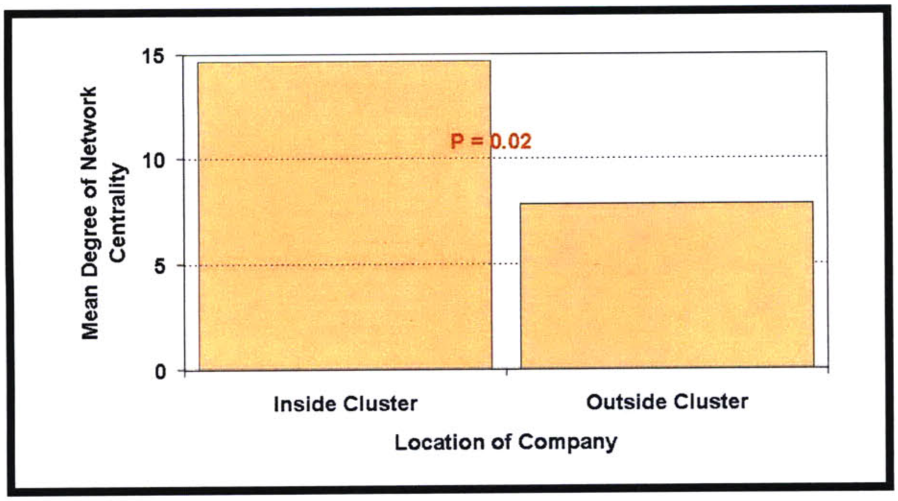


Figure 6 Mean Centrality of Organizations in the Experimental and Control Groups.

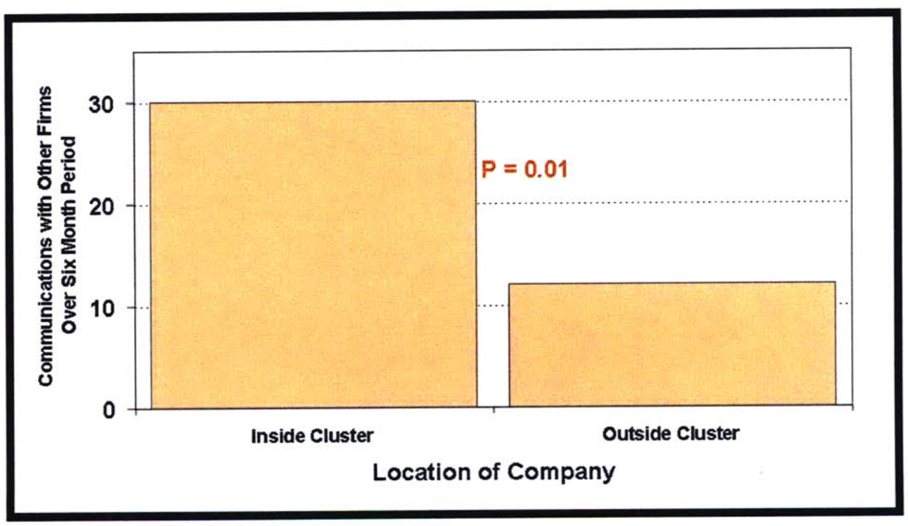


Figure 7 Mean Level of Communication

As our study focuses on the role of universities in particular, the next sections break down the communications to the universities per scientist. We do not distinguish or break down within the group of universities. This helps remove the innate biases that might exist within the universities (e.g. rankings, research objectives, etc). As such, the next part takes each hypothesis and reports the results.

H1. Firms inside the cluster will communicate more to the universities in comparison to the firms outside the cluster.

In order to analyze and form a conclusion to this hypothesis, the firm was seen to be a representative of the number of scientists within it. As some firms had more scientists, the unit of analysis representing firms became communication per scientist. As such, the data were split into three groups: communication per scientist to all the firms, communication per scientist to universities only and communication per scientist to non-university firms only. Next, it was further categorized into whether the communication arose from within or without the cluster. One-way anova was run to test and compare the means to see if there was any significance in the differences between the means. Bar graphs also provided visualization for comparison of the means.

A first look (Table 1) shows scientists communicated at an average of 1.4 communications every six months to Universities if they were inside the cluster. Surprisingly, scientists outside the cluster tended to communicate more to universities at the rate of 1.7 communications every six months. This compares to them communicating to all bio-tech firms at the very least 2.7 communications every six months and in an essence, communicating once to non-universities in the six month period. This corresponded to scientists inside the cluster communicating more to non-universities at the rate of 1.5 every six months. Thereby, their overall communication rate was found to be nearly 3 times to all bio-tech firms every sixth months. As such, while firms within the cluster tended to communicate more than their outside counterparts, firms outside the cluster communicated more to universities than the firms inside the cluster.

Table 1: Descriptive Statistics for Communications inside and outside the Cluster

Descriptive Statistics

		N	Mean	Std. Deviation	Std. Error
Communication per Scientist to universities	Inside Cluster	17	1.3519	1.96425	.47640
	Outside Cluster	13	1.6818	2.41459	.66969
	Total	30	1.4949	2.13749	.39025
Communication per Scientist to all organizations	Inside Cluster	17	2.8580	3.27967	.79544
	Outside Cluster	13	2.7443	3.32909	.92332
	Total	30	2.8088	3.24403	.59228
Communication per Scientist to non-universities	Inside Cluster	17	1.5080	1.47095	.35676
	Outside Cluster	13	1.0625	1.27630	.35398
	Total	30	1.3149	1.38500	.25286

However, when noting whether the differences were statistically significant, many different statistical methods were explored to compare the significance of means between each group in each category. Finally, One-way Anova test was used to compare the significance of means between each group (inside/outside the cluster) in each category.

Table 2displays the results from the One-way Anova test of comparing the significance in the means. It was noted the communication rates per scientists within the three categories were not statistically significant. That is, the effect of being in or outside of a cluster did not vary significantly between the three groups.

In conclusion, there is no statistically significant difference of communication to universities within or outside the cluster. Geographic location was not seen to be an influencing factor for firms.

One way ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Comm per Scientist to universities	Between Groups	.802	1	.802	.170	.683
	Within Groups	131.695	28	4.703		
	Total	132.497	29			
Comm per Scientist to all companies	Between Groups	.095	1	.095	.009	.926
	Within Groups	305.094	28	10.896		
	Total	305.189	29			
Comm per Scientist to non-universities	Between Groups	1.462	1	1.462	.756	.392
	Within Groups	54.167	28	1.935		
	Total	55.628	29			

Table 2: Anova Test for comparison of the Means

H2: Younger firms will communicate more to universities in comparison to older firms.

The analysis for this hypothesis focused on correlating the communication per scientist to universities data set against the age of each firm. The correlation coefficient was calculated to test the strength and direction of the relationship. In particular, the Pearson product-moment correlation coefficient, a standard method to quantify correlations, was calculated. This was then tested for significance.

Plotting of the firms' age against the communication per scientist to universities (Figure 8) shows that as the firm's age increases, the number of communication decreases. The high communicators to universities were the younger firms. Younger firms averaged between 7 to 9 communications in the six months as compared to the older firms who averaged less than 4 communications to the universities.

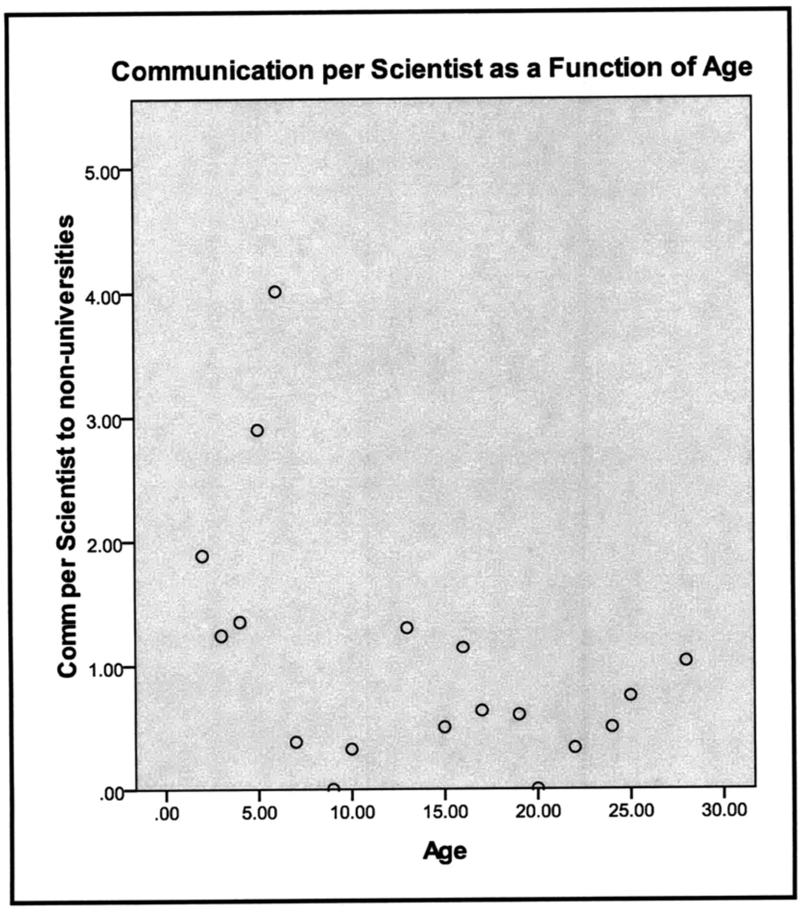


Figure 8: Communication per Scientist to Universities as a Function of Organizational Age

Using the Pearson Correlation 1-Tailed Test, Table 3 shows significant correlation of age increasing to communication decreasing with the correlation coefficient at -.34. The correlation is significant at the 0.05 level.

Table 3: Correlations Matrix of Age against Communications per Scientists to Universities

Correlations of Age against Communications per Scientists to Universities		
		Age
Communications per Scientists to Universities	Pearson Correlation	-.34*
	Sig. (1-tailed)	.03
	N	30

.Correlation is significant at the 0.05 level (1-tailed)

Therefore, the younger firms do communicate more to universities than the older firms. Interestingly, the same pattern exists for the firms and their communication to non-universities. The Pearson Correlation (

Table 4) for this is signification at the 0.01 level – indicative of a highly correlated function. From this, it is noted that younger firms communicate more than their older counterparts - irrespective of whether the communication is to a university or a non-academic institution.

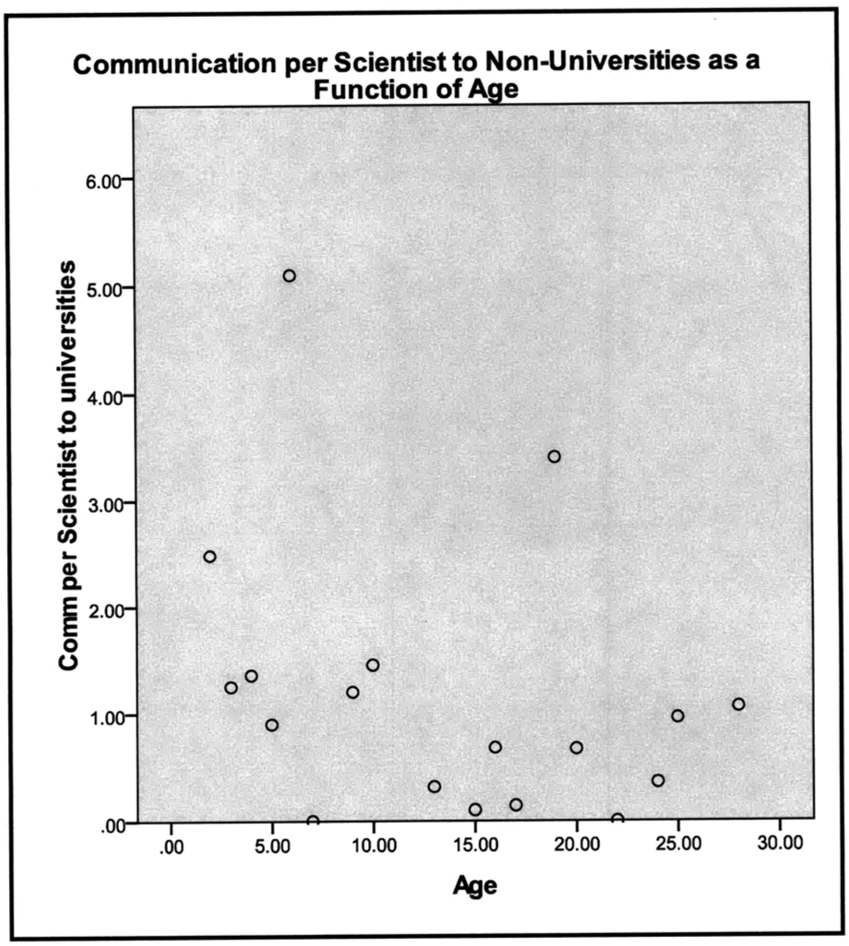


Figure 9: Age as a function of communication per scientist to non-universities

Table 4 Correlation matrix of Age as a function of Communication per Scientist to all non-universities.

Correlations of Age against Communications per Scientists to all non-Universities		
		Age
Communications per Scientists to non-Universities	Pearson Correlation	-.44*
	Sig. (1-tailed)	.01
	N	30

.Correlation is significant at the 0.05 level (1-tailed)

As such, while our hypothesis focused on firms communication to universities and any correlation with ages and was found to be significantly true, we found that all younger firms communicated more than their older counterparts.

H3: Smaller firms communicate more to universities in comparison to larger sized firms.

The metric size proved to be an interesting one. Size was quantified according to the number of employees a company had. While some companies were able to provide the exact number of employees, the larger companies/institutions reported a simple metric stating they had more than 1000 employees. As such, equal-sized categories were created where firms were placed into their respective categories.

As such, the categories became:

Size 1: Between 1 to 20 employees

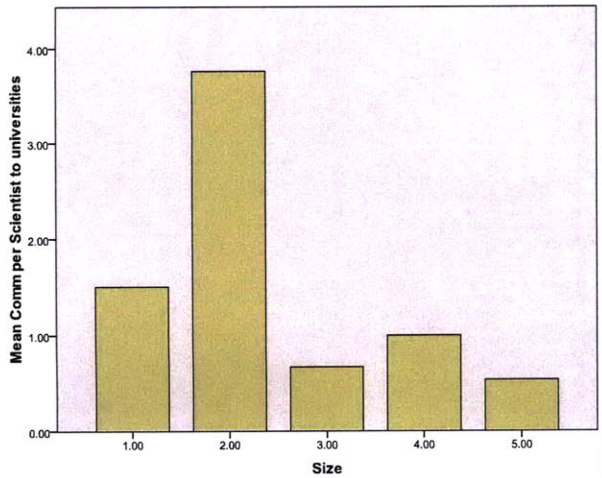
Size 2: Between 20 to 50 employees

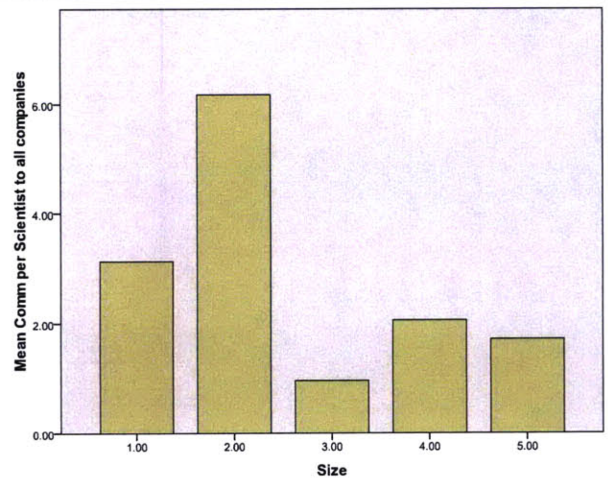
Size 3: Between 50 to 100 employees

Size 4: Between 100 to 500 employees

Size 5: 500+ employees

There was an equal number of firms in each category. This produced interesting results. It was noted that small to medium sized companies; that is, companies of sizes 1 and 2 were the highest communicators in all three categories (Figure 10).





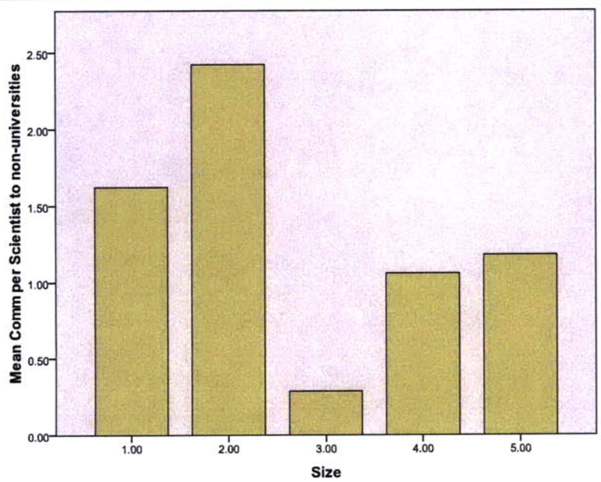


Figure 10: Size as a Function of Communications per Scientist

To find out the exact correlations, the Spearman Correlation tests were run (Table 6). Size remained significant at the 0.05 level for both communications per scientist to all organizations and communication to scientists to universities. It became significant at the 0.10 level for communications per scientist to non-universities.

Table 5: Spearman Correlation of Size as a function of Communication per Scientist

Correlations of Size against Communications per Scientists		
		Size
Communications per Scientists to Universities	Pearson Correlation	-.32*
	Sig. (1-tailed)	.04
	N	30
Communications per Scientists to non-Universities	Pearson Correlation	-.23
	Sig. (1-tailed)	.10
	N	30
Communications per Scientists to all organizations	Pearson Correlation	-.31*
	Sig. (1-tailed)	.05
	N	30

.Correlation is significant at the 0.05 level (1-tailed)

Therefore, our hypothesis that smaller sized companies communicate more than larger companies holds true.

H4: Firms with greater degrees of centrality communicate more to the universities

Plotting the degree of centrality against the communication per scientists to universities, there seemed to be an indication of firms on either end of the spectrum did not communicate as much as the firms who maintained a reasonable amount of centrality (Figure 11)

To find out how much, if any, correlation there is between communications per scientist to the Degree of Centrality of a firm, the Spearman's Correlation tests were run (Table 6). It was noted there were significant correlations of Degree of Centrality to Communication per Scientist to all companies (a coefficient of .334 with significance at less than 0.05) and to all non-academic institutions (a coefficient of .45 with significance at less than 0.01. University communication became significant at the .10 level.

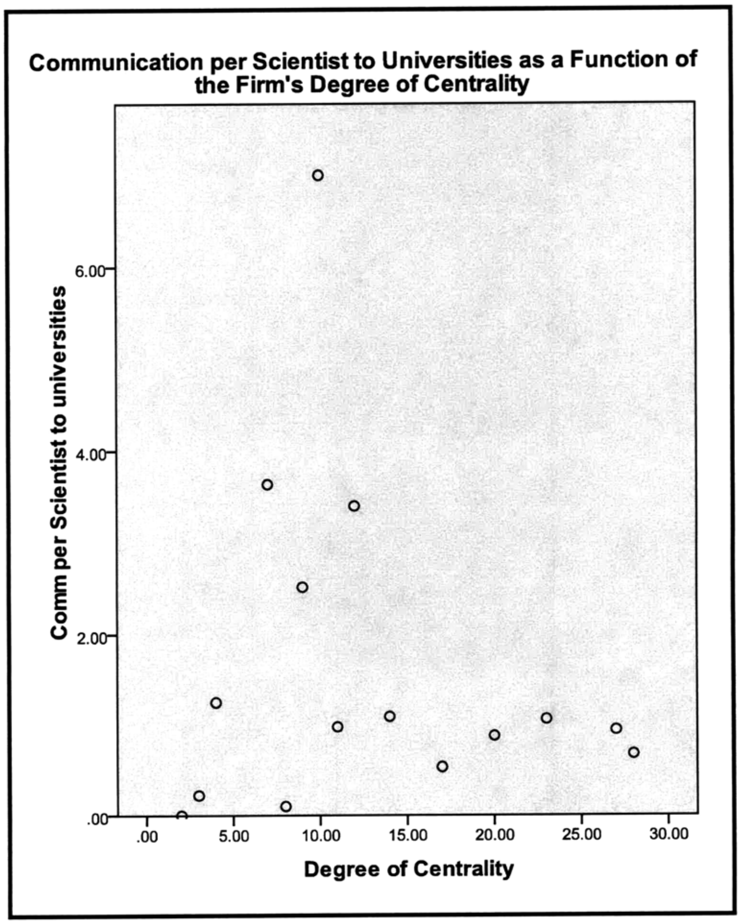


Figure 11 Degree of Centrality as a function of Communication per Scientist to Universities

Table 6 Spearman's Correlation of Degree of Centrality as a function of Communication per Scientist

Correlations of Degree of Centrality against Communications per Scientists		
		Degree of Centrality
Communications per Scientists to Universities	Pearson Correlation	-.24
	Sig. (1-tailed)	.10
	N	30
Communications per Scientists to non-Universities	Pearson Correlation	-.46**
	Sig. (1-tailed)	.01
	N	30
Communications per Scientists to all organizations	Pearson Correlation	-.33*
	Sig. (1-tailed)	.04
	N	30

.Correlation is significant at the 0.05 level (1-tailed)

*****. Correlation is significant at the 0.01 level (1-tailed)***

As such, our hypothesis that firms with greater degrees of centrality communicate more to universities than the firms with lesser degrees of centrality shows correlation at only 0.10 level.

Chapter 4: Discussion

In this section, we discuss each of the hypotheses.

- H1: *Firms inside the cluster will communicate more to the universities in comparison to the firms outside the cluster.*

There were no significant differences between the firms inside and outside the cluster with regard to their communication with the universities. In the similar way, there is no significant difference between the communication to all organizations and to non-academic institutions with regard to their location of being inside and outside the firm.

This may come as a surprise as the expectation would be that firms inside the cluster would communicate more. The metric here is communication per scientist over a period of six months. As noted in the beginning of the results section, the overall number of communications per firm was greater inside the cluster than outside. Furthermore, firms inside the cluster also maintained higher degrees of centrality; that is, the firms inside had a greater number of unique organizations they contacted over the six month period.

So while there may not be a significant difference in the communication per scientist inside or outside the cluster,putting the various metrics in perspective, we note that firms inside the cluster as a whole communicate more to a greater number of unique firms.

- H2: *Younger firms will communicate more to universities in comparison to older firms.*

Our results indicate a significant correlation of younger firms communicating more to universities than the older firms. The significance level was below 0.05. The correlation coefficient is -0.34.

Younger firms could be communicating to universities more than the older firms for many reasons. First, these younger firms are spin-offs from the universities. They are often founded by recent graduates who established companies based on their research work while at universities and therefore, continue to maintain strong ties to the universities. Professors too establish spin-offs from their research work and this helps them to maintain strong ties to the academic communities.

Another phenomenon that we came across which might explain why younger firms may communicate more is that many of the younger firms have asked professors from the university to be part of their advisory board. We found many of the younger firms in particular who have academic professors as part of their advisory boards. These startups are frequently sold off to larger well-established firms. As such, in either case, the professors are no longer part of the firm and therefore, this academic tie is broken and communication drops.

Finally, the older firms are also well established firms who maintain ties to the universities for a variety of reasons. They wish to recruit graduates, fund research and benefit from capitalizing published research. These ties do not qualify as scientific research as the topic of communication is not scientific in nature. As such, there may be a greater emphasis on the industrial links and communication that have little to do with technical research.

- H3: *Smaller firms communicate more to universities in comparison to larger sized firms.*

As stated previously, the metric used for size is the number of employees in each firm. Before discussing the results, using the number of employees as a metric has many caveats. The number of employees is not necessarily indicative of research capabilities or research objectives of a company. This is because the number of employees often includes the staff that helps with the overall operation of the company but little to do with its technical research or problem solving. A more accurate method to ascertain the size of a company, for the future, would be to use the number of scientists to represent the size of the company. However, this number is not always available and difficult to obtain[8]. Furthermore, the number of employees, irrespective of their role or position in the company, is a standard metric used to study many different effects, etc.

Consequently,, we chose to use the number of employees to represent firm size. Our results noted a significant correlation of size as a factor influencing the communication of firms. Significance was at the 0.05 level with the correlation coefficient -0.32. We noted smaller sized firms, in particularly firms with 20 to 50 employees communicated the most to both universities and non-academic firms.

While there may be many reasons for this as well, it is important to discuss whether or not too much communication for a smaller company is actually beneficial. Intuitively, the more the firm communicates may seem to be a good thing. However, smaller sized firms also mean that there are fewer employees trying to accomplish the same scientific work as their neighboring larger firms. The more time the employee spends communicating equates to that much less time spent on product development and research application. Both are vital to a firm's growth and survival.

[8] Companies often regard this statistic as proprietary.

Consequently, while it is important to maintain communication to universities and other firms, smaller-sized firms in particular need to be careful and balance the activities of communicating and producing.

- H4: *Firms with greater degrees of centrality communicate more to the universities.*

The degrees of centrality equate to the number of unique firms the firm contacted or communicated within the time frame. It shows how well embedded a firm is in the network. It is also interpreted in terms of the immediate risk for a node of catching whatever is flowing through the network (such as a virus, or some information). In our case, this is the risk of catching innovation/research that flows through the network. As such, by definition, the greater the centrality, the more innovation/research the firm is in a position to capture. In many ways, this may be a more important than the number of times the firms communicated.

Our results indicated that firms inside the cluster experience a greater degree of centrality – they have a greater set of unique firms who they contacted during the six month period. Degree of centrality was also directly correlated with the amount of a firm's communication. There was significance at 0.10 level for communication to universities with the correlation coefficient being 0.24.

We noted that firms at either end of the spectrum – that is, firms with too high or low degree of centrality – communicated less to universities. It was the firms that were in the middle who communicated the most to the universities.

It is understandable why firms with higher degrees of centrality may not be communicating more with universities. Their communication time is limited and split between their many contacts. The firms who have very low degrees of centrality can also be expected to communicate less to universities. They may not have enough contacts to include universities as part of their network and therefore, may be missing out on vital information being passed through the network.

The firms who are in the middle communicate the most to universities. These firms have maintained a modestly-sized network but universities play a central role in their technical communication and problem solving. They are possibly heavily reliant on university resources as their networks are not large enough to be able to tap into other resources to solve technical or research problems.

Chapter 5: Conclusion

In this study, we focused on the relationship of the firm and universities that are within a cluster. We looked at their location in terms of being inside or outside of the geographic area of the cluster, their age, size and their degree of centrality as the independent variables with communication per scientist as the dependent variable. We found the firm's location inside or outside the geographic cluster was not an influencing factor while age, size and degree of centrality were directly correlated with the firms' communication per scientist in the six month period. While we presented many reasons for these results, further research and studies need to be conducted to understand the reasons behind the various results. Finally, it would be interesting to revisit the firms to understand who within the universities the firms contacted – whether it was students, professors or post-docs. And to follow up with whether any publications resulted from the initial communications and the length of time before the communication resulted in a publication.

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