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EDITORIAL: LESSONS LEARNED FROM OUR DISCIPLINE, AND MORE EFFECTIVE USE OF TECHNOLOGY AT *THE INDUSTRIAL GEOGRAPHER*

Industrial geographers have long been interested in the manufacturing processes employed by the firms we study. We know well that change in the way in which industrial activities are organized can have a real and substantial impact on the firms and communities involved. For example, the introduction of "just-in-time" processes (Rubenstein 1986) to the North American automobile sector had profound implications for everyone connected to the industry. Although the long-run consequences of the heightened competition heralded by new production methodologies have included no small measure of pain for North America's "Big Three", most industrial geographers would agree that the global auto sector has become more efficient and now produces a much higher-quality product than at any time in the past. Change has been good for the automotive industry, even if the same cannot be said for every one of its constituent firms.

While we're hoping to not stretch a metaphor beyond advisable limits, the editors of *The Industrial Geographer* would like to announce some process-based changes that in some ways parallel the thinking behind "just-in-time" production. Effective with Volume 7 (2010), the *IG* will switch to what we might term "just-in-time" publishing, in an attempt to make our already-speedy production process even more efficient. We believe that both our authors and our readers should benefit from this move.

Under our new procedure, articles will appear on the journal's website within a target time of *one month after final acceptance*. Making this change, in many ways, is simply a matter of taking advantage of the inherent flexibility provided by our web publishing technology. Our readers will now have a reason to visit the *IG* site for new content more often throughout the year.

With this development, our goal is to keep initial review times unchanged from previous years, with a target of returning reviewer comments *six to eight weeks after manuscript submission*. However, publication times should still decrease, as articles will not have to wait for our previous, twice-per-year publication schedule. We hope this rapid turn-around will prove helpful to prospective authors.

Outside of shorter times to publication, another primary benefit that we would like to build through this change is the possibility of a degree of *immediacy in debate and exchange* that simply cannot be achieved by journals constrained to a costly and relatively inflexible hardcopy publishing schedule. There is a real opportunity here to build interesting discussions around the topics we publish.

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Of course, how this flexibility ends up being used is up to our readers and contributors in the industrial geography research community. We invite the submission of commentaries and follow-up analysis related to previously-published articles. We challenge our readers to examine the current issue for points amenable to reply or further discussion in the weeks ahead.

One final element is worth mentioning: even though we will publish articles as accepted during the year, our goal is to maintain at least two issues per annual volume. Articles published from January through June will generally appear in issue 1, with July through December articles comprising issue 2. As well, in maintaining distinct issues within a volume, we would like to continue to provide the possibility for researchers to organize special theme issues, in which a set of related articles could appear together in a collection. We invite special theme proposals for collections of anywhere from two to six papers.

In conclusion, a real and ongoing need exists for research that provides an empirical and applied perspective on the many phenomena we find interesting as industrial geographers. Our hope is that perhaps the research published here might in turn provide the inspiration for the next "just-in-time" breakthrough for our beleaguered automobile industry.

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Postscript

This issue includes a tribute to Alan MacPherson, a prolific contributor to industrial geography and good friend to many in the field, who passed away earlier this year. We will all miss him.

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CORPORATE DIRECTORS AND EDUCATIONAL AFFILIATIONS: A SPATIAL-TEMPORAL ANALYSIS

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ABSTRACT

Research examining the roles and locations of business leaders, including the boards of directors, makes an important contribution to our understanding of corporations. Within the context of the emerging literature focusing on firms as dynamic organizations constructed through social relations, the spatial dimension of business leadership is an important but under-investigated area of research. This paper contributes to this field of geographic investigation by identifying the most important universities for the education of directors of America's largest corporations. The results demonstrate the continuing dominance of Harvard University and other Ivy League institutions, with gains also experienced by major Sunbelt universities. Boston stands out from all U.S. metropolitan areas in terms of the breadth and depth of its universities' national network of director alumni. Finally, director affiliation linkages examined here are only weakly related to previous standard measures of corporate influence, such as metropolitan headquarters hosting status. Examination of the geography of corporate directors and educational affiliations represents a new and distinctive perspective on the spatial distribution of corporate culture and influence in America.

Key Words: boards of directors, educational affiliation, corporate culture

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INTRODUCTION

Corporate control in America has a long history of discussion and debate. The people who influence these corporations and how we might see this influence exerted are some of the most important themes in the business literature (Drucker 1946; Chandler 1962; Pfeffer & Salancik 1978; Domhoff 2002). This body of research on corporate control has emphasized the structure and composition of firms and how corporate structures relate to the strategies that these businesses pursue. Geographic research related to this theme has mainly focused on the cities where corporations are located, contributing to the literature of business location and economic development (Semple 1973; Wheeler 1988, 1990; Rice 2006; Rice & Pooler 2009).

Research examining the roles and locations of the leaders of corporations, including the boards of directors, also makes an important contribution to the understanding of corporations more generally. Where corporate leaders live, the nature of their family ties, and the social clubs to which they belong are just three attributes that shape the social fabric of decision-makers and the decision-making processes of corporations. The importance of corporate decision-makers has indeed been reflected in the literature (Sonquist & Koenig 1975; Useem 1984; Domhoff 2002). However, this area of study has thus far been dominated by sociology and business academics. With the emergence of economic geography research focusing on dynamic organizations constructed through social relations, the spatial dimension of business leadership offers an under-investigated area that could contribute to this field. Adding strength to this case, Yeung (2005, 310) contends that the firm is actually a constellation of network relations governed by social actors and that it is "conceptually important to map out the firm and its wider relations with other actors and institutions in society and space".

This paper takes up Yeung's challenge to examine from a spatial perspective one key characteristic of the leaders of corporations: their educational affiliations. It is asserted that the institution where directors obtain their educations, including the social networks established in these places, shapes their decision-making practices. Therefore, key choices made by corporate America are influenced in part by a director's university affiliation. Cities that host important universities influence the corporate culture of these firms.

The purpose of this paper is to identify the most important universities where directors of the largest American corporations received their training. Directors of the largest American firms in 1986 are compared with directors of the largest American firms in 2004, with the purpose of recognizing the changing influence of educational institutions associated with the directors of these firms. The intent is not about the universities themselves exercising direct influence over corporations. Rather, it is to highlight the social networks that universities create through their alumni connections and then suggest that these links are important mechanisms that contribute to corporate culture and influence.

From a geographical perspective, an extension of the universities question is to identify cities that possess a significant number of alumni connections, especially those that have become more noteworthy over time. The interest here lies in the social and geographical networks that universities create through their alumni connections. Here, transmission of corporate culture is from individuals located in one city to individuals and firms in other places. Employing a bivariate regression-based approach, the study then compares these findings with those of previous research that measures the location and concentration of corporate control in a different fashion. The goal of this methodology is to highlight those cities that have been underestimated in the previous literature on corporate geography across the United States.

FIRMS, INDIVIDUALS, AND CORPORATE CONTROL

Historically, much research in economic geography has utilized the firm as a basis for investigation (Averitt, 1968; Stolzenberg, 1978; Baron & Bielby, 1980). Nelson (2005) rationalizes this viewpoint by suggesting that individuals are interchangeable parts. More recently, though, academics have called for a more comprehensive view of the firm because this collection of parts is actually crucial to firm competitiveness (Garnsey 1998). Schoenberger (1997) and Adelstein (2008) argue the need to move research beyond where firms meet the world to highlight humans within the cultural manifestations of firms. Theories of firms as relational networks should be positioned within the interactive behavior of individuals.

Given that individuals are a suitable unit of analysis, and that the most appropriate focus for research is on economically-influential people, it is also important to understand the key groups of people involved in the top level of decision-making for corporations. Three principal players are central to corporate governance: the *shareholders*, who own the companies, the *management*, that leads the daily operations of corporations, and the *directors*, who are elected by the shareholders to oversee the management. Directors form the focus of the present analysis because of their responsibility as the ultimate caretakers of corporations (Johnson et al. 1996).

Directors have a great deal of influence in the power structure of businesses. In fact, it is well documented that boards of directors in large public companies tend to have more *de facto* power than their job title suggests (Mace 1971; Vives 2000; Scott 2006). This is a result of the ownership structure. Between the practice of institutional shareholders granting proxies to the board to vote their shares at general meetings and the large number of shareholders involved, the board can comprise a voting bloc that provides the power to commonly control the firm and thus influence the decision-making process (Easterbrook and Fischel, 1983). Mizruchi (2004) and LaPorta et al. (1999) show that this concentration of power is largely unique to the United States because of the extent of the dispersal of stockholders in the country.

The need to examine the influence of the board of directors was captured 75 years ago in the seminal work of Berle and Means (1932). In it they state "the divorce of ownership from control consequent on that process almost necessarily involves a new form of organization of society" (1932, p. *viii*). Later they go on to assert,

> *Control will tend to be in the hands of those who select the proxy committee and by whom, the election of directors for ensuing period will be made. Since the proxy committee is appointed by the existing management, the latter can virtually dictate their own successors.* (Berle & Means 1932, p. 87)

This is still true today. Mizruchi (1996), Lynall et al. (2003), and Roberts et al. (2005) all underscore the concentration of power in the hands of a selected few people and the need to study them.

There have been numerous movements to reform this power structure, with a plethora of attempts coming in the wake of the 2001 collapse of Enron. For example, Institutional Shareholders Services, Inc. called for U.S. corporations to have smaller boards and greater outside representation (Institutional Shareholders, Inc. 2003). Similarly, Abdel-khalik (2002) called for establishing a shareholders' board of trustees, independent of the board of directors and providing it with the responsibility of overseeing external auditors. Despite these reform attempts and the many changes to the corporate landscape that have occurred since Berle and Means (1932), the power possessed by corporate boards of directors has, for the most part, remained intact.

CORPORATE CONTROL IN THE CONTEXT OF GEOGRAPHICAL AND SOCIOLOGICAL RESEARCH

Quaternary location studies is a research field that examines the evolving corporate influence connected with urban and regional development around the world. There are many ways of investigating this influence, but research has traditionally focused on the geography of elite business activities. Headquarters have always remained at the forefront of this area of research, with a focus on their spatial concentration (Borchert 1978; Wheeler 1990), their spatial-temporal change (Holloway and Wheeler 1991; Horst and Koropeckyi 2000; Klier and Testa 2002; Klier 2006; Wheeler and Brown 1985), and the relationship between city characteristics and headquarters locations (Wheeler 1988).

A more extensive examination of the spatiality of corporate activities needs to move beyond the conventional idea that decision-making is solely linked to firm names and the cities that host these firms. Recent history has witnessed the emergence of new organizational forms that are significantly different from the hierarchical control of the firm's activities. As argued by Yeung (2005), economic geographers should view the firm as a constellation of network relations. The need for this relational approach arises because the firm can no longer be viewed as a self-contained, homogenous 'black box'. This case is actually an extension of Granovetter's (1985) embeddedness argument where he argues that the institutions to be examined are constrained by dynamic social relations and keeping these relations independent from the firm would be erroneous.

This conceptualization of the firm differs significantly from the neoclassical view as well as the transaction cost view by suggesting that the firm's existence lies in its capacity as an organizational entity to coordinate the social relations of actors. Schoenberger (1997) contends that research employing this approach could help us better appreciate the trouble Xerox experienced adjusting to the introduction of computers. Perhaps more importantly, Yeung (2005, 307) recommends this organizational perspective

> *shift our research agenda in urban and regional development from promoting the growth of the firm to understanding how the firm serves as a relational institution that connects spatially differentiated actors in different places and regions.*

Research must be modified to understand these social relations and recognize that despite the thousands of people involved in the operation of a typical *Fortune 500* firm, corporate influence is primarily wielded by a few people in the highest positions within these companies. A more comprehensive view of the firm then is to better understand the personal histories of these individuals. Applying this logic geographically, recognition of the cities that are a part of these personal histories offers a more well-rounded understanding of the social relations, and thus the geography of corporate influence of these firms.

Boston's position in the financial industry is a good example of this. Boston possessed only 2 of the top 65 finance and insurance firms in 2004 (*Fortune 500*, 2005). Any ranking by headquarters prominence would situate Boston well down the hierarchy of corporate influence. Examining the directorate network, however, reveals that Boston continues to occupy a position of influence in the banking industry that is not reflected by head office counts: over 25% of directors on the top 65 finance and insurance firms received their education from universities located in the Boston metropolitan area. Since Schoenberger (1997) argues that it is the training and experience of individuals that generates the firm's interpretive framework, she would point towards the city of Boston receiving greater recognition within the cultural manifestations of the banking industry.

To place this paper fully into the context of present economic geography research, it seems appropriate at this time to move the relational based discussion fully within the context of institutionalism. In his critique of relational approaches, Sunley argues (2008, 19)

> *It is clearly important for economy geography to study economic connections, relations, and networks, but it is counterproductive to abstract these connections from other features of institutions and social contexts and to seek a general theory that is rooted in network dynamics. Instead, it would be preferable to attempt to place these connections within an evolutionary and historical institutionalism….A properly institutionalist and relational approach in economic geography would give central attention to how coalitions of interest groups and responses by marginalized groups shape the evolution of these generative rules.*

Taking this as a basis then, institutionalism's chief contribution has been to take a macro level approach to understanding the differences in economic development between cities and regions. This methodology argues that the most useful knowledge sharing exists at the regional level because of enhanced social and cultural proximity between agents that are physically close. In other words, because geographical proximity offers cultural similarities, it facilitates interaction (and thus learning). As a consequence, regional borders are conceived to enclose collective learning processes and cultural similarities.

This approach argues that economic differences are primarily related to differences in institutions (Hodsgon, 1988; Saxenian, 1994; Peck 2005). They can include formal structures such as legal rules and laws, as well as informal habits and organizational cultures. Economic agents act through such institutions, rather than following a standard set of regulations. Schoenberger (1997) is interested in this corporate culture, the ways in which it is implemented, and how it shapes strategy. She argues that the dominant producers of these institutions or cultures of the firm are those at the highest levels of management and links her 'cultural crisis of the firm' to imperfect information and uncertainty possessed by these individuals.

Applying this logic to the geographical level, inherited institutional practices are viewed as essential to influencing how particular regions respond to the increasing competitiveness associated with globalization (Amin, 1999; Storper 1997). This process is employed because analyzing the different institutions between geographic units, whether they be regions or cities, can then translate into differences in economic development. Thus, an institutional approach takes discrepancies in organizational routines, business cultures, and management practices as the starting point of analysis. Of course many of these institutions are learned by directors at the university level and brought to the workplace.

The institutional approach recognizes that knowledge externalities are geographically bounded and that spatially proximate firms of knowledge sources gain the greatest benefit from these externalities (Van Oort et al., 2004). Externalization is the process by which ideas are presented to others and become accepted as part of the culture. Within the context of Cultural Ecology, culture is a group phenomenon and while individual persons may originate ideas or behavior, they do not create cultures alone. Cultures evolve from the relations of people with others, and a person's behavior becomes part of a culture when it is externalized. Relating this culture to the city level, Park (1915: 578) argues:

> *The fact is, however, that the city is rooted in the habits and customs of the people who inhabit it. The consequence is that the city possesses a moral as well as physical organization, and these two mutually interact in characteristic ways to mold and modify one another.*

Applying this approach to boards of directors then, the decisions made by this group of influential people is in large part determined by their educational lives and the cities within which these universities are located. Instead of firms, which are used by most economic geographers as a basis of research, we utilize the personal histories of high level mangers as the source of knowledge accumulation. Recognizing the complexity of social networks associated with the key decision-makers of companies promises a more encompassing understanding of the geography of corporate decision-making and its economic impact. Cities that possess these authority figures or maintain connectivity to them should be recognized as contributing to corporate culture and influence.

Geography of Corporate Control Through Directors

This paper argues that corporate boards of directors represent an important venue for geographic research. The modest body of geographic research that has focused on corporate directors has centered on the concept of interlocking directorates. An interlocking directorate occurs when multiple individual directors are shared amongst multiple boards. Green (1980) and Green and Semple (1981) established this field of geographic research with an examination of directors in the U.S. manufacturing belt. They explored the role that interlocking directorates played in the competitiveness of the region. More recently, O'Hagan and Green (2002a, 2002b, 2004) broadened this premise to examine the utility of interlocks in the knowledge network of North America as a whole. Each of the works cited above shares a common focus on interlocking directorates as an information-transmission mechanism. Rice and Semple's (1993) work provided an important complement to an information focus by examining interurban director linkages (i.e. links created by a director working in one city and serving on a corporate board in another city) as a mechanism of direct corporate influence.

Yet another approach to the spatiality of corporate control is to look at characteristics of directors themselves. A plethora of sociological research exists on the influence that socioeconomic backgrounds have on individuals (Duncan et al. 1972; Jackstadt and Grootaert 1980). A branch of this field is specifically devoted to examining the influence of socioeconomic characteristics on the decision-making of business leaders. At the forefront of this area of research is Domhoff (2002), who asserts that these individuals influence corporations and thus the nation as a whole. Consequently, it is important to recognize the background characteristics of these individuals. A spatial and relational adaptation to this reasoning is to argue that geographical characteristics of leaders can impact corporate decision-making as well.

As mentioned in the introduction, one exploratory work (O'Hagan et al. 2008) examined the directorate networks of Canada and the United States in relation to educational affiliations. O'Hagan and colleagues established a list of top universities, and applying Domhoff's concept geographically, they explored the spatiality of these top universities in terms of alumni in the North American corporate director community. They argued that the results for Boston were so robust that the city exerts a significant influence over the American corporate network, even without housing a substantial number of the largest companies. Their results showed that Boston's position was due largely to Harvard University; however, even without Harvard the analysis showed that Boston would be considered a major player. Also noteworthy was the fact that the vast majority of graduates of most universities sit on the board of a company either in the same city or in close geographic proximity to that university. Thus, the university attended had a major influence over where they worked. The paper then argued for further research into the geography of directors and educational affiliations, with a key element of research into this phenomenon being the temporal dimension. The present paper begins with this suggestion as a foundation for extended study by placing the university influence within the context of relational and institutional approaches.

DATA

The study examines director datasets for firms based in the United States. To examine boards of directors, the top 500 U.S. firms by revenues, as identified by *Fortune* (1987, 2005) for 1986 and 2004, were selected for analysis. 1986 and 2004 were used for analysis as the time period provides the opportunity to observe consequential changes to the director network. Over this period, the World Cities literature (Sassen 1991, 1999) has emerged to argue that corporate control is increasingly becoming concentrated in fewer, more powerful cities. By contrast, literature specific to the corporate geography of United States has detected a decentralizing phenomenon (Holloway and Wheeler 1991; Lyons and Salmon 1995; O'Hagan and Green 2004). Information on the directors of these firms was compiled using *Standard and Poor's Register of Corporations, Directors and Executives* (1987, 2005). Directors were cross-referenced across all firms to provide a database including the work location and education location of the directors. Education is defined as the university (and university city) where each director obtained their highest degree.

The result is a central database that includes 5,452 total directors in 1986 and 5,451 total directors in 2004. The headquarters city (i.e. the primary location of board meetings) for all directors was obtained, with 2,568 of these directors in 1986 and 2,354 of these directors in 2004 also having university education data.

RESEARCH QUESTIONS

Based on the literature and databases defined in the preceding sections, this study extracts three key research questions that guide the analysis of directors and their educational affiliations. The following defines these three questions, and discusses how this analysis relates to previous research in corporate geography.

1. "The University-Temporal Question": Which universities emerged to have a greater (or lesser) influence over time?

A great deal of research exists on the relationship of boards of directors and their educational affiliation, taking on different arguments to explain the significance. Influencing managerial style, prestige, and class hegemony are three examples introduced in the field of sociology.

The proposition that knowledge gained at universities molds the minds of students or that directors' managerial abilities are influenced by their education background is, of course, not new. This is why the academic world exists. It makes sense then that high-quality business schools possessing superior assets (professors, infrastructure, etc.) produce students with high levels of managerial skills and knowledge. The consequence would be for companies to be more or less competitive based on their directors attending specific universities. Collins (1979) found fundamental differences in behavioral and leadership styles and argued that superior business decisions are associated with directors who attended specific schools.

Evidence supports the notion that educational affiliation is also associated with prestige and power, especially among senior managers (Baltzell 1953; Clement 1975; Domhoff 2002; Zweigenhaft and Domhoff 1998). As Useem and Karabel (1986) noted, the extent of this mindset increased among older generations of managers. Finkelstein (1992) added to this viewpoint by establishing a "power roster" of upper class universities and argued that directors who graduated from these exclusive institutions possess "power" in the corporate network. Finkelstein's list is dominated by old, established universities, especially Ivy League schools. As an aside, Westphal and Milton (2000) suggested that educational affiliation with an Ivy League school was particularly important for minorities as there is potential for "out-group" biases.

Class hegemony holds that corporate control is exercised through the network of directorship relationships. Class hegemony refers to the belief that large corporations are controlled by a cohesive upper class whose core is the corporate elite (Domhoff 1970, 2002; Mills 1956; Useem 1979). Essentially, this perspective postulates that corporate elite members share vital capitalist interests, primarily those of wealth accumulation and advancement of the elite status (Baran and Sweezy 1966; Pitelis and Sugden 1986). This class cohesion view presumes that corporate managers seek protection from threats to their tenure leading in the pursuit of trusted business allies, which in turn leads to appointing trusted directors. These interests are achieved and maintained through the network of corporate relationships, especially among directors that attended the same upper class institutions.

The body of current research in the area takes a single time period look at the director-university relationship. It is important to determine if this relationship changes over time, and what trends, if any, exist. Following previous findings, it is expected that old, established universities, especially Ivy League universities, will be particularly prominent. With a lack of temporal research it is less clear which universities become more or less central to the director network over time. Nevertheless, it is expected that old, established universities will become less central over time (therefore influencing corporate culture less), as corporate geography research postulates that the corporate network of the United States is dispersing.

2. "The Geographical-Temporal Question": What university locations emerged to have a greater (or lesser) influence over time?

A second focus of this study is the cities where boards of directors attended university. As mentioned earlier, the vast majority of existing research on corporate geography has utilized headquarters locations as a base (Holloway and Wheeler 1991; Meyer and Green 2003; Rice 2005). Headquarters are the place where corporate decisions are formulated, but are other locations relevant in the discussion on elite corporate activities? In other words, are there additional locations that should be considered in the study of corporate decision-making? Returning to Yeung's (2005) challenge discussed earlier, mapping social networks provides a greater understanding of the firm and its wider relations. It is not suggested that headquarters locations should not be the focal point for the study of corporate influence; quite the contrary. Headquarters are the venue where the key decisions are made. But can cities influence corporate culture without housing corporate headquarters? The social networks that connect elite corporate players, the board of directors, offer an excellent opportunity to explore a different mode of corporate influence. The existence of a small set of elite universities and the connection of these universities to the cities in which they are hosted provides a foundation for this question to be answered within the context of relational and institutionalist approaches.

3. "The Corporate Network Question": Is there a connection to other corporate network indicators of the United States?

A third purpose of this research is to compare the directors-educational results of this paper with other networks. Is there a connection between previous findings and the university affiliation of directors found in this paper? Why or why not? To accomplish this, data central to previous corporate geography research are employed. Information will be analyzed on headquarter changes of established firms, headquarter changes for next wave firms, interlocking directorate changes, and corporate subsidiary headquarter changes for comparison purposes.

Headquarter changes of established firms. This variable is defined as the headquarters location for the largest companies in United States. Examining established firms has been used extensively by geographers as the data are readily available and because these businesses wield a great deal of corporate influence (Byrt 1981). In order to track changes, the headquarters location for the top 500 U.S. firms by revenues, as identified by *Fortune* for 1986 and 2004, were selected for analysis (Fortune 1987, 2005).

Headquarter changes for next wave firms. Next wave firms are the fastest-growing businesses in North America, as measured by percentage growth in annual revenues (Rice 2005, 2006; Rice and Lyons 2007, 2008). Next wave firms, also referred to as "gazelles", represent the cutting edge of change in the national economy (Stam 2005). Rapid business growth can be associated with high-technology firms, but it can also be associated with decidedly low-technology firms that have come up with some edge or insight that drives their growth. Again to follow changes temporally, information for this database was collected for the years 1986 and 2004 and comes from the annual *Inc 500* list of most rapidly-growing private firms in America.

Interlocking directorate changes. One key measure of the influence of university cities is in their occurrence and positioning within the corporate interlocking network. As introduced earlier, an interlocking directorate occurs when a person sitting on the board of directors of one firm also sits on the board of directors of another firm. As with the director database, the top 500 U.S. firms by revenues, as identified by *Fortune* for 1986 and 2004, were selected for analysis (Fortune 1987, 2005). The directors of these firms were compiled using *Standard and Poor's Register of Corporations, Directors and Executives* (1987, 2005). Directors were cross-referenced across all firms to provide a database including the work location and education location of the directors.

To measure the positioning of university cities within the corporate interlocking network, the notion of network analysis is utilized. Network analysis measures relationships between individuals in social networks, with these individuals often in the form of people, groups, organizations, nation-states, etc. Here they are in the form of university cities and by examining the linkages between the network nodes a city structure can be established. Within a network, certain cities maintain primary positions while others are relegated to the periphery. Calculating centrality allows for the determination of the most significant and least significant cities in the network. This can be useful for a number of reasons but here the purpose is to uncover a hierarchical network of cities within a constellation of network relations.

The basic method employed for measuring centrality is degree. This measure counts the number of nodes (university cities) that each node is connected to. Nodes that have more ties to other nodes may be in advantageous positions. Because they have numerous links, they may have alternative ways to satisfy needs, and hence are less dependent on other nodes. With more ties they may have access to more resources, in this case knowledge, of the network as a whole. Additionally, a greater number of ties means a more influential position in the network, a position that could more extensively influence corporate culture. By inserting a denominator into the equation, the number of links for each individual university city can be compared against the total number of links in the network.

$$Centrality_{Degree}(Pk) = \frac{\sum x_i}{\sum x_{ij}}$$

Where x_i is the total number of links for city *i*, and x_{ij} is the number of links between city *i* and city *j*. This method is especially well-suited for application here, as it allows for a depiction of the changing centrality of individual university cities over time. Those university cities that possess the most direct connections in the network are considered the most active nodes in the network making them 'connectors' or 'hubs'. By comparing 1986 to 2004 it is possible to determine if some university cities become more important connectors or less important connectors of corporate culture over time.

Corporate subsidiary headquarter changes. A corporate subsidiary is a business that is owned or controlled by an outside entity (Rice and Pooler 2009). Since subsidiaries are run by the parent company, the definitive influence is not located at the subsidiary's headquarters. While some subsidiaries operate with minimal input, it is worthwhile to examine the spatial organization of this network because in other cases the level of corporate decision-making handed over to the subsidiary's management can be substantial.

Again, the years utilized are 1986 and 2004, with data acquired from two primary sources: Dun & Bradstreet's *Business Rankings* and the LexisNexis *Corporate Affiliations* database. These data sources provide location information for the top 500 subsidiaries in the United States for 1986 and 2004. These sources provide no details as to the nature of the operations of each firm (for example, developmental versus quiescent subsidiaries), so the study is necessarily limited to a summary of business location and development patterns over the study period.

RESULTS

1. "The University-Temporal Question": What universities have emerged to be a greater (or lesser) influence over time?

The paper begins with an investigation of the university-temporal question. Table 1 displays the largest 15 increasing and largest 15 decreasing universities associated with the director network. In 1986, 48% of their directors received their educations from the top 25 schools. By 2004, this number increased to 53%. The list of increasing universities in Table 1 is a little unexpected since established universities, especially Ivy League universities, are particularly prominent. This agrees with the research conducted by Hoyler and Joens (2008), who quote a professor of mathematics at MIT as stating,

> *The top students will get into Harvard and to MIT and to Stanford and Chicago…one of the advantages of course of the very best universities is that all the students are good, so when you're a student you're talking to other very good students too.*

Similarly, Domhoff (2002) cites Baltzell (1953) to describe Ivy League alumni as a countrywide upper class surrogate family.

However, it was anticipated that old, established universities would become less central over time and be replaced by upcoming business schools in the Sunbelt, such as UCLA, the University of Texas at Austin, or the University of North Carolina-Chapel Hill. The results show this is not the case, as Ivy League schools actually increase their presence within the network from 1986 to 2004. It is particularly important to highlight the increasing dominance of Harvard University. Already possessing one tenth of all directors in 1986, its alumni share jumped almost 6% by 2004. Interestingly, three of the universities in the network that experienced the largest increase in alumni are Boston based, but this geographical prominence will be addressed later in the paper.

Table 1 also reveals universities at the other end of the spectrum. The largest 15 decreases of directors in their educational affiliation have lost prevalence in the director network over time. It is interesting that prominent universities located in Midwestern United States are clearly represented in the dataset. Unfortunately, the diminishing role of these universities has a great deal to do with the geography of corporate America. In an earlier paper, O'Hagan et al. (2008) argued that the university-headquarters relationship has a remarkable spatial orientation. They found that geography plays a role in the relationship between where a director receives his/her education and where he/she works. Since the manufacturing belt possesses fewer top corporations in 2004 than in 1986, the result is fewer directors from universities in this region. Again, this geographical premise will be expanded upon in the next section.

This level of concentration concurs with the overall pattern of network, which can be explored through the concept of density. This describes the level of interaction among all universities. Density is the proportion of ties in a network relative to the total number possible. For a valued network, density is calculated as the total of all valued university-director relationships divided by the total number of ties (Borgatti, Everett, & Freeman 1999). In this case, density provides the mean number of links per university to the director network.

Table 1: Largest 15 Increasing and Largest 15 Decreasing Universities Associated with the Director Network, 1986-2004

University	1986 %	2004 %	Difference %
Harvard Univ.	10.1	15.9	5.8
Univ. of Chicago	1.9	3.5	1.6
Columbia Univ.	2.7	3.7	1.0
Stanford Univ.	2.1	3.1	1.0
Northwestern Univ.	1.8	2.5	0.7
Univ. of California, Berkeley	0.4	0.9	0.5
Princeton Univ.	1.1	1.6	0.5
Duke Univ.	0.1	0.6	0.5
Georgia State Univ.	0.0	0.5	0.5
Howard Univ.	0.0	0.5	0.5
Massachusetts Inst. of Tech.	2.1	2.5	0.4
Univ. of Pennsylvania	2.7	3.1	0.4
California State Univ.	0.1	0.5	0.4
Boston Univ.	0.2	0.6	0.4
Univ. of Cincinnati	0.55	0.21	-0.33
U.S. Naval Academy	0.35	0	-0.35
Pennsylvania State Univ.	0.82	0.47	-0.35
Ohio State Univ.	1.21	0.72	-0.48
St. John's Univ.	0.55	0.04	-0.5
Univ. of Detroit	0.51	0	-0.51
New York Univ.	2.96	2.42	-0.54
Georgetown Univ.	0.78	0.21	-0.57
Purdue Univ.	1.09	0.51	-0.58
Texas A & M Univ.	0.66	0.09	-0.58
Lehigh Univ.	0.7	0.09	-0.62
Univ. of Minnesota	1.25	0.47	-0.78
Univ. of Michigan	2.77	1.74	-1.02
Univ. of Illinois	1.83	0.55	-1.28

When each university in the network is more connected to companies, the network increases in density. Results presented in Table 2 do indeed indicate that the network increases in density from 5.52 in 1986 to 6.03 in 2004. This indicates that on average universities that are represented in the network possess a greater number of links to corporations over time. This result, along with the fact that the total number of links within the network is fairly similar for 1986 and 2004, reveals that the university alumni network is converging on fewer universities over time.

Table 2: Density of University-Director Relationships, 1986-2004

Density Measure	Year	
	1986	2004
University density	5.52	6.03
University city density	9.99	9.45

As suggested earlier, the result is somewhat surprising. It was anticipated that an increasing number of upcoming business schools across the United States, including the Sunbelt, would become involved with the network. The opposite actually occurs, which provides the opportunity to move to the second question and examine the geographical dispersion of university cities temporally.

2. "The Geographical-Temporal Question": What locations have emerged as to be a greater (or lesser) influence over time?

The paper now turns to the geographical-temporal question. Figure 1 categorizes states into those whose universities experienced large decreases, large increases, or minimal change in their alumni connections to the national director network over time. A large increase is defined here as *growth equaling more than 1% of all directors in the national network*. Similarly, a large decrease is defined here as *a loss equaling more than 1% of all directors nationally*. These results suggest that the leaders of the largest companies in the United States increasing obtained their educations from universities located in Massachusetts, Illinois, and California. Perhaps as relevant, and corresponding with the results in the previous section, is the large decrease in director educational affiliations associated with universities located in much of the Northeast. This makes the Massachusetts results even more notable.

At the city level, Table 3 displays the largest 15 increasing and largest 15 decreasing university cities associated with the director network. In 1986, 65% of the directors received their educations in the top 25 cities. By 2004, this number increased to 70%. This would suggest an increasing concentration into central cities of the network. As at the university level, these results are again compared to the overall density of the network. In this case, however, density provides the mean number of links per university city to the director network. When each university city in the network is more connected to companies, the network increases in density.

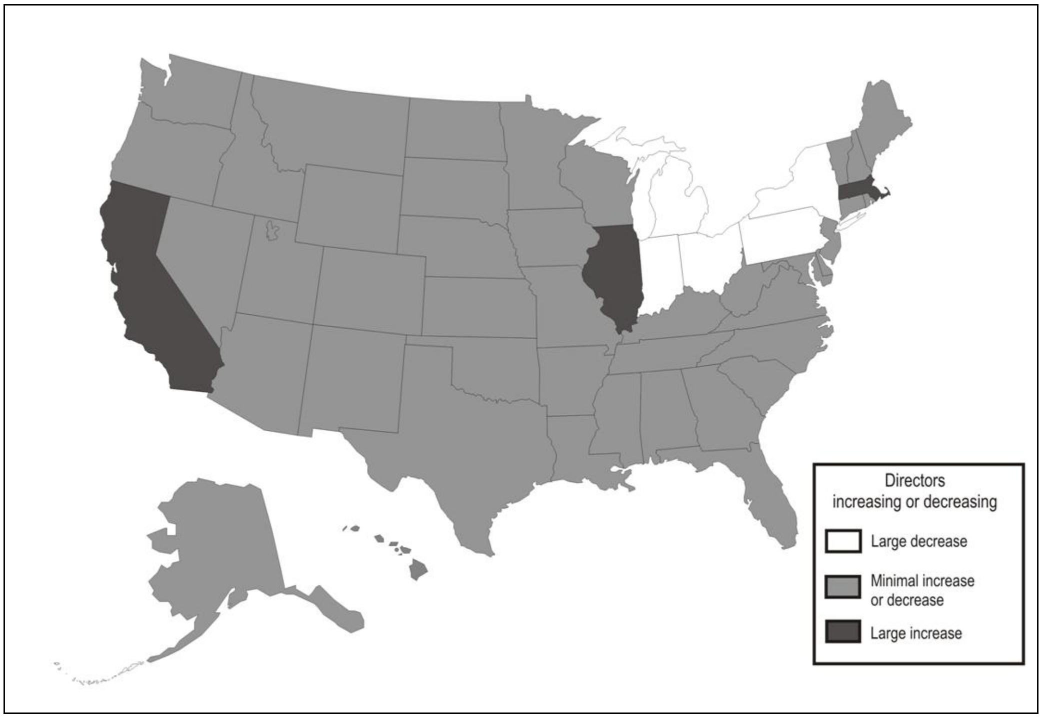

Figure 1: Change in University Alumni Connections to the National Director Network, Aggregated at the State Level, 1986 to 2004.

As before, density is the proportion of ties in a network relative to the total number possible. Results presented in Table 2 indicate that the network decreases in density from 9.99 in 1986 to 9.45 in 2004. This indicates that university cities that are represented in the network possess fewer links to corporations. The result deviates from the findings in Table 3. Thus, the director network concentrates in the top 25 cities over time, but when the entire network is taken into account, the spatiality of the network disperses. Amalgamating density results for universities and university cities suggests that university alumni hail from fewer universities but that these universities come from a greater number of cities across the country (and less likely in the old manufacturing belt). Thus, corporate culture in the United States is becoming more centralized in fewer universities. However, a geographical examination suggests that corporate culture is decentralized amongst more cities over time.

By examining individual cities, Table 3 provides interesting results as it pertains to a relational network. Perhaps most important, Boston extends far beyond any other city in the network. While the city was well represented in 1986, it added 6.8% of all directors to become significantly more influential over time. By 2004, 21% of all directors received their education from a Boston institution.

Table 3: Largest 15 Increasing and Largest 15 Decreasing Urban Areas Associated with the Director Network, 1986-2004

City	1986 %	2004 %	Difference
Boston, MA	14.2	21.0	6.8
San Francisco, CA	2.3	4.4	2.1
Chicago, IL	6.1	7.7	1.6
Philadelphia, PA	3.2	3.9	0.7
Princeton, NJ	1.1	1.6	0.5
Washington, DC	1.7	2.2	0.5
Durham, NC	0.1	0.6	0.5
Atlanta, GA	0.7	1.2	0.5
San Diego, CA	0.2	0.6	0.4
Lubbock, TX	0.0	0.3	0.3
Fayetteville, NC	0.0	0.3	0.3
Phoenix-Tempe, AZ	0.0	0.3	0.3
Memphis, TN	0.1	0.3	0.2
Providence, RI	0.3	0.5	0.2
Chapel Hill, NC	0.5	0.7	0.2
South Bend, IN	0.7	0.3	-0.3
Pittsburgh, PA	1.4	1.1	-0.3
St. Louis, MO	1.0	0.7	-0.4
Richmond, VA	1.4	1.0	-0.4
Cincinnati, OH	0.7	0.3	-0.4
Columbus, OH	1.4	0.9	-0.5
Ann Arbor, MI	2.2	1.7	-0.5
Cleveland, OH	1.2	0.7	-0.5
Baltimore, MD	1.3	0.8	-0.5
West Lafayette, IN	1.1	0.5	-0.6
Minneapolis-St. Paul, MN	1.3	0.6	-0.7
Madison, WI	1.6	0.8	-0.7
State College, PA	0.8	0.0	-0.8
Allentown-Bethlehem, PA	1.0	0.1	-0.9
New York City, NY	9.7	8.6	-1.1

This result is even more important when considering the decreasing density of the network. In other words, while the average number of links to cities decreased, Boston, which was the most important city by far in 1986, increased in representation even more by 2004.

Table 3 reveals a second tier of prominent corporate cities, San Francisco and Chicago, which increased significantly over the study period as well. It is important to note that these two cities are well represented in the previous headquarters literature. In other words, these cities have traditionally maintained an influential position in the corporate geography of the United States through headquarters as well as with links to prominent universities. This is followed by a third tier of varied cities. Cities such as Princeton and Durham are associated with universities. Others such as Atlanta and San Diego are noticeable because of their South and Southwestern geographical location. Finally, cities such as Tempe and Lubbock are Southwestern cities that possess a strong university presence. This third tier result concurs with the findings of O'Hagan et al. (2008) pointed out earlier. They revealed that a considerable portion of directors sit on the board of a company that is in close proximity to where they attended university. As headquarters move to Southern and Southwestern United States, it is logical that and increasing number of alumni should be coming from these areas as well.

Geography is prominent in the lower portion of Table 3 as well, which reveals the largest 15 decreasing university cities associated with the director network. All cities with the exception of Richmond and St. Louis are Northeastern cities. Again, this makes the Boston results all the more significant. Contrary to Boston's strong growth trend, New York City stands out as experiencing the greatest decrease in university alumni. That understood, New York City still maintains a large number of headquarters as well as the second largest university alumni network to play a central role to corporate America. Perhaps the results of State College, Madison, and Ann Arbor are more important relative to local impacts, as alumni director affiliations are by far the main linkages that these college cities have to the corporate network.

3. "The Corporate Network Question": Is there a connection to other corporate network indicators of the United States?

The final aim of this paper is to compare results on the university affiliation of directors found in this paper to previous corporate geography findings. Are changes to the geographical networks similar or different? Since the investigation is interested in the association between two sets of paired variates, a bivariate regression at the city level is performed.

To carry out the regression, university education change was the dependent variable while all other variables–headquarter changes of established firms, headquarter changes for next wave firms, interlocking directorate changes, and corporate subsidiary headquarter changes–were the independent variables. The purpose of this exercise is not necessarily to determine a cause and effect relationship. Rather, it is interested in the strength of the relationship between the variables as well as identifying cities that are overrepresented. Most important, though, the purpose is to highlight cities that are underrepresented in the present corporate geography literature.

Regression results are displayed in Table 4. As expected the only comparative variable that showed a strong relationship was interlocking directorate changes. This can be explained by the fact that both variables used directors as a basis for data collection. All other variables uncovered a weak or no relationship at all. This is significant in the sense that results from this paper are dissimilar to previous findings, suggesting these results add a distinctive perspective to the corporate geography literature. While these results are interesting, they are not the main rationale behind this study. The initiative is to draw attention to cities that are not linked to previous conclusions on the urban corporate hierarchical network.

For the purposes of this study, Table 4 identifies those residuals with a standard score of less than -2.0 or greater than +2.0. Since the residuals are standardized, they can be compared against different regression equations. Clearly, the most significant outcome of this table is the highlighting of Boston, again substantiating the results found in questions 1 and 2. This result suggests that Boston is significantly underrepresented in the previous corporate geography literature.

Examining the results in more depth, it is intriguing to observe that the Boston residual for the headquarter changes for next wave firms equation was less than the headquarters changes of established firms. This would indicate that Boston is a base for smaller firms experiencing rapid growth. The collection of important universities has transcended into more innovative smaller firms starting up or locating there as compared to a location for established firms.

Similar to descriptive statistics results, a second tier of underrepresented cities emerges. San Francisco and Chicago and to a lesser extent Philadelphia stand out as being underrepresented. As the smaller residuals reveal though, these cities are much better represented in previous research. On the other hand, a number of Northeastern cities emerge as being overrepresented by previous corporate geography studies. New York and Allentown-Bethlehem were significant outliers in three of the datasets. Ann Arbor, Madison, Minneapolis, Newark, and State College were notable outliers in two of the datasets.

As the *Interlocking Directorate Changes* result was the only regression equation to show a significant relationship, it is worthwhile here to provide the results of the centrality testing introduced earlier. Table 5 reveals results of the degree procedure for cities that possessed a centrality of at least .01 in either 1986 or 2004.

Table 4: Residual Results - Ordinary Least Squares Model Regression

Urban Area	Established firms	Next wave firms	Corporate subsidiaries	Interlocking directorates
Allentown-Bethlehem, PA	-2.002	-2.054	-2054	
Ann Arbor, MI	-2.736	-2.366		
Boston, MA	15.639	8.661	9.423	3.133
Chicago, IL	2.472	3.892	2.350	
Madison, WI		-2.336	-2.323	
Minneapolis-St. Paul, MN		-2.117	-2.265	
New York City, NY	-2.736	-2.017		-2.445
Newark, NJ	-2.001	-2.136		
Philadelphia, PA		2.187		
Providence, RI				2.394
Richmond, VA				
San Francisco, CA	3.505	4.680	3.072	
State College, PA		-2.049	-2.357	
Washington, DC				
Pearson Correlation – r (Boston Included)	***-0.087***	***0.114***	***.250***	***0.816***
Pearson Correlation – r (Boston Excluded)	***0.123***	***0.170***	***.366***	***0.754***

In table 5, the maximum centrality value that an individual city can obtain is 1. This indicates that the city under investigation accounts for all links in the corporate network. At the other extreme, a centrality value of 0 implies that the city retains no links in the network. The higher the value, the more central the city.

The results here substantiate the related results of *Question 2*. Boston dominates interlocking at the city level. While it controlled the interlocking network in 1986, it increased its occurrence in 2004. Once again, this cements the idea that the city plays a pivotal role in the American corporate network. As with residuals in Table 4, a lower tier of cities emerges over time, which can be categorized into university cities, such as Providence and Chapel Hill, or into established corporate cities, such as San Francisco and perhaps Philadelphia and Chicago. Decreasing centrality presents the same two interesting findings discovered earlier in the paper. First is the severe decrease of New York City in the interlocking network over time. This result might be considered as surprising, given the continuing status of the city as the dominant American headquarters center (Rice 2006; Rice and Pooler 2009). Again, the geographical locations of almost all other cities that have a decreasing occurrence are located in Northeastern United States, suggesting that corporate cultural influence is fading from this region

Table 5: Centrality in Interlocks by Urban Area, 1986 Compared to 2004

University Location	Centrality 1986	Centrality 2004	Centrality interlocks change
Boston, MA	0.146	0.227	0.081
Providence, RI	0.003	0.039	0.036
Chapel Hill, NC	0.005	0.030	0.025
San Francisco, CA	0.024	0.046	0.022
New Haven, CT	0.024	0.042	0.018
Philadelphia, PA	0.033	0.049	0.016
Chicago, IL	0.052	0.067	0.015
St. Louis, MO	0.011	0.026	0.015
Tempe, AZ	0.000	0.014	0.014
Kent, OH	0.001	0.013	0.012
Louisville, KY	0.002	0.014	0.012
Tallahassee, FL	0.000	0.010	0.010
Los Angeles, CA	0.032	0.038	0.006
Salt Lake City, UT	0.003	0.009	0.006
Milwaukee, WI	0.003	0.009	0.006
Ithaca, NY	0.011	0.013	0.002
Newark, NJ	0.015	0.016	0.001
Washington, DC	0.018	0.017	-0.001
Austin, TX	0.011	0.010	-0.001
Baltimore, MD	0.013	0.012	-0.001
Princeton, NJ	0.010	0.009	-0.001
Detroit, MI	0.010	0.007	-0.003
Richmond, VA	0.014	0.010	-0.004
West Lafayette, IN	0.011	0.007	-0.004
Allentown-Bethlehem, PA	0.010	0.004	-0.006
Minneapolis-St. Paul, MN	0.014	0.007	-0.007
Madison, WI	0.016	0.009	-0.007
Columbus, OH	0.014	0.006	-0.008
Bloomington, IL	0.012	0.004	-0.008
Ann Arbor, MI	0.028	0.020	-0.008
Pittsburgh, PA	0.014	0.005	-0.009
Cleveland, OH	0.012	0.003	-0.009
New York, NY	0.099	0.042	-0.057

A potential difficulty arises from Table 4, as Boston is an extreme value far removed from all other data points. Table 4 shows the Boston observation impacts every regression equation. To be cautious, Boston was eliminated for additional testing. However, it is important to note that the general trends suggested above remained the same. Cities associated with old Ivy League schools retained their preeminence, cities in Southern and Western United States were underrepresented, while old Northeastern cities fell in importance and were overrepresented. For example, in the changes for next wave firms regression equation, the Pearson Correlation co-efficient changed from 0.114 to 0.170. More important, cases that were added to the list of outliers include West Lafayette, Baltimore, and Cincinnati as being overrepresented and Durham and Princeton being underrepresented.

CONCLUSION

The purpose of this paper is to make a contribution to the emerging economic geography research that focuses on dynamic organizations constructed through social relations. Within the context of this research, the relational framework of the firm argues that the firm is an organizational unit bringing together diverse social relations in which actors in the firm are embedded. As argued by Yeung (2005, 321),

> *because social actors, not the firm as an abstract entity, become the key analytical focus, it is important to shift our attention from the underlying capitalistic logic of the firm to the relations among these firm specific actors.*

These relations come in many forms and, as Badaracco maintains, these broader relations of individuals define the boundary of the firm. In the context of this paper they take the form of university alumni relationships and its purpose is to place the cultural make-up of the firm in a spatial context.Temporally examining the university alumni relationships with the largest firms in the United States substantiates the influence of Boston, with the city's importance increasing over time. It is argued in the context of this paper that Boston has been concealed in previous corporate geography literature and that the city influences corporate culture more greatly than has been previously acknowledged. Additionally, a second tier of cities emerges over time. Chicago, San Francisco, and to a lesser extent Philadelphia fit into this category as old established corporate cities. Furthermore, a number of university cities (especially Ivy League university cities) and cities located in the American Southwest cement their positions within a relational view of the firm. Since Schoenberger (1997) argues that it is the training and experience of individuals that generates the firm's interpretive framework, she would point towards these cities receiving greater recognition within the corporate culture of the United States. Institutions learned in these cities are brought by directors to where they work.

Also of interest, a dramatic decrease occurs in Northeastern United States.

At first glance, New York City is most noticeable as experiencing the largest decrease. However, the city still maintains the second largest university alumni network, and previous literature properly identifies the city as maintaining an advanced level of corporate influence through alternative methods (in many cases more significant methods), such as corporate headquarters. It obviously still plays a central role to corporate America. Again, as observed earlier, perhaps the most troubling in terms of negative local implications are the results for State College, Madison, and Ann Arbor, as university-associated connections are by far the main links that these college cities have to the corporate network. Schoenberger (1997) would contend that these cities are less influential within the corporate culture of the United States and that these cities are fading in the constellation of network relations governed by social actors.

Once again, this study spurs further questions on the subject. Perhaps a temporal study with shorter intervals would be most helpful. In an earlier paper, O'Hagan et al. (2008) argued that the university-headquarters relationship has a remarkable spatial orientation. They found that geography plays a role in the relationship between where a director receives their education and where they work. Since the manufacturing belt possesses fewer top corporations in 2004 than in 1986, results from this paper agree with this hypothesis, as fewer directors are represented from universities in this region as well. It raises an important question. Do directors decreasingly obtain their educations from universities in these cities because there are fewer corporations located there? Alternatively, do these universities graduate less qualified individuals, which results in less competitive companies? In other words, does company competitiveness influence university success, or does university success influence company competitiveness?

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HOW MUCH DOES HISTORY MATTER? AN ANALYSIS OF THE GEOGRAPHIC DISTRIBUTION OF VENTURE CAPITAL INVESTMENT IN THE U.S. BIOTECHNOLOGY INDUSTRY

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ABSTRACT

This study investigates the changing geography of venture capital investment in the U.S. biotechnology industry. From 1995 to 2007, all major regions in the U.S. experienced some growth in venture capital investment, though at various rates. Regarding the spatial distribution of investment in the absolute magnitude, our analysis shows that regional investment is positively associated with past investment. Similarly, when the share distribution of investment is considered, the current pattern is positively related to the historical pattern as well. Furthermore, we find that regional investment volume is related to recent national economic growth and stock market returns. Overall, our results suggest that areas receiving more investment in the history tend to receive even more in the future and the affluent regions become more affluent in term of relative shares.

Key Words: venture capital investment, biotechnology, spatial distribution

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INTRODUCTION

Venture capital is the investment made by specialized investors in high-growth, high-risk, and often high-technology firms that need capital to finance product development or growth (Black and Gilson 1998). Being a relatively new source of equity financing, venture capital plays an important role in technology innovation of new, private companies (Black and Gilson 1998; Jeng and Wells 2000; Schmidt 2003; Global Insight 2007). Many highly successful firms, such as Microsoft, Apple, Genetech, and Google received venture capital finance in their infancies. For many start-up companies, venture capital may be their only choice of financing, because tremendous risk and information asymmetry make traditional financing channels unavailable to them (Gompers et al. 1998; Gompers and Lerner 2001). Once venture capitalists are involved, they provide not only financial support, but also monitoring and advisory services, networking support, further funding opportunities, and more credibility (Cuny and Talmor 2005). Some evidence shows that venture capital-backed companies have outperformed their non-venture capital-backed counterparts in product development, revenue growth, and job creation in the long run (Brav and Gompers 1997; Gompers et al. 1998; Hellman and Puri 2000; Global Insight 2007). In 2006, public companies that were once venture-backed were estimated to account for 10.4 million jobs and $2.3 trillion in revenues in the United States, which equates to 17.6 percent of the Gross Domestic Product (Global Insight 2007). Therefore, venture capital plays an important role in both corporate innovation and the U.S. national economy.

However, not all regions have reaped the benefits of venture capital equally. Instead, it is well recognized that there are spatial clusters of venture capital investment in the U.S. and other parts of the world (Leinbach and Amrhein 1987; Thompson 1989; Florida and Smith 1993; Mason and Harrison 2002; Zook 2002; Klagge and Martin 2005). For instance, California and the New England region have concentrated a large share of venture capital investment in the United States. Likewise, London has accumulated the largest proportion of venture capital investment in the United Kingdom (Martin 1989). Furthermore, some studies suggest that the spatial distribution of venture capital is a dynamic phenomenon (Klagge and Martin 2005). Florida and Smith (1993) found that the U.S. venture capital industry increased by $30.9 billion from 1977 to 1989, among which California alone accounted for 31 percent of the growth. It is also possible that the regional disparity increases over time. In the United Kingdom, it is found that new investments tended to concentrate in the already more prosperous southeastern part of the country (Martin 1989). Similarly, Mason and Harrison (2002) indicate that regions continuously receiving a large amount of venture capital investment may reduce the investment in other areas in the long run.

One growing industry that has been attracting venture capital investment is biotechnology (Cooke 2008). Based on the biological science in genetic engineering and recombinant DNA knowledge, biotechnology has applications in a wide variety of businesses, especially pharmaceuticals (United States Department of Commerce 2003). Due to its high-cost and high-risk nature, commercial activities in biotechnology started with venture capital, and many new start-up firms would not have survived the harsh business environment without venture funding and the expertise provided by the venture capitalists (Kenney 1986). In 2007, it was estimated that around 25 percent of U.S. biotechnology companies received venture capital funding (www.bio.org). From 1995 to 2005, venture capital investment in the U.S. biotechnology industry (termed "Bio-VC investment" hereafter) increased from $830 million to $3,893 million [1]. Meanwhile, its share in the overall venture capital investment in the U.S. increased from 10 to 17 percent. In the second quarter of 2009, reports show that biotechnology led all industry sectors by a 25 percent share of all venture capital invested (Dellenbach 2009). While the Bio-VC investment has been increasing at the national level, its geographical distribution has changed significantly. For example, the once leading Boston area in Bio-VC investment in the 1980s was overtaken by San Diego in the late 1990s (Carnegie Mellon University 2002a; 2002b).

The purpose of this study is to explore the changing geographic distribution of the Bio-VC investment in the U.S. How does the past Bio-VC investment pattern influence the future? Do the leading areas in Bio-VC investment keep attracting more capital, or does the gap in capital between prosperous and underprivileged areas diminish over time? Also, is there a significant historical clustering effect when share distributions are considered? Furthermore, how are the fluctuations in Bio-VC investment related to changes in the national economy and stock markets? We try to answer these questions through statistical models in this study.

Our study attempts to add to the growing literature of financial geography. As the western countries shift from a modern to postmodern society, money, capital investment, and their related activities are playing more important roles in economies at local, national, and global levels (Gehrig 2000; Sassen 2006). Due to these changes, Martin (1999) calls for a more comprehensive understanding of financial geography. In the study of venture capital investment, some scholars have implied that historical trend has influenced the geographic clustering (Martin 1989; Florida and Smith 1993; Mason and Harrison 2002). However, few have utilized quantitative methods to explicitly explore this issue. Our study fills this gap with a time series regression analysis. We are also interested in the share distribution of the venture capital investment in different regions. Do leading areas receive larger percentages in new investment,

[1] data source: Moneytree survey https://www.pwcmoneytree.com

or do these areas receive more investment but not disproportionately so? Answers to these questions will add further insights in the study of venture capital investment clustering and business clustering in general. In addition, by including national economic changes and stock market returns in the analysis, we contribute to the literature by identifying some new macroeconomic factors that help explain the fluctuations in the venture capital investment.

VENTURE CAPITAL INVESTMENT

Venture capital is a long-term equity investment in highly risky but highly profitable companies (Black and Gilson 1998). Though venture capitalists' funding commitments are influenced by the profitability prospects of the firm, decisions of funding are mainly made on ideas instead of existing marketable products (Black and Gilson 1998; Gompers and Lerner 2001; Gompers et al. 2008). The funds invested convert to liquid stock or cash after these companies go public, merge into, or are acquired by other companies (Cumming 2002; Hand 2007). In general, investors are cautious about start-up companies' future and tend to infuse small amounts of capital into companies in their early stage of development (Sorenson and Stuart 2001). If the business outlook of a start-up company weakens, venture capitalists may cut funding or avoid further investment commitment (Sahlman 1990; Hsu and Kenney 2005). In contrast, when firms grow and move into the later stage of development, there is more assurance of future success and venture capitalists are more likely to infuse their money (Hsu and Kenney 2005). On average, the investing period of VC, calculated as the interval between the time of first round of investment and the time when venture capitalists exit the company, is about six years (Global Insight 2007).

Since the nature and history of venture capital investment have been discussed in details in previous studies (Tyebjee and Bruno 1984; Gompers and Lerner 1998; Gompers and Lerner 2001; Sorenson and Stuart 2001; Cuny and Talmor 2005), they are not repeated here. To serve the purpose of this study, we will focus on the factors that influence the overall venture capital investment, such as the profitability of the industry, the status of the public equity market, and the macro economic conditions (Gompers and Lerner 1998; Gompers and Lerner 2001; Gompers et al. 2008).

Similar to investment decisions on individual firms, the overall venture capital investment in an industry has been sensitive to the profitability of that economic sector and the satisfaction of the investors (Gompers and Lerner 2001). In the 1970s and early 1980s, high returns of some venture capital-backed companies lured more money into the venture business. By contrast, in the mid 1980s, profit returns of venture investment were not as high as expected, resulting in less capital infusion in the late 1980s and early 1990s (Gompers and Lerner 2001;

Cochrane 2005). Then in the late 1990s, the phenomenal success of venture capital-backed companies, such as eBay and Yahoo, trigged another huge wave of venture capital investment activities (Gompers and Lerner 2001). In the early 21st century, with the burst of the Dot-com bubble and many failed investments, venture capital funds declined sharply (Green 2004).

Since venture capital investment is a type of equity investment, investors' return could not be realized until the invested company is listed in a stock exchange through an Initial Public Offering (IPO), or is acquired by or merged into other companies. According to the literature, high profits from IPO are one key driving force for the involvement of venture capitalists (Black and Gilson 1998). When there were active IPO activities, more start-up companies were established, together with a greater venture capital commitment and a more vibrant entrepreneurial economy (Farrell et al. 1995). Since many new high-technology firms are listed on the National Association of Securities Dealers Automated Quotations (NASDAQ) stock exchange, some scholars have utilized NASDAQ indexes to represent the performance of IPOs (Brav and Gompers 1997; Ritter and Welch 2002; Hine and Griffiths 2004; Gompers et al. 2008). NASDAQ index is also used to estimate market-adjusted returns to venture capital investment (Brav and Gompers 1997; Ritter and Welch 2002; Hine and Griffiths 2004). By similar rationale, NASDAQ Biotechnology Index is a ready barometer for the performance of the biotechnology industry. The index includes stocks of companies classified as either biotechnology or pharmaceuticals. To be listed in the NASDAQ biotechnology index, a company must have a market capitalization of at least $200 million and an average daily trading volume of at least 100,000 shares (NASDAQ 2008). Hine and Griffiths (2004) suggest that there is a strong impact of the NASDAQ biotechnology index upon investment in the industry. Empirically, it is found that low NASDAQ index has negatively impacted IPO in the biotechnology industry (Dibner et al. 2003). Consequently, low expectation of the NASDAQ index would then become a negative factor for further venture capital investment.

Venture capital investment might also be influenced by the national economic growth (Gompers et al. 1998; Jeng and Wells 2000; Allen and Song 2002). This could be explained by the demand for and the supply of the venture capital. On the demand side, when the economy is expanding and the consumer confidence is high, entrepreneurs may find more business opportunities, and the demand for venture capital increases accordingly (Gompers et al. 1998; Jeng and Wells 2000). As biotechnology products find most of their applications in consumer product industries, which are influenced strongly by the overall performance of the macro economy (Romer 2001), it is reasonable to expect that there exists a demand effect caused by the GDP growth. On the supply side, when the economy is growing, people are more willing to take risks and invest their money. As venture funds come from a variety of sources, such as state and private pension funds, university financial endowments, foundations, insurance companies, and pooled investment vehicles, it is much easier for venture capitalists to raise funds when the economy performs well and market confidence is strong (Black and Gilson 1998). In an empirical study, Gompers et al. (1998) find that a higher GDP growth rate leads to a larger volume of venture capital investment in the U.S. from 1972 to 1994.

THE GEOGRAPHY OF VENTURE CAPITAL INVESTMENT

Previous studies have shown that a large share of venture capital investment is concentrated in a few geographic clusters (Florida and Smith 1993; Gompers et al. 1998; Gompers and Lerner 2001; Stuart and Sorenson 2003). In the biotechnology industry, investments are concentrated in regions where there is a strong life science research base, a strong entrepreneurial spirit, large pharmaceutical companies, and/or an urban environment that boosts innovative activities (Sainsbury 1999; Powell et al. 2002; Oliver 2004; Chen and Marchioni 2008). For instance, with a number of world-class universities and institutes in life science research, Silicon Valley rises as a global leader in biotechnology and attracts a large amount of venture capital investment. In comparison, biotechnology firms thrive in the New York metropolitan area through strong ties with large pharmaceutical companies and easy access to financial institutions. While in the Washington D.C. area, biotechnology firms might benefit from proximity to first-rate hospitals that conduct life science research, the Food and Drug Administration, the National Institute of Health and other federal agencies. Due to these regional characteristics, some areas have concentrated a significant amount of biotechnology firms and attracted a large sum of venture capital investment (Cortright and Mayer 2002).

Though the spatial disparity of venture capital investment is well recognized, there is no unanimous opinion regarding the historical change of the geographic pattern over time. Would the regional disparity in venture capital investment expand or diminish as time goes on? In the economic literature, Myrdal (1957) proposes that capital investment has a snow-ball effect, and that regions with an initial advantage in capital investment would very likely take the lead in the future. According to this cumulative causation theory, there is a virtuous circle in heavily invested areas and a vicious circle in under-invested areas.

Various explanations have been offered for the positive virtuous circle or snow-ball effect, including scale economy, specialized labor pooling, decreased transaction costs, and knowledge spillover (Marshall 1892; Krugman 1991; Desrochers 2001; Pinch et al. 2003; Vom Hofe and Chen 2006). Among these explanations, knowledge spillover is especially important for explaining investment clustering in biotechnology industry where technology innovation requires intensive exchanges of knowledge and ideas among researchers and entrepreneurs. This type of knowledge is now widely recognized as tacit, mostly transmitted via personal contact in limited spaces, such as face-to-face interactions (Almeida and Kogut 1999; Lawson and Lorenz 1999; Desrochers 2001; Pinch et al. 2003). When new firms are located close to established companies, it is easier for them to develop communication networks, acquire investments, utilize specialized labor, and access relevant knowledge (Desrochers 2001; Pinch et al. 2003). Given these positive externalities, the concentration of investment is very likely to generate a pattern of circular causation and a historical lock-in (Arthur 1988; Krugman 1991).

In a contrasting perspective, however, Thompson (1989) argues that there might be a spatial diffusion or the trickle-down effect in venture capital investment. When firms concentrate in a given area, it may become a challenge for individual businesses to keep their technology a secret (Fosfuri and Ronde 2004). Besides, the high mobility of labor in a dense business area may destabilize the technology base of a firm, and then decrease its competitiveness in innovation. Furthermore, higher living costs and traffic volumes would also make existing industrial clusters less attractive for future investment. As a result, new firms may want to distance themselves from competitors and choose to locate in areas with less existing venture capital investment. Another argument for spatial dispersion of venture capital investment is the life cycle theory developed by Vernon (1966). He suggests that as high-technology industry matures from the research and development stage to the mass production stage, firms tend to relocate from the center to peripheral areas to take advantage of the potential markets and lower labor costs in these places. As a consequence, capital investments disperse as well. For example, Mason and Harrison (2002) find some supportive evidence that venture capital investments were more evenly distributed in the 1990s than in the 1980s in the U.K.

Our analysis on the venture capital investment in the U.S. biotechnology industry aims to add new empirical evidence to this unresolved issue on the historical trend. While many existing studies have illustrated historical changes in numbers, we base our analysis on more rigorous and formal statistical models. In addition to the analysis of the Bio-VC spatial distribution in absolute amount, we also consider relative shares, which are equally important in examining the theories on investment clustering and dispersion.

DATA DESCRIPTION

Data on biotechnology venture capital investment used in this research are from the MoneyTree survey, a quarterly study of venture capital investment activities in the United

States.[2] The same database has been used in several other venture capital studies (Zook 2002; Green 2004; Chen and Marchioni 2008). In the MoneyTree survey, there are a variety of sources for venture capital investment, including professional venture capital firms, small business investment companies (SBICs), and venture capital investment subsidiaries of corporations, institutions, and investment banks. While the majority of venture capitalists are domestic, some are overseas investors. All invested companies in this database are private U.S. biotechnology firms, which specialize in developing technologies in drug development, disease treatment, and other relevant activities.

From the first quarter of 1995 to the fourth quarter of 2007, a total of $39,872 million was invested in the biotechnology industry, accounting for 10 percent of all venture capital investments in the United States. The annual investment increased steadily from 1995 to 1999. Then there was a sharp increase in the fourth quarter of 1999 when the Dot-com bubble began to form (see the bar graph in Figure 1). After the investment reached a peak in the third quarter of 2000, the amount invested declined in the following two years. Afterwards the investment began to recover. When the investment shares in the biotechnology industry are considered, the percentages were lowest during 1999 and 2000 (see the line graph in Figure 1). Then the percentage share increased gradually.

Two important factors may have contributed to Bio-VC's gain in market share in the past decade. First, when investors lost money after the burst of the dot-come bubble, they turned to other more profitable industries such as biotechnology, to seek investment opportunities (Metzger et al. 2003). Second, the acceleration in the approval of new biotechnology drugs by the Food and Drug Administration (FDA) makes new drug development more lucrative (Metzger et al. 2003). A promising market outlook and expected high revenue returns have attracted more investment into biotechnology, which increased its share in the total venture capital investments (Carnegie Mellon University 2002b).

Geographically, venture capital investment in the U.S. biotechnology industry is distributed very unevenly. The geographic units we use in this study conform to the definition by the MoneyTree survey, which divides the U.S. into eighteen areas: Silicon Valley, New England, San Diego, Los Angeles, New York, Southeast, Texas, Northwest, Midwest, Washington D.C., Philadelphia, Southwest, Colorado, North Central, Upstate New York state, Sacramento, South Central, and Alaska /Hawaii/Puerto Rico (see Appendix 1 for the detailed definitions of these regions). Alaska, Hawaii and Puerto Rico are excluded from this study due to too much missing data. Though it would be

[2] The investment literature in economics shows that investment varies significantly across quarters. Because quarterly data have a higher frequency than yearly data, these data are widely used in investment studies in economics (Romer, 2001).

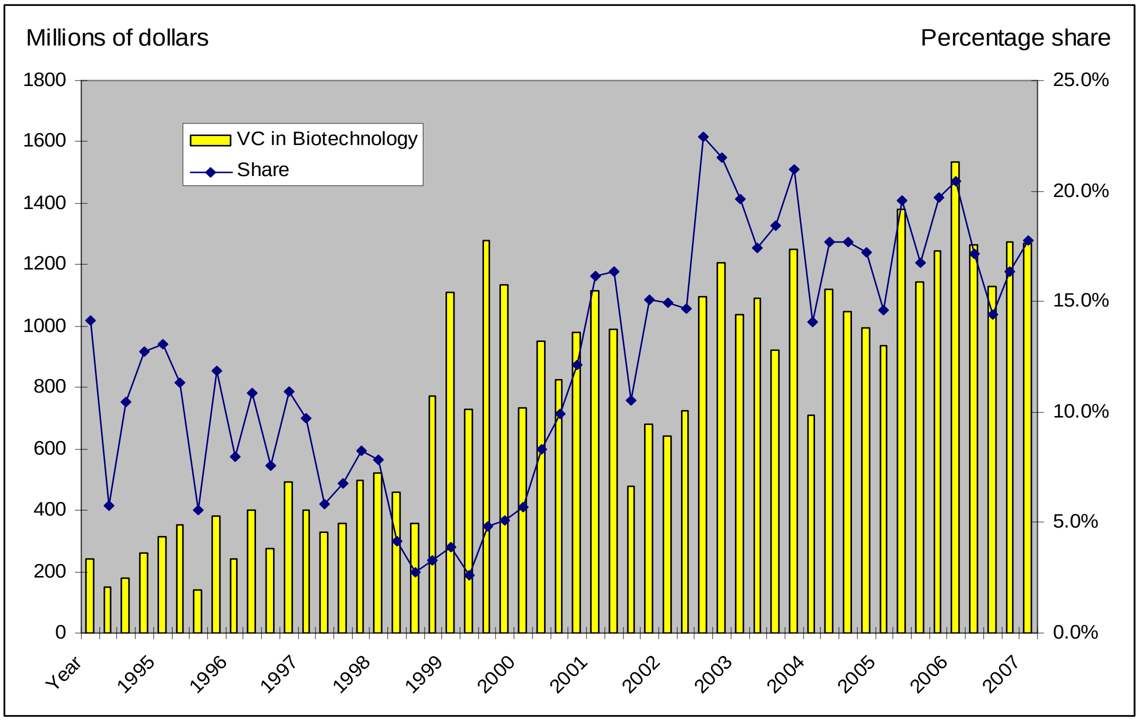


Figure 1: Venture Capital Invested in the U.S. Biotechnology Industry

desirable to use state or metropolitan area as spatial units, such data are not available on the Moneytree website. Despite the seemingly problematic scale definition, each area does have some unique regional characteristics. For instance, Silicon Valley is distinctive with high concentrations of venture capital investment businesses and high-technology firms, although its area and population size are much smaller compared to other regions. Similarly, San Diego is unique as a fast growing biotechnology center. In contrast, Midwest is aggregated as one unit, since it is the traditional manufacturing center of the U.S. and has a relatively late start in venture capital business. Also, the North Central area is characteristic of having little cutting edge research and few venture capital investing activities. Therefore, it is reasonable to use these regions as the spatial units.

Quarterly Bio-VC investments in each region are displayed in Figure 2. When ranked by total investment in the study period (see Table 1), Silicon Valley occupies first place, receiving $9,790 million in venture capital investment. This region is followed by New England ($7,195 million), the San Diego metropolitan area ($5,376 million), the New York metropolitan area ($3,340 million) and the Philadelphia metropolitan area ($2,981 million). Sacramento, South Central and Upper New York were the regions receiving the least amounts of investment.

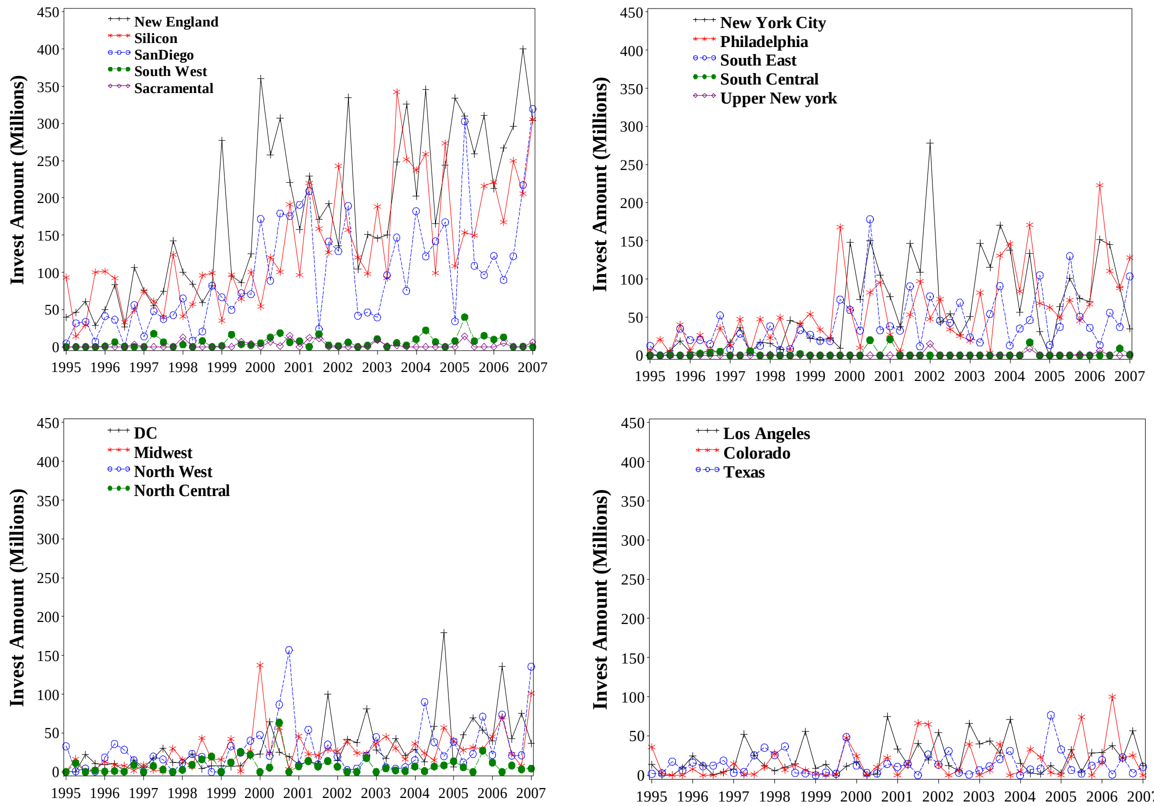


Figure 2: The regional distribution of venture capital investment in the U.S. biotechnology industry

Though all regions experienced some increases in investment volume from 1995 to 2007, their growth rates were different. This results in considerable changes in the share distribution of Bio-VC investment (Figure 3). For instance, both Silicon Valley and San Diego have increased their proportions over the years. Similarly, Midwest's share increased gradually. In contrast, the New England area has been receiving declining percentages in the Bio-VC investment. Some areas gained larger shares during the Dot-com bubble period than other years, such as New York City metro. In comparison, other regions had their lowest shares during this period, including Philadelphia, Southeast, Washington D.C., Northwest, Texas, and the North Central region.

MODELS

The objective of this research is to investigate the historical change in the spatial distribution of Bio-VC investments in the U.S. To be more specific, we are interested in understanding how the regional allocation of investment is related to historical distribution, national economic growth, and stock market

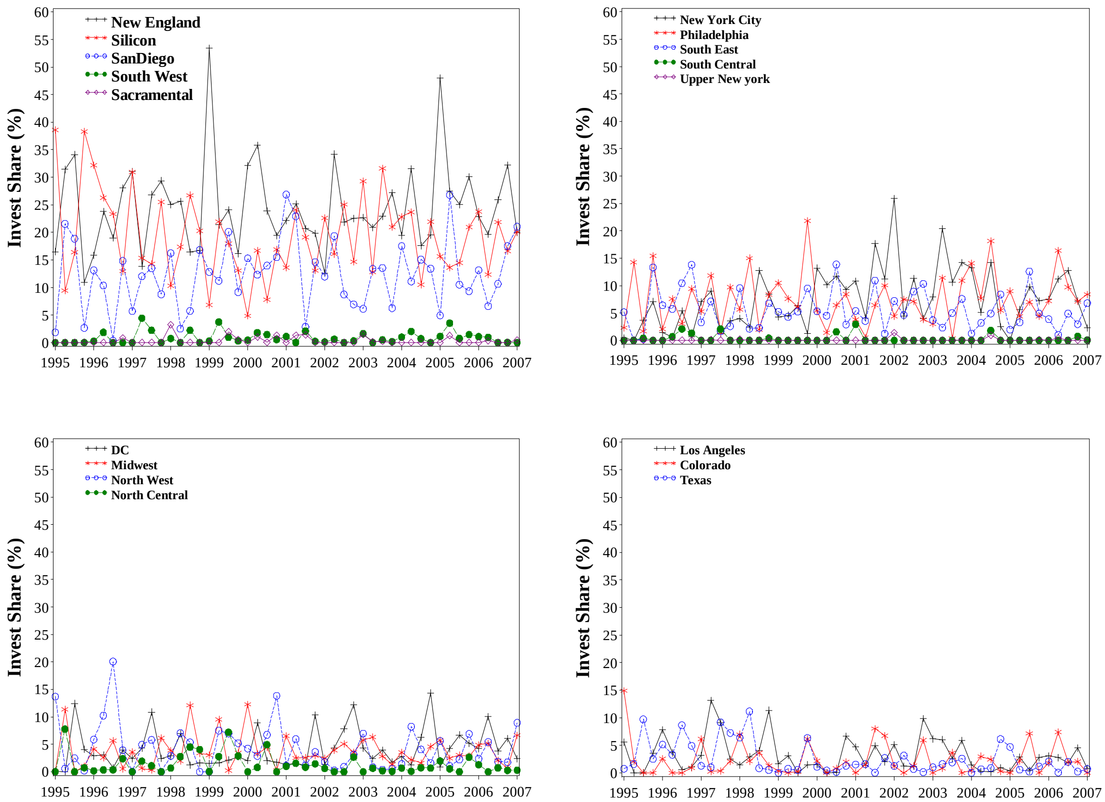


Figure 3: Regional Shares of Venture Capital Investment in the U.S. Biotechnology Industry

Table 1: Regional Distribution of Venture Capital Investments in the U.S. Biotechnology Sector

Rank	Region	Investment 1995-2007 ($ m)	Share in 1995 (%)	Share in 2001 (%)	Share in 2007 (%)	Growth 1995-2007 (%)
1	Silicon	9,790	21.19	21.94	24.55	611.0
2	New England	7,195	28.55	17.61	17.39	273.8
3	San Diego	5,376	9.29	16.55	18.35	1,112. 4
4	New York City	3,340	3.14	10.81	4.97	872.3
5	Philadelphia	2,981	8.45	5.35	5.69	313.7
6	South East	2,216	5.78	5.06	6.10	548.2
7	Washington, D.C.	1,817	3.99	3.88	5.81	792.6
8	Midwest	1,582	2.36	3.49	6.48	1,584.8
9	North West	1,549	4.69	3.13	4.91	541.8
10	Los Angeles	1,255	2.77	3.08	4.18	826.7
11	Colorado	948	4.70	4.25	2.57	236.0
12	Texas	761	3.39	1.51	1.79	223.6
13	North Central	463	1.62	1.24	1.59	502.6
14	South West	316	0.00	0.80	0.39	51,543.9
15	Sacramento	132	0.00	0.68	0.52	-
16	South Central	91	0.08	0.61	0.09	585.7
17	Upper New York	42	0.00	0.00	0.18	-

return. Two statistical models are established to explore the regional distribution of Bio-VC investment measured in both absolute amount and relative share. The spatial units are the seventeen areas defined by the Moneytree Survey. Since such a spatial division mixes cities and regions together and might cause problems, we construct two additional sets of data to test the same models. One dataset includes six city/metropolitan areas: Silicon Valley, San Diego, New York City, Philadelphia, Washington D.C., and Los Angeles. All the remaining eleven regions are pooled in the other dataset.

Model one: spatial distribution of investment in absolute magnitude

In model one, we examine how the amount of current investment is influenced by the past investment, national GDP growth rate, and NASDAQ biotechnology index. Seasonal and regional dummies are included as control variables. This is expressed mathematically in Equation 1.

Equation 1:

$$I_{it} = \alpha_i + \beta_1 CI_{i,t-1} + \beta_2 Growth_{t-1} + \beta_3 Nasdaq_{t-1} + \beta_4 Quarter_{1t} + \beta_5 Quarter_{2t} + \beta_6 Quarter_{3t} + \varepsilon_{it}$$

i=1, 2, …, 17; t=2, 3, …, 51.

The dependent variable I_{it} represents the current investment amount in the i^{th} area in quarter t. Independent variable $CI_{i,t-1}$ represents the cumulative investment from the first quarter of 1995 up to the t-1^{th} period in the i^{th} area. To deal with the heteroscadascity problem, all investment data are adjusted using square root transformation. Independent variable $Growth_{t-1}$ is the national GDP growth rate in period t-1, and $Nasdaq_{t-1}$ is the NASDAQ biotechnology index in period t-1. Quarterly GDP growth rates are calculated based on the data from the Bureau of Economic Analysis (BEA). NASDAQ biotechnology index data are from the NASDAQ official website. Variables $Quarter_{1t}$ to $Quarter_{3t}$ are dummies for the control of seasonal effects. For example, $Quarter_{1t}$ takes the value of 1 if it is quarter one in time period t and 0 otherwise. When all three dummy variables are zero, it refers to the fourth quarter. Parameters α_1, α_2, … α_{17} are included to capture regional differences. The order of the regions is the same as the rank of overall investment from 1995 to 2007 in Table 1. The error term ε_{it} is assumed to have an identical independent normal distribution. In the model, time period t starts with a value of two because there is a lag in the explanatory variables. All together, with 17 areas in 51 periods, there are 867 observations in the regression model. Detailed definitions of the variables are provided in Table 2.

If path dependence theory holds true, we would expect a positive impact from $CI_{i,t-1}$ upon I_{it} and a snow-ball effect in capital investment. In other words, areas that have received more Bio-VC investment in the past tend to receive more investment in the future. We also conjecture that economic growth rate in the recent past ($Growth_{t-1}$) has a positive effect on Bio-VC investment, as suggested in the relevant literature (Gompers and Lerner 1998; Jeng and Wells 2000). In addition, we expect a positive impact from the recent return in the stock market, measured by the NASDAQ biotechnology index in the previous quarter ($Nasdaq_{t-1}$) (Brav and Gompers 1997; Ritter and Welch 2002; Hine and Griffiths 2004). A preliminary autocorrelation analysis shows that there are high autocorrelations for up to eight lags for each of the variables $CI_{i,t-1}$, $Growth_{t-1}$, and $Nasdaq_{t-1}$. To avoid a multicollinearity problem in the Ordinary Least Squares regression, we use only one lag for each of these three variables.

Table 2: Description of Variables

Variable	Description
I_{it}	Venture capital investment (after square root) in t^{th} quarter in the i^{th} region
$I_{i,t-1}$	Venture capital investment (after square root) in $t\text{-}1^{th}$ quarter in the i^{th} region
$Share_{it}$	Venture capital investment share in t^{th} quarter in the i^{th} region
$Share_{i,t-1}$	Venture capital investment share in $t\text{-}1^{th}$ quarter in the i^{th} region
$CI_{i,t-1}$	Accumulated venture capital investment (after square root) in $t\text{-}1^{th}$ quarter in the i^{th} region
$CShare_{i,t-1}$	Accumulated venture capital investment share in $t\text{-}1^{th}$ quarter in the i^{th} region
$Growth_{t-1}$	GDP growth at $t\text{-}1^{th}$ quarter
$Nasdaq_{t-1}$	NASDAQ biotechnology index in the $t\text{-}1^{th}$ quarter
$Quarter_{1t}$	Dummy variable, 1 if the t^{th} quarter is the first quarter, 0 otherwise
$Quarter_{2t}$	Dummy variable, 1 if the t^{th} quarter is the second quarter, 0 otherwise
$Quarter_{3t}$	Dummy variable, 1 if the t^{th} quarter is the third quarter, 0 otherwise
Silicon(a_1)	Regional dummy for Silicon Valley
New England(a_2)	Regional dummy for New England
San Diego(a_3)	Regional dummy for San Diego
New York City(a_4)	Regional dummy for New York City
Philadelphia(a_5)	Regional dummy for Philadelphia
South east(a_6)	Regional dummy for South east
D.C. (a_7)	Regional dummy for Washington D. C.
Midwest(a_8)	Regional dummy for Midwest
North West(a_9)	Regional dummy for North West
Los Angeles(a_{10})	Regional dummy for Los Angeles
Colorado(a_{11})	Regional dummy for Colorado
Texas (a_{12})	Regional dummy for Texas
North Central (a_{13})	Regional dummy for North Central
South West(a_{14})	Regional dummy for South West
Sacramento (a_{15})	Regional dummy for Sacramental
South Central(a_{16})	Regional dummy for South Central
Upper New York(a_{17})	Regional dummy for Upper New York

To solve the coefficients α_1, α_2, … α_{17}, and β_1, β_2, …, β_6, we define $Y_t=(I_{1,t}, I_{2,t},\ldots, I_{17,t})^T$, $\beta=(\beta_1, \beta_2, \ldots, \beta_6)^T$, $\alpha=(\alpha_1, \alpha_2, \ldots \alpha_{17})^T$, $e_t=(\varepsilon_{1,t}, \varepsilon_{2,t},\ldots, \varepsilon_{17,t})^T$

and

$$X_t=\begin{pmatrix} CI_{1,t-1} & Growth_{t-1} & Nasdaq_{t-1} & Quarter_{1t} & Quarter_{2t} & Quarter_{3t} \\ CI_{2,t-1} & Growth_{t-1} & Nasdaq_{t-1} & Quarter_{1t} & Quarter_{2t} & Quarter_{3t} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ CI_{17,t-1} & Growth_{t-1} & Nasdaq_{t-1} & Quarter_{1t} & Quarter_{2t} & Quarter_{3t} \end{pmatrix}$$

$$Z=\begin{pmatrix} 1 & 0 & \cdots & 0 \\ 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 \end{pmatrix}_{17\times 17}$$

Then for any period $t=2,\ldots, 51,$ combining all regions, Equation 1 turns to be $Y_t = Z\alpha + X_t\beta + e_t$ $t=2, 3, \ldots, 51$.

Now, consider all time periods together to solve the parameters α and β. Let

$$Y=\begin{pmatrix} Y_2 \\ Y_3 \\ \vdots \\ Y_{48} \end{pmatrix},\ X=\begin{pmatrix} Z & X_2 \\ Z & X_3 \\ \vdots & \vdots \\ Z & X_{48} \end{pmatrix},\ e=\begin{pmatrix} e_2 \\ e_3 \\ \\ e_{48} \end{pmatrix}.$$

We have $Y = X\begin{pmatrix} \alpha \\ \beta \end{pmatrix} + e$.

By the OLS method, the estimated α and β are given by equation 2.

Model two: spatial allocation of venture capital investment in relative shares

Model two is constructed to investigate the share distribution of Bio-VC investments. It is similar to model one except that the dependent variable becomes the share of investment in period *t* for each region ($Share_{i,t}$), and $CI_{i,t-1}$ becomes the share of the cumulative investment $CShare_{i,t-1}$ in the previous quarter. Again, square root transformation is used for these variables to deal with the heteroscadascity problem. If there is a positive impact from $CShare_{i,t-1}$ upon $Share_{i,t}$, our analysis will provide further support for the theory of snow-ball effect. In other words, the geographic unevenness in the share distribution of venture capital tends to increase over time. In contrast, a negative impact signals a dispersion pattern and the share distribution of venture capital across regions tends to become more even over time. As in model one, economic growth, stock market return, quarterly and regional dummies are included. The model is expressed mathematically in Equation 3.

Similarly, we define:

$Y_t=(Share_{1,t}, Share_{2,t},\ldots, Share_{17,t})^T$

and

$$X_t=\begin{pmatrix} CShare_{1,t-1} & Growth_{t-1} & Nasdaq_{t-1} & Quarter_{1t} & Quarter_{2t} & Quarter_{3t} \\ CShare_{2,t-1} & Growth_{t-1} & Nasdaq_{t-1} & Quarter_{1t} & Quarter_{2t} & Quarter_{3t} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ CShare_{17,t-1} & Growth_{t-1} & Nasdaq_{t-1} & Quarter_{1t} & Quarter_{2t} & Quarter_{3t} \end{pmatrix}$$

.

Equation 2:

$$\begin{pmatrix} \hat{\alpha} \\ \hat{\beta} \end{pmatrix} = (X^T X)^{-1} X^T Y$$

Equation 3:

$$Share_{it} = \alpha_i + \beta_1 CShare_{i,t-1} + \beta_2 Growth_{t-1} + \beta_3 Nasdaq_{t-1} + \beta_4 Quarter_{1t} + \beta_5 Quarter_{2t} + \beta_6 Quarter_{3t} + \varepsilon_{it}$$

i=1, 2, …, 17; t=2, 3, …, 51.

The other terms are defined in the same way as in the first model. The estimations of α and β are given in Equation 2.

RESULTS

Regression results of the first model when all seventeen areas are included are presented in Table 3. The R-square is 0.76. Both the QQ plot and residual plot illustrate a normal distribution of the error term (Figure 4), which is the assumption of the model. The second dataset (six city/metropolitans) and the third dataset (eleven state/regions) produce similar regression results regarding the significance terms. Therefore, we only report the regression results using the pooled data with all regions.

Independent variables CI_{t-1}, $Growth_{t-1}$ and $Nasdaq_{t-1}$ all have significantly positive effects (Table 3). The positive impact of CI_{t-1} indicates that areas with more historical investment tend to obtain more new investment. This result supports the theory of path dependence and circular causation. There is also a positive impact from GDP growth rate in the previous quarter. This outcome is different from Jeng and Wells (2000) but agrees with Gompers et al. (1998) and Dibner (et al. 2003). Besides the impact from long-term economic fluctuations upon venture capital investment (Gompers et al. 1998; Dibner et al. 2003), our results suggest a short term effect as well. As most biotechnology products are consumer goods that are directly related to the national economy, changes in the latter will impact the demand for the medical products and consequently the supply of the investment. A positive influence from the NASDAQ biotechnology index in the previous quarter signals that venture capital investment responds positively to the recent performance of capital market return, a result consistent with previous studies (Dibner et al. 2003; Hine and Griffiths 2004).

Regarding seasonal effects, the dummy variables for the first three quarters are all significantly negative. This means that, compared to the fourth reference quarter, there are

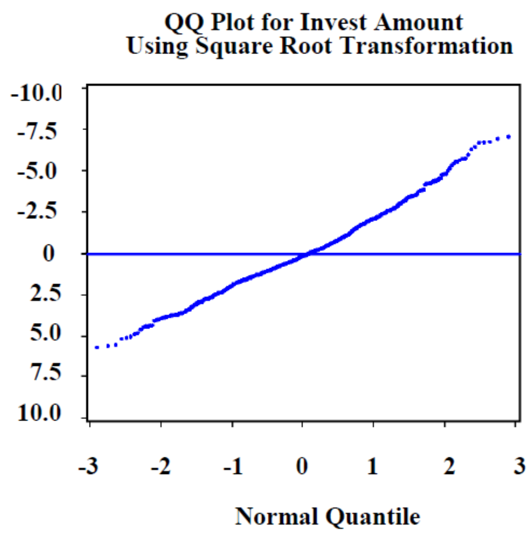
Table 3: Regression Result for Model One

Dependent variable: I_t (after square root transformation), or venture capital investment in the t^{th} quarter (N=867)

Variable	Estimate	Standard Error	t test	P Value
CI_{t-1}	0.097	0.007	13.760	**<.0001**
$Growth_{t-1}$	29.997	16.376	1.830	**0.067**
$Nasdaq_{t-1}$	0.002	0.000	4.950	**<.0001**
$Quarter_{1t}$	-0.490	0.213	-2.300	**0.022**
$Quarter_{2t}$	-0.404	0.209	-1.930	**0.054**
$Quarter_{3t}$	-0.617	0.209	-2.950	**0.003**
Silicon(a_1)	7.908	0.565	14.000	**<.0001**
New England(a_2)	6.588	0.538	12.240	**<.0001**
San Diego(a_3)	5.662	0.504	11.240	**<.0001**
New York City(a_4)	4.149	0.475	8.730	**<.0001**
Philadelphia(a_5)	4.003	0.476	8.420	**<.0001**
South east(a_6)	3.347	0.467	7.170	**<.0001**
D.C. (a_7)	3.157	0.454	6.950	**<.0001**
Midwest(a_8)	2.876	0.454	6.330	**<.0001**
North West(a_9)	2.392	0.458	5.220	**<.0001**
Los Angeles(a_{10})	2.213	0.452	4.890	**<.0001**
Colorado(a_{11})	1.494	0.447	3.350	**0.001**
Texas (a_{12})	1.602	0.447	3.580	**0.000**
North Central (a_{13})	1.033	0.441	2.340	**0.019**
South West(a_{14})	0.878	0.438	2.010	**0.045**
Sacramento (a_{15})	0.148	0.436	0.340	0.734
South Central(a_{16})	-0.084	0.436	-0.190	0.847
Upper New York(a_{17})	-0.905	0.447	-2.020	**0.043**
R square	0.766			

fewer investments from January to September. All regional dummies have significantly positive effects, except for South Central and Upper New York. Excluding Texas, the estimated coefficients for regional dummies have a descending order, which is consistent with the rank of overall investment value. Since the t-tests presented in Table 3 do not examine the difference between non-reference regions, a joint test for the null hypothesis $a_1 = a_2 = \ldots a_{16} = 0$, is further performed. Such a null hypothesis is strongly rejected (p-value<.0001), again providing sufficient evidence that regional difference is significant.

To illustrate the effects of the independent variables on the



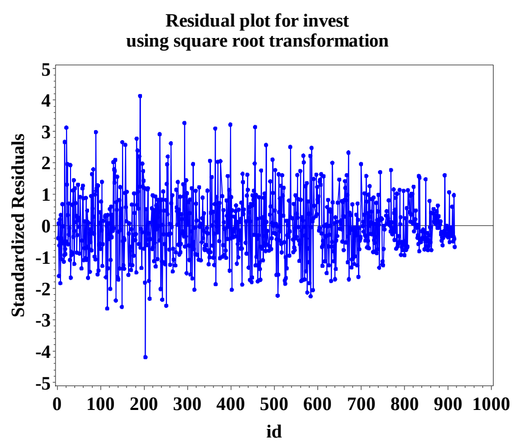


Figure 4: QQ Plot and Residual Plot for Model One (Absolute Amount after Square Root Transformation)

predicted investment, the fourth quarter of 2007 in Silicon area is taken as an example. In this quarter, the accumulated investment was $9,790 million, GDP growth rate was 1.46 percent, and NASDAQ biotechnology index was 815.72. Using our estimated model, the predicted investment in the first quarter of 2008 for Silicon Valley would be $317.8 million. If the accumulated investment increases by $100 million, the predicted investment would be $319.6 million with an increase of $1.8 million, given the same values for GDP growth rate and biotechnology index. If we only increase the GDP growth rate by one percent, the predicted investment would be $328.7 million. Also, if only the biotechnology index increases by 100, the predicted value would be $323.6 million. Now take Midwest for comparison. The accumulated investment in Midwest was $1,582 million in the fourth quarter of 2007 and its predicted investment in the first quarter of 2008 is $50.5 million. A $100 million increase in the accumulated investment would increase the predicted investment to $52.2 million in the first quarter of 2008. A one percent increase in GDP growth rate would result in $54.8 million, and an increase of biotechnology index by 100 would result in $52.8 million in the predicated value.

When the share distributions are analyzed in model two, again, all three data sets produce similar regression results. Hence we only report the results using the pooled data with all seventeen regions (Table 4). The R-square is 0.78. The QQ plot and residual plot show that the assumption of the model is satisfied (Figure 5). Variable $CShare_{t-1}$ has a significantly positive effect (P-value<.0001). This means that, in general, areas with larger shares in the cumulative investment amount in the past continue to receive larger proportions in the future. This result gives further support for the theory of path dependence. Different from model one, none of $Growth_{t-1}$, $Nasdaq_{t-1}$, and quarterly dummy variables is significant. Regarding the impact of regional dummy variables, only Colorado is significant at a level of .05, when compared to the reference Upper New York region. Similar to model one, we also test the joint null hypothesis $a_1 = a_2 = \ldots a_{16} = 0$ here. The testing result strongly rejects the null hypothesis, suggesting that regional difference is significant.

Combining results from both models, we conclude that, from 1995 to 2007, areas that attracted more Bio-VC investment in the recent past will continue to receive more and larger shares of new investment. In other words, the gap between the leading areas and others is increasing. Being consistent with some prior studies of the changing geography of venture capital investment (Martin 1989), our results provide further empirical evidence to the theory of path dependence through rigorous statistical model testing.

DISCUSSION AND CONCLUSION

This paper investigates the changing geography of venture capital investment in the biotechnology industry in the United States from the first quarter of 1995 to the fourth quarter of 2007. When the spatial distribution of Bio-VC in absolute amount is considered, we find that current investment is positively associated with historical investment. Leading areas in Bio-VC investment, such as Silicon Valley and New England, will continue to receive more capital in the future. In contrast, lagging areas in Bio-VC investment, including North Central and South Central, tend to receive fewer new investments than other areas. When the share distribution is considered, we find that a region's historical share has a significantly positive impact on its future share. Therefore, we conclude that areas with more venture capital investment in the past tend to not only attract more investments, but also gain larger shares over other

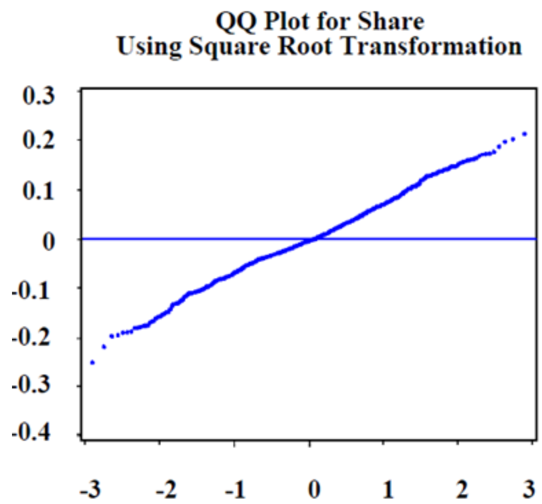
Table 4: Regression Result for Model Two

Dependent variable: $share_t$ (after square root transformation), or venture capital share in t^{th} quarter (N=867)

Variable	Estimate	Standard Error	t test	P Value
$CShare_{t-1}$	1.024	0.081	12.690	<.0001
$Growth_{t-1}$	0.096	0.547	0.180	0.861
$Nasdaq_{t-1}$	-1.59E-07	8.75E-06	-0.020	0.986
$Quarter_{1t}$	-0.006	0.007	-0.790	0.430
$Quarter_{2t}$	-0.004	0.007	-0.510	0.613
$Quarter_{3t}$	-0.003	0.007	-0.420	0.672
Silicon(a_1)	0.001	0.040	0.030	0.973
New England(a_2)	-0.024	0.038	-0.640	0.521
San Diego(a_3)	0.000	0.030	0.020	0.988
New York City(a_4)	0.010	0.023	0.450	0.654
Philadelphia(a_5)	-0.010	0.025	-0.420	0.675
South east(a_6)	-0.018	0.023	-0.760	0.446
D.C. (a_7)	0.009	0.020	0.460	0.648
Midwest(a_8)	-0.001	0.020	-0.050	0.962
North West(a_9)	-0.037	0.022	-1.710	0.088
Los Angeles(a_{10})	-0.025	0.020	-1.230	0.219
Colorado (a_{11})	-0.041	0.019	-2.160	0.031
Texas (a_{12})	-0.028	0.019	-1.460	0.144
North Central (a_{13})	-0.021	0.017	-1.240	0.214
South West(a_{14})	-0.008	0.015	-0.510	0.613
Sacramento (a_{15})	-0.014	0.015	-0.920	0.355
South Central(a_{16})	-0.022	0.015	-1.510	0.130
Upper New York(a_{17})	-0.007	0.015	-0.460	0.645
R square	0.776			

places in the future investment. Through rigorous statistical modeling, our results have added further evidence to the theory of business clustering (Martin 1989).

As the biotechnology industry is becoming more global (Cooke 2008), it is highly possible that leading regions will keep attracting both domestic and international capital, and that their positions will be strengthened in the United States and the world. By contrast, for the lagging areas to bridge the gap, it might be necessary for them to develop relevant regional attributes, such as more input in public research in life science, better



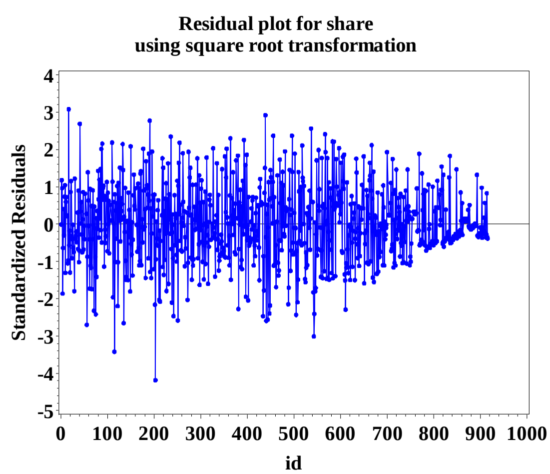


Figure 5: QQ plot and residual plot for model two (share after square root transformation)

regional infrastructure, and more innovative business environment. Finally, we find that the amount of Bio-VC investments at the regional level is positively related to recent national GDP growth rate and the return performance of biotechnology stocks. We will continue to explore these relationships as the relevant information becomes available.

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TRIBUTE: ALAN MACPHERSON

Our good friend and colleague Alan MacPherson passed away in May. Most of us, undoubtedly, know of Alan's acumen and accomplishments as a researcher and teacher at the University at Buffalo. His research record was impressive: Alan's work on international trade, technological change, and regional economic growth was without compare and certainly informed the work of many others in our field. What is perhaps more remarkable was that his work was entirely straightforward, easily accessible, and highly applicable to real-world issues of interest to geographers, economists, regional scientists, and policymakers. Many geographers from Buffalo, of course (present company included), remember Alan as a graduate advisor who truly cared about his students and without exception, made them better researchers. On a personal note, Alan was a truly inspiring advisor, always ready with helpful suggestions and encouragement. Perhaps more importantly, he taught me not to take things so seriously and to keep everything in perspective…critically important advice! Beyond the academic tasks and accomplishments, all of us remember Alan as a good friend. To be honest and I think one finds general agreement here, there were few people who were more enjoyable to grab a beer, a sandwich, a chat, and a football (or hockey) game with than Alan. The fact that he was so genuinely fun to spend time with and moreover, that he was game for any adventure, is testament to his impact on his friends. Alan will be truly missed.

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All manuscripts are subject to double-blind peer review. Upon receipt of the manuscript, a paper will be sent out for review to three (3) professionals with expertise in the core area investigated. The three (3) reviewers will be comprised of at least one (1) editorial board member and one (1) non-board member. Ideally, the initial review process will be completed within six (6) to eight (8) weeks from initial submission. No initial review should exceed twelve (12) weeks. Please note that July submissions will not be sent out for review until the first week of August.

Submissions

Expectations and Formats

The Industrial Geographer solicits high-quality research in economic geography, encompassing both the traditional, research article format, and shorter research notes and discussions. All submissions to *The Industrial Geographer* must represent the original work of the author(s). It is the responsibility of the author(s) to obtain copyright permissions, if necessary. Simultaneous submissions of works to other journals are not acceptable. A cover letter must be provided along with any submission that certifies that the above conditions have been met, and will be met as long as *The Industrial Geographer*'s review process is ongoing.

<u>We encourage electronic submissions</u>. Submissions can be made via e-mail directly to the editors. Microsoft Word documents (97-2003 or 2007 file types if possible) are the preferred submission format. Submissions in other Microsoft Word-accessible formats are also acceptable, but may require author modifications for review or acceptance. Tables, maps, and figures should not be embedded with the main text, but must be submitted separately (i.e. separate table file, figure file, etc).

We also accept hard-copy submissions, although we prefer electronic submissions. Hard-copy submissions should be made in triplicate to the appropriate co-editor with any potential identifiers (acknowledgements, names, etc.) placed on the first, or cover, page along with the manuscript title. The second page should also include the manuscript title, along with the abstract. The main text of the manuscript should appear beginning on the third page.

Articles

Article submissions should conform to the standard format followed in past issues of *The Industrial Geographer*. Detailed style guidelines can be found below. Alternative article formats should be presented to the co-editors before submission. In-depth research articles covering issues from throughout industrial and economic geography form the core of each issue of the journal. *The Industrial Geographer* welcomes innovative, well-written, and thought-provoking research that makes a clear contribution to the advancement of knowledge in economic geography. Generally, articles should not exceed 5000 words (including abstract, text, and bibliography).

Please submit articles to: Ron Kalafsky, Co-Editor, *The Industrial Geographer,* <u>kalafsky@utk.edu</u>, or Department of Geography, The University of Tennessee, Knoxville, TN 37996-0925. E-mail submissions are preferred.

Research Notes & Discussion Items

The Industrial Geographer also encourages the submission of notes that present short 'data-driven' case studies, examples of applied industrial geography, explore methodological issues, or concisely discuss or review the trajectory of industrial geography or related conceptual issues. Additionally, we also encourage 'creative' or non-conventional research notes that may provide new insights into industrial geography and related social sciences or the humanities. Creative notes might include "wide format" posters or other unique formats that are more easily published in an electronic format. Research notes should not exceed 2500 words (including text and bibliography).

Please submit research notes and discussion items to: Murray D. Rice, Co-Editor, *The Industrial Geographer*, <u>rice@unt.edu</u>, or Department of Geography, University of North Texas, 1155 Union Circle #305279, Denton, TX 76203-5017. Again, e-mail submissions are preferred.

Style Guidelines

Abstracts and Key Words

All articles must include a 150-200 word abstract that summarizes methods and key findings. Both articles and research notes should include a maximum of five (5) key words for the purposes of indexing. Ideally, the keywords would detail location, topic, method, and two (2) other related descriptors.

Headings & Tables

The format of headings and tables will be left to the discretion of authors. In the case of tables, the portrait orientation is always preferred.

Illustrations

Color, grayscale, or black and white illustrations are acceptable. Authors should be mindful that all illustrations must be high quality and submitted in their final form as a TIF file with a 360 dpi resolution.

Citations & References

Parenthetical citations are used in the body of the text. Examples are presented below:

Single Author—(James 1934)

Multiple Authors—(Smith 1992; Billings 1989; Jones & Hanham 1995)

Direct Quote—(Billings 1989 p. 12)

References should be arranged alphabetical and chronologically. The general style for publication types is presented below:

1. Articles

Lindahl, D. & Beyers, W. 1999 The creation of competitive advantage by producer service establishments. *Economic Geography* 75:1-20.

2. Chapters

Swyngedouw, E. 1997 Neither global nor local: "Glocalization" and politics of scale. In *Spaces of Globalization: Reasserting the Power of the Local,* edited by K. Cox, pp. 137-166. New York: Guilford Press.

3. Presentations

Graves, W. 1997 Mapping the new economy: Estimating intellectual capital distributions from balance sheet data, Presented at the Southeast Division of the American Association of Geographers (SEDAAG).

4. Books

Illeris, S. 1996 *The Service Economy: A Geographical Approach*. New York: Wiley.

5. Working Papers or Other Resources

Atchison, S. 1993 Care and feeding of lone eagles. *Business Week,* November 15, p. 58.

DeVol, R. 1999 America's High-Tech Economy: Growth, Development, and Risks for Metropolitan Areas. Milken Institute, Santa Monica, CA.

Rickman, P. 2001 Official, United Auto Workers Local 12, Toledo, OH, telephone interview August 15.

McKinnon, J. 2001 Liberty a symbol of Jeep's rebirth in insecure times. *Toledo Blade*, February 18 [http://toledoblade.com], accessed January 1, 2002.

6. Hypertext

Authors are encouraged to use hypertext (or WWW links) within their manuscript. However, authors are responsible for the overall validity of the link. To insure the shelf life of submitted manuscripts, links should be limited to 'root' directories—not individual web pages. Also, authors should seek to limit the use of hypertext to more stable internet sites, such as government agencies, non-governmental organizations, and/or major corporations.