AN ECONOMIC DEVELOPMENT PARADOX: THE IMPACT OF LINKAGES AND SYNERGIES AMONG LOCAL AGENTS IN THE DEVELOPMENT OF AN EMERGENT BIOSCIENCE CLUSTER AND ASSOCIATED ENTREPRENEURIAL ECOSYSTEMS

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ABSTRACT

Although bioscience industrial clusters have been widely researched in the last decade, the role of knowledge creation, management, and transfer as driving forces for industrial cluster competitiveness remains unclear. A better appreciation of knowledge creation and retention as determinants of industrial cluster success, and the role of foreign direct investment may be of value to industry decision makers, policy makers, and researchers worldwide. Our research revealed a paradox regarding the intensity of foreign direct investment (FDI) by multinational companies (MNCs) and the limited development of a local entrepreneurial ecosystem in an emergent bioscience cluster. While cluster development seems a logical outcome of MNC investment, our study demonstrated it is not a foregone conclusion. Our research of Puerto Rico's bioscience cluster experience sheds light on a key theoretical and policy issue: *to what extent can the development strategy of attracting FDI from global multinationals be leveraged to transfer knowledge and develop indigenous innovation capabilities?* The paper draws upon national innovation systems knowledge management, and social network theory to examine these issues.

Keywords: bioscience clusters; competitiveness; entrepreneurial ecosystem; foreign direct investment; knowledge transfer; innovation systems.

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INTRODUCTION

This paper analyzes how linkages and synergies between local agents that impact knowledge creation, transfer and retention may hinder the development of an emergent bioscience cluster and associated entrepreneurial ecosystems. During the last two decades, industrial clusters have been one the main vehicles utilized by policy makers for economic development (Altenburg & Meyer-Stamer, 1999; Rodrik, 2004). To date, very limited academic research has been conducted in emergent bioscience clusters in island states. Although Puerto Rico is recognized as a major pharmaceutical manufacturing location, no scholarly work has been conducted contrasting bioscience clusters there with developed biomedical and bioscience clusters in other geographical areas. A better appreciation of knowledge creation and retention as determinants of industrial cluster success, and the role of foreign direct investment in such clusters may be of value to industry decision makers, policy makers, and researchers worldwide.

As knowledge has become a strategic asset (Winter, 1987) and a source of competitive advantage (Quinn, 1992; Nonaka, 1994), regions have often benchmarked and imitated one another (Huggins, 2008, European Union Commission, 2008). Economic development has always been a moving target and governments have continually searched for new tools and policy formulas to enhance their strategies to effect it (Waits, 2000). Although bioscience industrial clusters are one of the most researched areas in the last decade (Feldman & Francis, 2004), the role of knowledge creation, management, and transfer as driving forces for industrial cluster competitiveness remains unclear (Alavi & Leidner, 2001; Bathelt, Malmberg, & Maskell, 2004; Orsenigo, 2006).

In the past two decades, two important frameworks emerged in knowledge management that sought to explain how knowledge creation, transfer and innovation could be generated and sustained in specific geographic areas: knowledge ecology (Pór & Spivak 2000; Mecalfe & Ramlogan, 2005) and the social network model (Granovetter,1985; Gordon & McCann, 2000; Basant & Chandra, 2002). Pór and Spivak, borrowing from the field of biology, pointed out that knowledge exists in ecosystems, in which information, ideas, and inspiration cross-fertilize and feed one another while Mecalfe and Ramlogan argued that individuals, repositories and generators of the existing and new knowledge, ensure the flow of information within information system of "ecologies" (Pór & Spivak 2000; Mecalfe & Ramlogan, 2005). The social network model proposes that social networks are key sourcing channels that facilitate knowledge flow through either formal or informal routes, although it does not implicitly implies spatial applications (Granovetter, 1985; Gordon & McCann, 2000; Basant & Chandra, 2002). Both models address knowledge creation, transfer and retention and innovation through the analysis of industrial complexes, agglomerations, knowledge and innovation platforms or social networks (Basant & Chandra, 2002). As a means of understanding how the modus operandi of industrial clusters is evolving, we suggest examining a possible bridge between the two theoretical conceptualizations.

For the purposes of our research, and to minimize possible confusion with language used by researchers in the biotechnology field, the term "embedded knowledge" is utilized to describe the knowledge potentially realizable by the combination of regional stocks of tacit knowledge (Madhavan & Grover, 1996), and as knowledge created within the region as distinct from knowledge imported from outside (Chang & Chen, 2004).

Qualitative research was conducted in bioscience clusters in Northeast Ohio, a developed cluster, and Puerto Rico, an emergent cluster, to reveal the relationship dynamics of local agents and explore their role in both the knowledge creation and retention process, and the scope of their economic activities as dimensions of performance, competitiveness and eventual regional economic success.

Our findings, derived from interviews with cluster agents (i.e., entrepreneurs, multinational companies, local enterprises, research and development institutions, local public policy entities, academic institutions, venture capital firms, and specialized suppliers of industry-specific inputs, among others entities) may make a novel contribution to the domain of knowledge management and innovation research. Findings may have important implications for designing and implementing knowledge-base innovation strategies and creating sustainable competitive advantage.

RESEARCH QUESTION

How and to what extent do cluster agents create, absorb and retain knowledge so as to make regional biotechnology industry clusters more competitive? A conceptual model was constructed to guide the research (Figure 1). We aimed to discover factors that might impact the process of knowledge creation, absorption and retention. A review of pertinent literature suggested these might include the interactions of external agents (i.e., foreign direct investment, supply-chain, customers and other organizations and individuals), local agents, (i.e., local individuals, organizations and networks), and public policy (i.e., local authority industrial cluster strategies and policy networks). We wondered if knowledge creation, absorption and anchoring by such agents affected local and/or regional cluster knowledge diffusion and exploitation capacities. Successful outcomes could include employment effects, industry agglomerations, and technology transfers, development of indigenous industries, and enhanced company and industrial cluster competitiveness (Blomström & Kokko, 1998).

LITERATURE REVIEW

Although extensive research has been conducted on industrial clustering, innovation systems, and knowledge creation and management, and theorists have suggested a positive relationship between them and overall cluster performance as driving regional economic development (Audretsch & Feldman, 1996; Porter, 1998; Carlsson & Braunerhjelm, 2002; Cooke, Heidenreich, & Braczyk, 2004; Morosini, 2004; Orsenigo, 2006; Bathelt, Malmberg, & Maskell, 2004; Braunerhjelm & Feldman, 2006; Huggins, 2009), it is conceded that there are "large gaps in the body of knowledge in this area" (Alavi & Leidner, 2001). We reviewed the literature in two phases. First, we explored scholarly inquiry about industrial clustering and innovation systems to assess the applicability of previous work to our own and its appropriateness to our research problem of practice (i.e., the impact of local cluster agent actions on knowledge creation, transfer and retention). Next, we reviewed literature associated with knowledge creation, and flow dynamics (Nonoka, 1994; Basant & Chandra, 2002; Nissen, 2002; Mecalfe & Ramlogan, 2005; Cooke, 2008) to analyze the link between knowledge creation, transfer, and retention and cluster performance.

Industrial Clusters and Innovation Systems

Early contributions to the cluster literature used division of labor, transaction costs, and geographical agglomeration to explain the concentration or “clustering” of economic activities (Marshall, 1890; Schumpeter, 1939; Becattini, 1979, 1990). The focus of these studies was on traded relationships in the form of input − output linkages. More recently, the focus has shifted from traded to untraded interdependencies (Basant, 2002). Clusters are seen as regional innovation systems generating, diffusing, and using technology through networks of agents interacting in specific economic/industrial areas under particular institutional infrastructures (Carlsson, Jacobsson, Holmén, & Rickne, 2002). Innovation has been identified as a key driver for entrepreneurial activity and economic development (Orsenigo, 2006). In turn, entrepreneurial activity is critical for industrial cluster development (Braunerhjelm & Feldman, 2006).

Recently there has been some shift in the academic and policy debate on innovation from a more traditional systems approach to ecologies and/or ecosystems (Mecalfe & Ramlogan, 2005) transferred from the world of biology to the social world to explain the evolutionary nature of interrelations between different individuals, their innovative activities and their environment. Researchers (e.g., Cooke, Heidenreich, & Braczyk, 2004) have criticized the generality of the NSI approach and have stressed the need for detailed empirical research of innovation interactions at a regional level.

Agglomeration forces keep innovative activities localized through networks of relationships among agents (Orsenigo, 2006). Networks are considered as a specific form of organization of innovative activities, substituting the traditional model based on research and development, and joint and contingent effects of geography and network connections are recognized as crucial to the innovative capacity of high-tech clusters (Powell, Kelly Porter, & Bunker, 2005).

Although industry clusters and innovation systems have been the focus of considerable academic research, there is limited understanding of the knowledge transfer dynamics within these networks (Feldman, 2002; Bathelt, Malmberg, & Maskell, 2004). Researchers, such as Malerba and Orsenigo (2002) have examined knowledge transfer and innovation in the pharmaceutical industry and biotechnology industries due to their specific institutional development dynamics.

Knowledge flow dynamics and knowledge ecology. Many scholars (e.g., Drucker, 1994) have argued that knowledge represents one of the very few sustainable sources of comparative advantage. While the modern organization depends upon timely and effective flows of knowledge for success, knowledge is not evenly distributed through the enterprise (Nissen, 2002). Further, the few theoretical knowledge-flow models available (e.g., Nonaka, 1994; Dixon, 2000) have not yet been developed to a point where they can effectively inform the design of information systems and business processes to enable, automate and support knowledge flow in the enterprise. A survey of current practice (Nissen et al., 2000) shows that such system and process design is accomplished principally by trial and error.

Alavi and Leidner (2001) argue that recent interest in organizational knowledge and knowledge management is motivated by (a) the shift to the information age with rapid advancement in information technology and (b) a shift in organizational theory and praxis to consider knowledge as the primary source of economic growth manifested in new thinking and practice (e.g. benchmarking, knowledge audits, best practice transfer, and employee development. "The emergent patterns of literature and research as well as practice in the field imply the central role of knowledge as the essence of the firm" (Alavi & Leidner, 2001).

Nonaka (1994) asserts that new knowledge is created only by individuals in the organization and is necessarily tacit in nature. The first flow of knowledge is then theorized to occur through a process termed socialization. Knowledge is later externalized through explicit channels (e.g., coded information). Building on Nonaka, knowledge management theorists (e.g., Nissen, 2002), examine complex dynamic as knowledge flows along a life cycle.

Knowledge ecology, and its related concept of information ecology, hypothesize that knowledge exists in ecosystems, in which information, ideas, and inspiration cross-fertilize and feed one another following the network patterns of living systems (Pór & Spivak, 2000). Knowledge ecologies are typically national in scope, and reflect rules of law and language, business practices and the social and political regulation of the economies in which they are located (Carlsson, 1997; Carlsson, Jacobsson, Holmen, & Rickne, 2002; Cooke, Boekholt, & Todtling, 2000).

By utilizing a biological premise, knowledge ecology theory offers a limited understanding of the complex and historical social networks which play a crucial role in the interrelations of industrial innovation.

Social capital and synergies. Tacit knowledge (i.e., the knowledge within the heads of individuals rather than written down and codified (i.e., explicit knowledge) is less likely to be sourced through markets (Huggings, 2009). In this case, social networks are key sourcing channels, facilitating knowledge flow through either formal or informal routes.

The term "social capital" initially appeared in community studies, highlighting the central importance(for the survival and functioning of city neighborhoods) of networks of strong, crosscutting personal relationships developed over time that provide the basis for trust, cooperation, and collective action (Jacobs, 1965). Through "weak ties" (Granovetter, 1985) and "friends of friends" (Boissevain, 1974), network members can gain privileged access to information and to opportunities. But, social capital is not a traded commodity (Maskell, 1999). Social capital has its roots in social networks (Basant & Chandra, 2002).

The generalizability of this model is limited. Much of the interest in social capital as a productive asset, particularly within the field of spatial planning, arises from the fact that the social network model has been viewed as largely applicable to particular observations of spatial industrial clustering in Northern Italy, California and Massachusetts (Scott, 1988; Rogers & Larsen, 1984; Saxenian, 2005).

METHODS

Methodology

An exploratory approach was adopted for building a theory using Glaser and Strauss's (1967) grounded theory framework. This research approach involves the simultaneous collection, analysis, and interpretation of data. We used semi-structured interviews as the principal means of data collection, asking open ended questions and encouraging respondents to narrate experiences rather than utilizing a rigid protocol. The process we employed, in line with the recommendations of Glaser and Strauss (1967) was reflexive and iterative, requiring movement between data, literature and theory.

This method is “an inductive approach to the study of social life that attempts to generate a theory from the constant comparing of unfolding observations” (Babbie, 2007) − one that stresses rigorous research procedures. Key characteristics of grounded theory are theoretical sampling and constant comparison. Rather than defining our sample a priori, its size and composition evolved, as recommended by Strauss & Corbin (1998), over the course of simultaneous data collection and analysis.

Sample

Our research compared and contrasted two bioscience clusters: a developed biomedical cluster in Northeast Ohio, and an emergent biotechnical cluster in Puerto Rico.

Twenty two practitioners ─ nineteen males and three females aged 35 to 63 ─from biotechnology “anchor” firms, research and development institutions, local public policy entities, academic institutions, venture capital firms, and specialized suppliers of industry-specific inputs professionals participated in the research. Most had advanced graduate degrees, including 10 with Ph.D.'s. All respondents were contacted through local biotechnology industry organizations.

Two sample industrial clusters (Table 1) were identified taking into account the cluster agents different characteristics including stage of development, ownership structure, innovation capacity, density, and breadth and depth of economic activity (Enright, 2003).

TABLE 1
Biotechnology Cluster Sample

Industrial Cluster Region	Local Agent Description	Number/ Quantity
Puerto Rico	MNC Biomed/Biotechnology Manufacturers	2
	Local suppliers/contractors	3
	Professional Organizations	3
	MNC suppliers	1
	Academia	1
	Government entities	1
	Entrepreneurs/Venture Capitalist	1
Northeast Ohio	Biomed/Biotechnology companies	3
	Local suppliers/contractors	2
	Hospitals and Health care organizations	2
	Academia and Research organizations	2
	Entrepreneurs/Venture Capitalist	1

The clusters were chosen in the area of biomedicine, defined broadly to include pharmaceutical (not only those based on biotechnology), medical equipment and supplies, diagnostics, software, and a variety of supporting services (Carlsson & Braunerhjelm, 2002a).

A cross-case analysis of the two industrial clusters was conducted to deepen understanding and explanation, and enhance generalizability to ensure that events and issues are not wholly idiosyncratic to one area (Miles & Huberman, 1994).

Data Collection

The research was conducted in Northeast Ohio and Puerto Rico from June through August of 2009. Semi-structured interviews of biotechnology cluster actors and agents constituted the primary data collection method. Participants were recruited by sending initial private emails to individuals who satisfied the sample criteria. The final response rate was of approximately 60%. When a positive answer was received, the researcher called the individual to arrange a confidential interview or telephone call. 12 interviews were conducted face to face and 10 by telephone. The interviews, of approximately 60 minutes in duration, were audio-recorded and later transcribed by a professional transcription service.

A predesigned protocol (see Appendix A) was used to guide but not to dictate the interviews. Six open-ended questions were asked (see Appendix A). The first question was intended to elicit background information about the respondent and his professional role in his biotech firm (as used in appreciate inquiry) (Ludema, 2003). The next set of questions allowed the interviewer to understand the industrial cluster history and development. Next, we explored the interviewee's understanding of how knowledge and innovation was acquired, created, transferred, retained, diffused and exploited in the cluster. The interviewee was also asked to assess how this process impacted the cluster's performance. The interviewee was asked to identify and discuss two examples (one successful and one not) of knowledge retention and transfer, and describe how the process may have worked differently. Also, the interviewee was asked to prioritize examples of specific steps that might have been involved in improving the process. The interview closed by giving the interviewee a chance to think about key aspects that could enhance of the cluster's future success (another approach drawn from appreciative inquiry).

Data Analysis

We collected and analyzed the data using an iterative approach, going back and forth between the data and the developing theory (Strauss & Corbin, 1998). The recorded interviews were listened to multiple times, and the transcripts read repeatedly. Consistent with the principles of grounded theory, data collection and analysis were conducted simultaneously and continued until theoretical saturation was achieved. Both written transcripts and recorded interviews were reviewed numerous times to solicit meaning, develop logical categories or themes, and consider classifications in which groups of categories could be assigned without reference to our conceptual model or reflecting preconceived assumptions.

The coding process commenced with open coding, a process that requires rigorous line by line examination of transcripts to identify “codable moments” (i.e., fragments of data with potential significance). 880 such fragments were identified. In the axial phase of coding, the “moments’ were iteratively grouped and regrouped, and labeled and re-labeled as they accumulated from successively coded transcripts to form themes and concepts. As seen in Table 2, this reduction process resulted in five key categories. Throughout the process, as themes and concepts began to emerge, we returned to the literature, moving recursively between it and the data. Eventually, patterns of relationships among concepts become clearer. In the third phase of the coding (selective) this process of “fracturing” the data and subsequently rebuilding yielded twelve themes from which our findings emerged (refer to Table 2).

TABLE 2
Thematic Codes

Constructs/Categories	Coding Themes
Environmental Factors	
Industry ecosystem	Individual refers to the state of cooperation/symbiosis of a group of independent but interrelated elements comprising a unified whole.
Critical mass	Individuals refers to a point of change: a point or situation at which change occurs.
Dynamism / Interaction	
Networking capabilities	Individual refers to interacting with others to build relationships for current and future benefits.
Information flow/exchange	Individuals refers to bidirectional information transmission/information transfer
Trust between cluster agents	Individuals refers to the level of reliance among local cluster agents.
Informal contacts/communication	Mentions the disseminate ideas, products, processes or services through non-formal channels.
Knowledge network	
Knowledge creation	Individual refers to the process and activities involved in the conception of new ideas.
Knowledge transfer	Refers to the process and activities involved in the transfer and implementation of new ideas
Knowledge retention/anchoring	Refers to the process involved in the embeddedment of new ideas in a geographical area.
Innovation	
Innovation system	Refers to networks of agents interacting in specific areas under particular infrastructures and involved in the generation, diffusion, and utilization of technology.
Organizational culture	Mentions shared norms and values at an organization, cluster and/or geographical level.
Risk propensity	Refers to the inclination to undertake decisions involving risk from a business/organizational standpoint .
Performance	
Cluster competitiveness/success	Refers to the state of cooperation/symbiosis of a group of independent but interrelated. Individuals refers to a point of change: a point or situation at which change occurs.

FINDINGS

Our data revealed a complex set of linkages and synergies between local bioscience industrial cluster agents that impact the knowledge creation, transfer, and retention process in bioscience clusters. The data obtained through the contrast between the Northeastern Ohio biomedical cluster, a developed cluster, and the Puerto Rico bioscience cluster, an emergent cluster, yielded three major findings that have constrained the development of the emergent biotechnology cluster:

1. Multinational biotechnology manufacturing companies (MNCs) have thwarted the development of entrepreneurial bioscience activity and hampered the development of the bioscience cluster in Puerto Rico.

2. Social networks in the biotechnology industry in Puerto Rico have not sufficiently developed to nourish an entrepreneurial ecosystem as in the developed cluster area.

3. Embedded knowledge enhances knowledge retention and cluster performance.

Finding 1: Multinational biotechnology manufacturing companies (MNCs) have thwarted the development of entrepreneurial bioscience activity and the development of the bioscience cluster in Puerto Rico.

Respondents in Puerto Rico acknowledged that a economic development strategy focusing on attracting foreign direct investment and multinational biotechnology manufacturing companies (MNCs) has delayed the development of entrepreneurial bioscience activity categorized as "critical" for further cluster growth by respondents in the developed cluster.

Finding 1.1: Limited linkage between Multinational (MNCs) biotechnology manufacturing companies and local cluster agents limits innovation and the development of the bioscience cluster in Puerto Rico.

All of the twelve Puerto Rico respondents revealed that only very limited linkages had been achieved between MNCs and local entities (i.e., suppliers, research and development institutions, academic institutions, venture capital firms, and specialized suppliers of industry-specific inputs) since the inception of the bioscience cluster in early 2003.

Several respondents concurred that large multinational companies do not foster an innovation-driven environment, and indicated that this situation has encumbered the development of a local knowledge intensive entrepreneurial ecosystem and a very limited number of local spin-offs had been developed. A Puerto Rico government official criticized the “overdependence” on external capital in the form of foreign direct investment (FDI) and pointed out its benefits and limitations., while an industrial support association official compared and contrasted Puerto Rico’s success in the pharmaceutical industry cluster with the bioscience cluster and stated that “we are in a different situation: tax incentives, a good labor force and investment climate help, but we need to understand that bio is a high value, low volume operation.” He contrasted this with the pharmaceutical industry’s focus on high volume production. One pharmaceutical plant ex-general manager indicated that the industrial ecosystem in the emergent cluster was evolving and that “limited backward linkages”, mostly supply of basic production inputs, had been created between multinational and local companies.

An official of a Puerto Rico bio industry support association categorized the establishment of a bioprocess development and training facility in early 2009 as a “step in the right direction to strategically enhance Puerto Rico´s capabilities in biotechnology manufacturing, research, bioprocess improvement, and training,” but added that, to date, “no clear vision of its long-term relationship and interaction with MNCs has been formulated.”

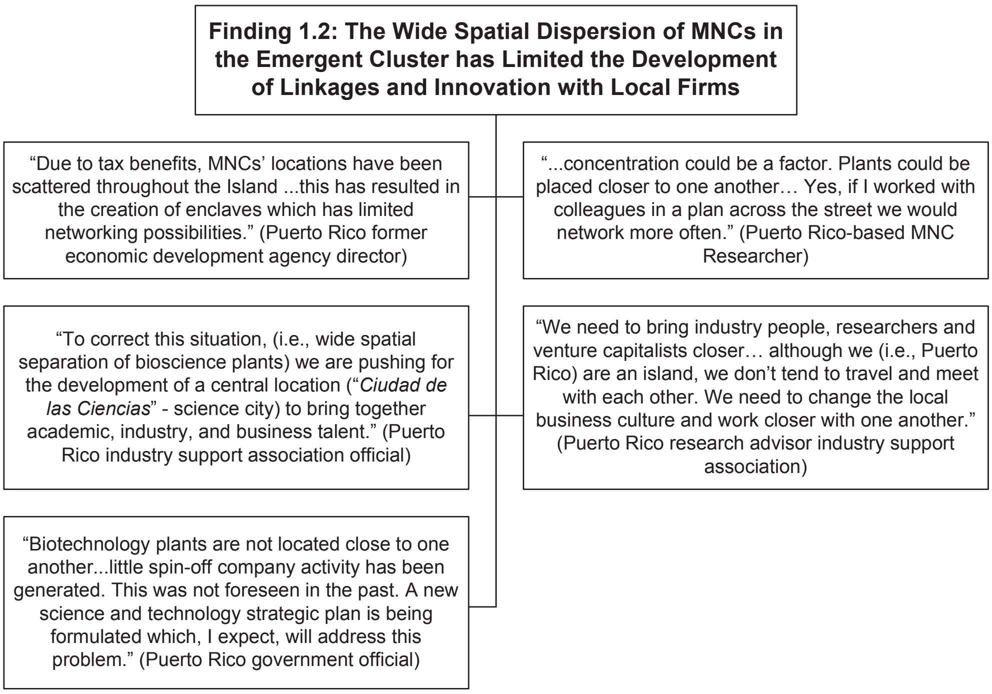
Finding 1.2 – The wide spatial dispersion of MNCs in the emergent cluster has limited the development of linkages and innovation with local firms.

Seven of twelve Puerto Rico respondents explained that the five “anchor” or major bioscience manufacturing plants there are widely dispersed in a geographical area covering a radius of 25 miles. In contrast, interviewees in the developed cluster pointed out that that Cleveland Clinic and University Hospitals, the two major healthcare centers in the Cleveland and Northeast Ohio area, are located within a radius of 1 to 2 miles from each other. No major multinational pharmaceutical or bioscience firms were reported to be operating in the

Northeast Ohio region.

A top official of a industrial professional association and former head of the government economic development agency in Puerto Rico pointed out that the location of manufacturing sites on the Island was based on "geographically-based tax incentives" (i.e., lower tax rates in remote areas of the Island) which "did not encourage close contact between sector specific (clusters) entities." As a result, MNCs created "enclaves" with limited links to the local economy, which in turn has restricted the creation and development of knowledge networks (Figure 1).

FIGURE 1
Finding 1.2: The Wide Spatial Dispersion of MNCs in the Emergent Cluster has Limited the Development of Linkages and Innovation with Local Firms



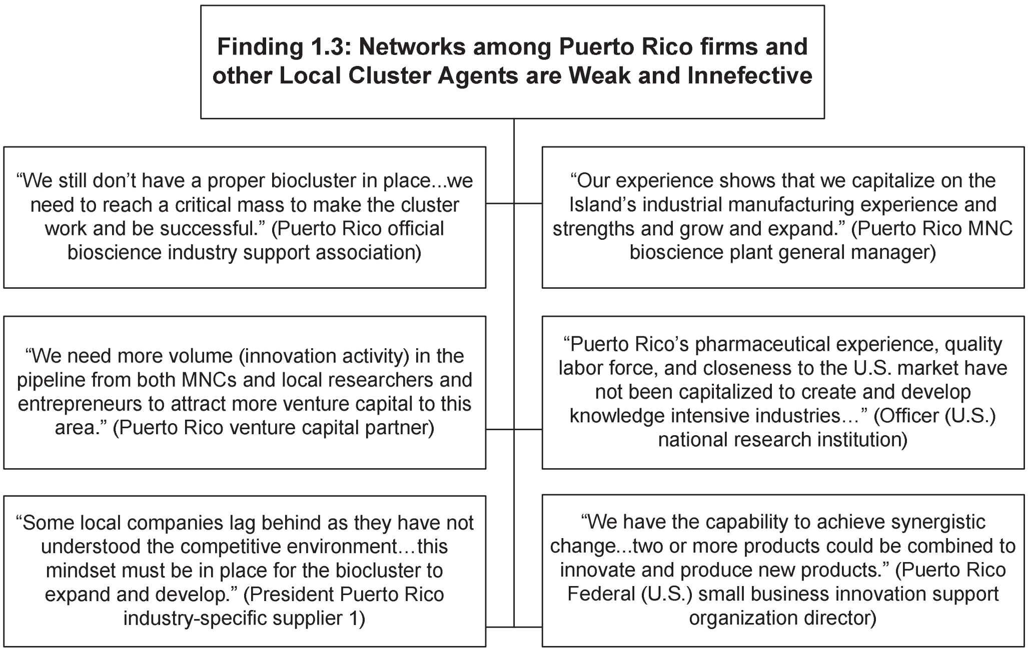
One Puerto Rico MNC researcher, two officials of an industry support association, and an academic researcher pointed out that networking would increase if manufacturing plants were more concentrated and located closer to each other. An interviewed government official indicated that this problem is beginning to be addressed in a new science and technology strategic plan being formulated by the Island's central development agency. An interviewed officer of a bioscience support organization indicated that a "science-city" ("*Ciudad de las Ciencias*") was been constructed close the state university's main campus and medical center with the goal of bringing top academic, industry and business talent to a centralized location.

Finding 1.3 – Networks among Puerto Rico firms and other local cluster agents are weak and ineffective.

Eight respondents in the emergent cluster indicated that the networks between Puerto Rico firms and other cluster agents (such as academe, local entrepreneurs, and venture capitalists) are weak and ineffective. They added that due to this situation, the "critical mass" of the emergent bioscience cluster still had not been attained and/or was evolving.

As seen in Figure 2, an official of a Puerto Rico bioscience industry support association indicated that "as yet, we do not have a proper bioscience cluster in place on the Island."

FIGURE 2
Finding 1.3: Networks among Puerto Rico Firms and Other Local Cluster Agents are Weak and Ineffective



The president of a successful industry-specific service provider in Puerto Rico explained that many potential local suppliers do not fully comprehend the competitive environment and added, in reference to industry networking and innovation, that "this mindset must be in place for the bioscience cluster to expand and develop."

The partner of a local Puerto Rico venture capital and the director of a Federal (i.e., US) sponsored industry small business innovation organization indicated the need to develop more innovation activity at both the local and MNC levels as a requisite for attracting angel and venture capital investors to the market. The small business innovation organization official added that the "value-added proposition for doing business in the bio-cluster must be clear" to encourage MNCs to expand from their current focus on manufacturing operations and invest in research and development activities in the emergent cluster.

The director of a federal (US) sponsored industry small business innovation organization in Puerto Rico argued that local industry in the emergent cluster, over time, had the capability for pursuing not only "incremental change" in their products and service offerings, but that "synergistic change" could be achieved which could help to attract "brainpower, related industries, and investment to the region."

Finding 2 – Social networks in the biotechnology industry in Puerto Rico have not sufficiently developed to nourish an entrepreneurial ecosystem as in the developed cluster area.

Comparing the Puerto Rico bioscience cluster with the Northeast Ohio biomedical cluster, several respondents in the developed cluster indicated that a sizeable number of biomedical spin-off companies have been established in the region. Nine respondents indicated that the main vehicle for this attainment were the "connections" developed and linkages harnessed, over time, within and between industrial social networks in the region. They described these networks as "formal and informal" interactions and programs, university research, institutional intellectual property protection arrangements, technology transfer support, initial venture funding, government support (e.g., tax incentive structures), and the interaction between local specialized suppliers and multinational firms.

A university vice president in the develop cluster area signified that Cleveland's unique history and presence of non-profit institutions has created networking capabilities and skills that have been harnessed to initiate and expand the bioscience cluster and create an "innovation-driven" environment. As an example, he indicated that "200 to 300 inventions are generated annually" as a result of research funding in the develop cluster region (refer to Figure 3).

FIGURE 3
Finding 2: Social Networks in the Biotechnology Industry in Puerto Rico have not Sufficiently Developed to Nourish an Entrepreneurial Ecosystem as in the Developed Cluster Area

Finding 2: Social Networks in the Biotechnology Industry in Puerto Rico have not Sufficiently Developed to Nourish an Entrepreneurial Ecosystem as in the Developed Cluster Area

"We need to develop points of contact between local businesses, entrepreneurs, and researchers." (Puerto Rico former economic development agency director)

(Comparing Northeast Ohio with Puerto Rico) "In Ohio, networking is crucial...people talking to each other...without it there's no innovation, there's no kind of cross-fertilization of ideas." (Officer 2 Cleveland bioscience support organization)

"We need to create a functioning entrepreneurial ecosystem. One of its basis is to encourage intrapreneurship in large companies (i.e., MNCs) and foster contact with local entrepreneurs." (Puerto Rico academic researcher)

(Comparing Northeast Ohio with Puerto Rico) "In Ohio, trust developed in the network enables knowledge transfer and innovation...So a contractual relationship is more intimate. You're not just going to bring in anyone." (Cleveland bioscience consultant)

"The advantage we have...we're in a town (i.e., Cleveland) that, again, 100 years ago had a phenomenal economy, we have the luxury of having non-profit foundations." (Cleveland hospital researcher)

(Comparing Northeast Ohio with Puerto Rico) "...these foundations...have given money to the university, to start-up companies, etc. ...and to help us find a way to develop these technologies networking capabilities and skills that have been harnessed to initiate and expand the bioscience cluster and create an "innovation-driven" environment. As an example, we're handling between $400 million and $500 million a year of basic and applied research… 200 to 300 inventions a year at least that are coming out of the region." (Cleveland University vice president)

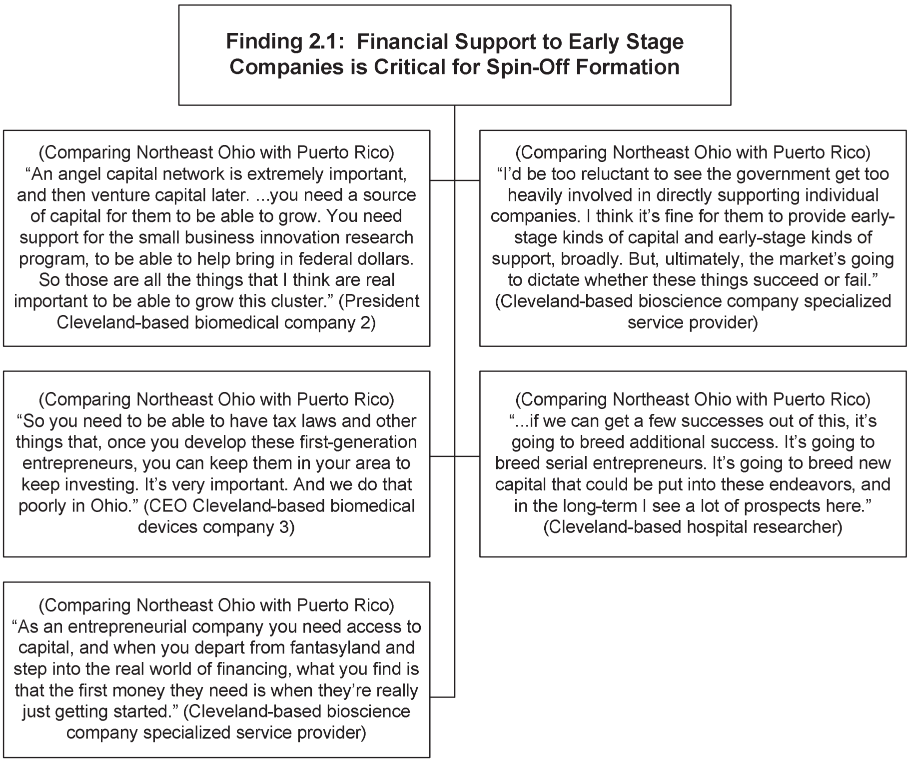
Comparing the Puerto Rico and Northeast Ohio clusters, officers of a Cleveland-based bioscience technologies support and commercialization organization indicated that the business networks in the developed cluster area played a "critical role" in the formation and presence of serial entrepreneurs which, they pointed out, were crucial for new business formation.

Finding 2.1 – Financial support at early stage is critical for spin-off company formation

All of the respondents in the Northeast Ohio cluster stressed that an important "lesson learned" in the development of that bioscience cluster is the importance of creating and sustaining a vibrant entrepreneurial ecosystem. Six respondents in the developed cluster explained that it is critical to provide financial support to spin-off companies during early-stage company formation (refer to Figure 4). One Cleveland-based bioscience company consultant, who assists early-stage companies, emphasized the “critical need” to support organizations during the initial phases of their development to help them to the next level through angel and strategic capital. A hospital researcher pointed out the limitation of government funding and the eventual need of entrepreneurs to seek market support and not rely on public subsidies.

Three Cleveland-based bioscience company owners contrasted the state of the developed and emergent clusters, and indicated that to enable the transition of companies from small spin-offs to larger regional “players”, local cluster agents (i.e., academic institutions, state and local government, and capital markets) must provide support mainly in the form of financial capital and tax incentives. According to the interviewees, this would help to create an “entrepreneurial culture” and encourage “serial entrepreneurs” to take the emergent cluster to a higher level.

FIGURE 4
Finding 2.1: Financial Support to Early Stage Companies is Critical for Spin-off Formation



Finding 3. – Embedded knowledge enhances knowledge retention and cluster performance.

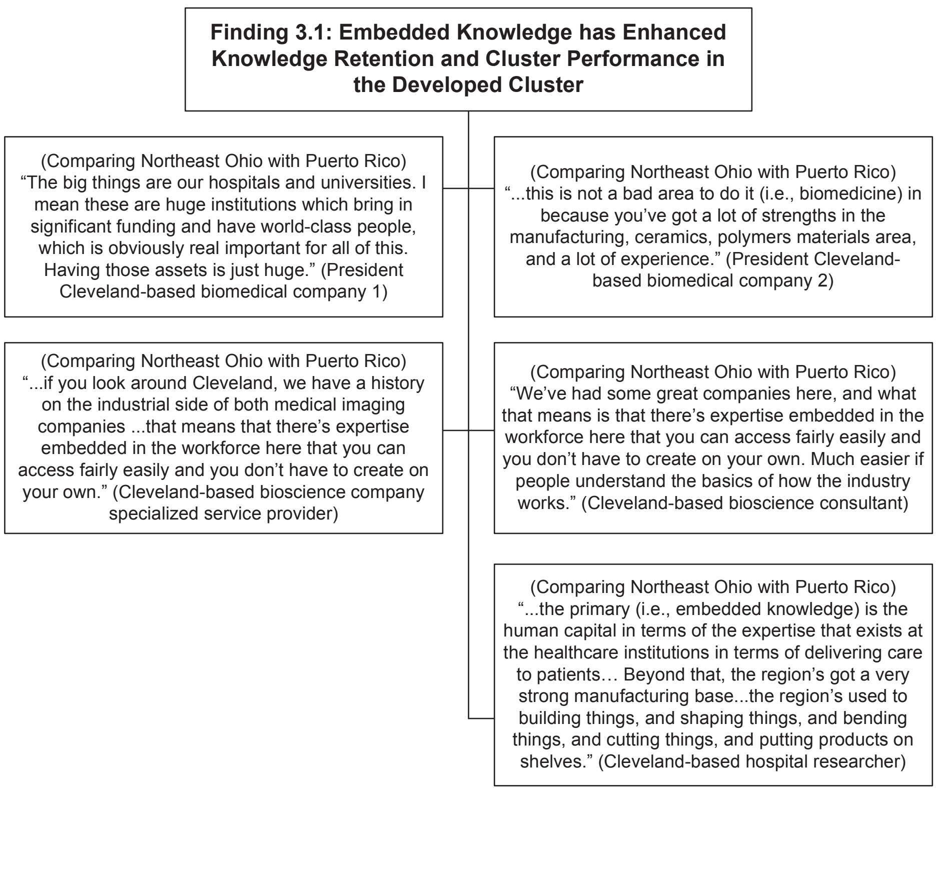
Twenty respondents in both the emergent and developed cluster emphasized that embedded knowledge influences industrial cluster performance as specialized knowledge becomes enmeshed or retained in local social and specialized business networks.

Finding 3.1 – Embedded knowledge has enhanced knowledge retention and cluster performance in the developed cluster.

Contrasting the Puerto Rico and Northeast Ohio bioscience clusters, eight interviewees in the developed cluster region stressed that increased access to inputs, skills and talent, information, technology and institutions provided a basis for higher company productivity, greater innovation and venture creation (See Figure 5).

All respondents emphasized the developed region's knowledge sourcing, absorption and transfer capabilities. Seven respondents mentioned Northeast Ohio's historic heavy manufacturing base as providing the basic competence and "hard mechanics" involved in a fabrication process. All respondents indicated that the presence of world-class healthcare facilities and universities in the area was the prime "driver and enabler" for the formation and development of the bioscience cluster in the Cleveland area and environs.

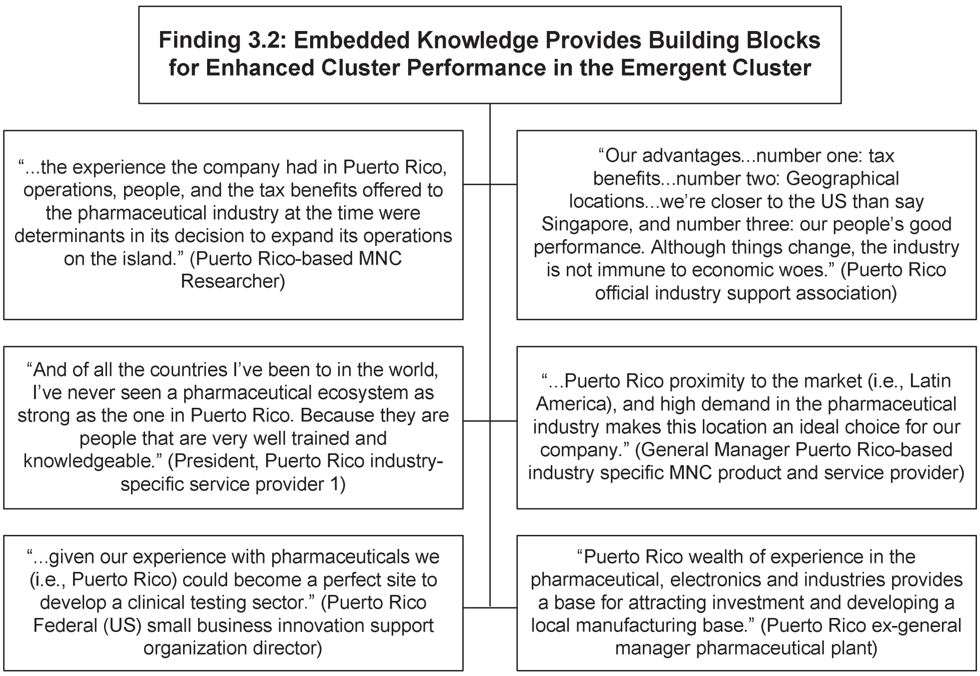
FIGURE 5
Finding 3.1: Embedded Knowledge has Enhanced Knowledge Retention and Cluster Performance in the Developed Cluster



Finding 3.2 – Embedded knowledge provides building blocks for enhanced cluster performance in the emergent cluster

Respondents in the Puerto Rico cluster explained that pharmaceutical and industrial manufacturing expertise and related infrastructure provides building blocks and a foundation for future bioscience cluster performance (refer to Figure 6). Seven respondents cited the local pharmaceutical manufacturing experience as a major reason for locating bioscience ventures on the Island. Also, five respondents, mentioned "tax incentives and a well trained work force" as important factors involved in the decision to locate in the region. Four respondents also pointed out the advantage of clusters' closeness to both the US and Latin American markets, and its potential to become a clinical research and trials center.

FIGURE 6
Finding 3.2: Embedded Knowledge Provides Building Blocks for Enhanced Cluster Performance in the Emergent Cluster



An officer of a national (i.e., US) bioscience research institution contrasted the developed cluster with the emergent cluster region and commented that “the secret for biotech success is having experienced venture capital, experienced management, and a serial entrepreneurial culture.” He indicated that the emergent cluster’s “world class pharmaceutical industry background” provided a platform for the Island (i.e., Puerto Rico) to move into the biotechnology area. But, he added, that bioscience is a” lot bigger than just focused biopharmaceutical, and research and testing.” There was room for clusters like Puerto Rico to “capitalize on their distinct strengths” and carve “successful niche strategies.” The general manager from one of the MNC anchor plants in Puerto Rico, agreed, and suggested that the emergent bioscience cluster’s competitiveness could be improved by “capitalizing on the Island’s industrial manufacturing experience and strengths.”

DISCUSSION

Our research revealed a paradox regarding the intensity of foreign direct investment (FDI) by multinational companies (MNCs), and the limited development of a local entrepreneurial ecosystem in an emergent bioscience cluster. While cluster development seems a logical outcome of MNC investment, our study demonstrated it is not a foregone conclusion. Our research of Puerto Rico’s bioscience cluster experience sheds light on a key theoretical and policy issue: to what extent can the development strategy of attracting FDI from global multinationals be leveraged to transfer knowledge and develop indigenous innovation capabilities? Puerto Rico, one the most open economies in the world, exporting and importing more than $105 billion worth of goods every year, with levels of FDI (118% of 2007 GDP), comparable to that of Ireland Taiwan, and Singapore (Government Development Bank for Puerto Rico, 2008), has pursued for over 50 years an economic development strategy of attracting FDI from leading multinationals through a combination of financial incentives, world-class infrastructure, a highly skilled workforce and a business-friendly environment. (Puerto Rico Industrial Development Company, 2008). Despite all of these advantages, a vibrant entrepreneurship ecosystem has failed to flourish.

Several studies suggest that multinational experience positively affects local linkage formation (MaAlesse & McDonald, 1978; Dunning, 1993; Sachwald, 1998). MNCs set up linkages with foreign firms and institutions to explore, evaluate and utilize resources, skills and expertise available on a global scale, combining these with their own assets (Castellani, & Zanfei, 2002). Empirical research suggests that linkages between MNCs and local businesses increase over time (Görg & Ruane, 1998). Backward and forward linkages may translate into higher employment, increased industry agglomerations, technology transfers, and the development of new indigenous industries (Görg & Strobl, 2002). Our results however, suggest this is not always the case. Although major biotechnology manufacturing sites have been established in Puerto Rico, linkage development has been limited (Martin & Sunley, 2006).

Empirical research conducted in other FDI-intensive regions indicates that emergent bioscience clusters face similar difficulties. Finegold, Wong and Cheah (2004) examined the development of the Singapore biotechnology industry and the conditions necessary to establish a high-skill ecosystem. Results pointed toward the need for large and sustained financial commitment, local entrepreneurs who understand the unique requirements of the biotechnology sector, and a critical mass of scientific researchers. Research conducted on bioscience cluster activity in Ireland and South Korea present similar findings (Görg & Ruane, 1998; Görg & Strobl, 2002; Sung Cho, Hyun, & Lee, 2007). Our research suggests that the emergent bioscience cluster in Puerto Rico faces analogous challenges.

Literature argues that knowledge flows in biotechnology clusters are heavily dependent on social networks and the level of close interactions among their members (Powell, Porter, & Bunker, 2005; Huggins, 2009). The development and functioning of a vibrant entrepreneurial ecosystem is required for the successful establishment of a bioscience cluster (Braunerhjelm & Feldman, 2006). Our research supports these observations.

As Schumpeter (1942) acknowledged, entrepreneurs are active forces in the economy that seek to organize resources and actively refine the environment to be conducive to their pursuits. Our findings exemplify how regional economic development policy has concentrated on the development of "hard infrastructure" (i.e., highways, manufacturing plants, research and development facilities, etc.), but less so on the development of "soft infrastructure" (human capital, academic and research and development institutions, etc.) to enhance the knowledge absorption capacity of the region.

Current research on science networks focuses on specific types of relationships – contractual ties, patent or publication citation networks, or academic entrepreneurs (Powell et al., 1996; Fleming, Cofer, Marin, and McPhie, 2004; Shane, 2004). Our research suggests that, given the life sciences sector's need for strong networks and overlaps of science and commerce, in which research spillovers fuel the growth of the industry, bioscience cluster development can be examined from a social capital perspective.

Our results suggest a link between knowledge ecology and social networks theories. Although these theories look somewhat divergent, we argue that the two premises can overlap and coexist. Furthermore, our data implies that the synergies and dynamics observed among local agents in both the emergent and developed bioscience cluster constitute examples of complex exchanges and collaboration at individual, community, industrial and regional levels of knowledge transfer in knowledge-intensive industry. New ideas and innovations are shared within social network structures in patterns that could be described as biological and symbiotic in nature. A bridge or balance between the knowledge ecology and social network hypotheses can be attained.

The results of our study advocate the need to formulate regional economic development policy strategies directed to support learning and investment in local firms. Foreign direct investment can play an important role in raising a country's technological level, creating new employment, and promoting economic growth, but must be effectively managed. Social networks and knowledge management processes can serve as building blocks for the creation, transfer, spillover and retention of knowledge, and improve high technology industrial cluster competitiveness and success.

The conceptual model that guided our study assumed that the association between external agents (i.e., foreign direct investment, supply chain, customers and other organizations and individuals), local agents, (i.e., local individuals, organizations and networks), and public policy entities (i.e., local authority industrial cluster strategies and policy networks) might affect regional cluster competitiveness.

Our findings substantiated this assumption demonstrating that the effect of social networks on cluster competitiveness can be substantial. This was demonstrated in the mature Ohio biotech cluster quite strongly. There, an active non-profit sector served as a vehicle and conduit for the formation of social networks which, in turn, helped the development of an entrepreneurial ecosystem in the biomedical cluster. In contrast, in Puerto Rico, the absence of a strong social network appears to have stymied the development of the biotech cluster.

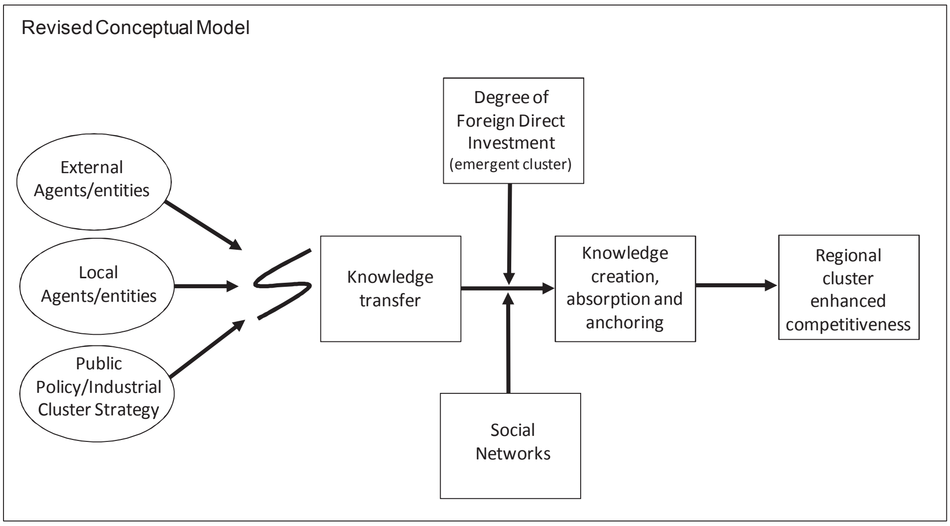
The social-network model argues that there is more order to inter-firm interactions and less order to intra-firm interactions than economic models would imply (Granovetter, 1985). The reason for this is that strong interpersonal relationships can transcend boundaries; with the result that many inter social interactions may be stronger than their intra-firm counterparts (Gordon & McCann, 2000).

Although there is nothing inherently spatial about the social-network model, it has explicit spatial applications (Gordon & McCann, 2000). This is because social networks are a form of durable social capital, created through a combination of social history and ongoing collective action. In this sense, their strength is inherently problematic, depending upon a prior accumulation of trust, circumstances which facilitate monitoring of others' behavior, a source of leadership and/or a sense of common interest, as well as the expectation of significant gains (Olson, 1965).

Research has indicated that social networks, in the form of collaborative innovation grids, can facilitate knowledge flow and diffusion (Gloor, Paasivaara, Schoder, & Willems, 2008). Our study of knowledge management and flows in the emergent and developed bioscience clusters of Puerto Rico and Cleveland corroborates this finding.

While we designed the inquiry to explore industrial cluster elements that potentially impact the process of knowledge creation, absorption and retention, we concluded by recognizing that social networks, including entrepreneurial ecosystems and foreign direct investment influence and moderate the knowledge transfer process. Knowledge creation, absorption and retention mediate the impact of the synergies generated amongst local agents on regional industrial cluster competitiveness. Our revised model is presented below in Figure 7.

FIGURE 7
Revised Conceptual Model



CONTRIBUTIONS

This study analyzes how linkages and synergies between local agents impact knowledge creation, transfer and retention within high technology industrial clusters. Little scholarly research has been conducted of the industrial cluster activity in the Caribbean and Puerto Rico region. To date, limited academic research has been conducted in emergent bioscience clusters in island states. No scholarly work has been conducted contrasting the Puerto Rico bioscience clusters with develop bioscience clusters in other geographical areas.

While previous research has utilized knowledge ecology or social network models separately to examine intra and inter industrial cluster relationships and interactions, our approach examined and leveraged both theories, and the views and biases of actual practitioners to suggest a plausible bridging of the two models, and an explanation of how the issue of knowledge management and innovation is addressed in practice.

IMPLICATIONS FOR PRACTICE AND FUTURE RESEARCH

The results or our research could hold significant contributions for policy formulation supporting regional economic development. Our research suggests that focus on development of knowledge and social networks and value and supply chains may be more instrumental for both practitioners and policy makers to design appropriate economic development and business competitiveness strategies.

Our work suggests the need for further research about the formation and development of knowledge ecosystems and social networks and their effects on industrial cluster development. Our research also points toward a possible relationship between the development of high technology industrial clusters and the presence of nonprofit “anchor” organizations. Further research is recommended in this area.

Of note to other researchers is that the next phase of this study will include a quantitative assessment of the drivers of knowledge retention and its impact on economic development.

Finally, further research is suggested to bridge the gap between knowledge ecology and ecosystems research and social network models. A better understanding of the knowledge diffusion and innovation processes within networks could result in an important potential contribution to the body of knowledge in this area.

LIMITATIONS

The size and composition of our sample may limit the generalizability of our findings. The sample is specific to bioscience (i.e., biotechnology, biomedical and medical devices sectors) firms in two specific geographical regions – Northeast Ohio and Puerto Rico. Our results thus may not be generalizable to other industries or to industries in other geographical regions.

Because we invited respondents to recall past experiences, our data may be compromised by the effects of time on memory. Furthermore, our interview protocol required interviewees to describe a situation (i.e., innovation, synergies, knowledge creation, transfer, and retention) that could be ambiguous. To ensure accuracy and prevent constructive memory, some benefits can be obtained by interviewing participants actively engaged in the process while emotions are fresh. This risks capturing the emotions of the moment that prevent accurate descriptions due to a lack of complete knowledge of "how the story ends." Some researchers believe hindsight avoids the emotional upheaval of the moment and provides time to see the entire event from beginning to end, and reflect on it (Folkman & Moskowitz, 2004).

Some interviews were conducted by telephone because of geography constraints and/or demands on respondents' schedules. Telephone interviews prohibit the assessment of non-verbal behavior which may have signaled important points of inquiry otherwise missed by the listener or "disfluency" on the part of the speaker (Pasupathi, 2001).

A broad variety of entities were included in our sample to take into account the diverse characteristics, history and nature of the two bioscience clusters studied. Emphasis was given to high technology research entities, specialized suppliers, and commercial spin-offs to help identify possible patterns in the research data and take into account the variability of the local agents' composition. Furthermore, this study's finding may also be limited by the unequal sample size of respondents in the two regions. However, interviewing similar entities describing the same or similar interactions and relationship dynamics served to mitigate this restriction.

Finally, although conscious effort was made to reduce researcher bias, we acknowledge that the principal investigator has experience in the field as a practitioner.

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