THREE ESSAYS ON SERIAL INNOVATOR FIRMS AND GEOGRAPHICAL CLUSTERING

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THREE ESSAYS ON SERIAL INNOVATOR FIRMS AND GEOGRAPHICAL CLUSTERING

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS OR ABBREVIATIONS

ANOVA	Analysis of Variance
IE	International Entrepreneurship
IT	Information Technology
MNC	Multinational Corporation
MSA	Metropolitan Statistical Area
NAICS	North American Industry Classification System
NIST	National Institute of Standards and Technology
OE	Organizational Ecology
OLS	Ordinary Least Squares
R&D	Research & Development
RISC	Reduced Instruction Set Computer
S&E	Science and Engineering
SEC	Securities and Exchange Commission
SIC	Standard Industry Classification
SME	Small and Medium Enterprise
2SLS	Two stage least squares
USPTO	United States Patents and Trademarks Office
WW II	World War Two

SUMMARY

Small, technology-based firms in the United States play a very important role as drivers of technological and economic change. This research was initiated in the belief that not all small, innovative firms are alike, and that firm heterogeneity leads to differences in both locational preferences and performance characteristics between an unusual population of small, highly innovative firms, hereafter labeled serial innovators, and a set of matched technology-based firms, hereafter labeled non-serial innovators.

This study aims to elucidate firm and performance attributes of a population of small, elite companies that assume prominent positions in their respective technological spaces and product markets. More specifically, this study addresses the role and impact of industrial agglomeration on the location and performance characteristics of serial innovator firms. The dissertation was conceived as a collection of three distinct but related essays. The first essay examines whether serial innovator firms are located in technology clusters with higher average levels of regional specialization than non-serial innovator firms. It also reports on whether serial innovator firms are physically located in closer proximity to the science base (research universities) than their non-serial innovator counterparts. The second essay assesses the role and impact of these companies' spatial context on two measures of firm performance in the upstream section of the innovation process. The third and final essay seeks to examine the role of industrial agglomeration on the internationalization efforts of serial innovator firms.

The first essay on the geographical location of firms with high levels of innovative prowess, i.e. serial innovator firms vis-à-vis technology clusters and research universities, indicates that these firms are not necessarily located in Metropolitan

Statistical Areas (MSA) with higher average levels of industry clustering than non-serial innovator firms of similar size. Serial innovator firms and their less innovative counterparts appear to have the same need and capacity to absorb knowledge spillovers in technology clusters. Further analysis, however, revealed that serial innovator firms in the Pharmaceutical, Biotechnology, and IT hardware industries are located in MSAs with significantly higher levels of regional specialization than non-serial innovator firms in that industry. This suggests an asymmetric need for knowledge spillovers by these firms. Furthermore, serial innovator firms seem to be located in MSAs with a significantly higher number of research universities than a non-serial innovator firm, although differences across industries can be noted. This again indicates an asymmetric use and need for academic knowledge spillovers, and pecuniary advantages offered by these institutions.

The analysis in the second essay reveals that serial innovator firms located in MSAs (Metropolitan Statistical Areas) with elevated levels of industrial clustering announce significantly more new products than their counterparts located in MSA areas with low levels of industrial clustering. However, no differences were found in the pace of technological progress of the technologies developed by serial innovator firms located in technology clusters and those outside of clusters.

Finally, the research reported in the third essay indicates that the level of industrial agglomeration has a positive impact on the export performance of serial innovator firms. These firms benefit proportionately more from technology clusters than non-serial innovator firms.

1. INTRODUCTION

The spatial co-location of firms across and within industrial sectors has long intrigued regional economists and research policy scholars and was observed and introduced into the social science literature first by Adam Smith (1776) and later by Alfred Marshall (Marshall, 1920). Marshall, however can rightly be seen as one of the earliest and most important scholars of agglomeration theory. He sought to explain economic agglomeration by the existence of three factors: 1. Availability of specialized labor pools; 2. Expansion of supporting firms; and 3. Specialization of firms in parts of the production process. This triad of localization factors that collectively contribute to an agglomeration advantage has been at the center of the debate on industry clustering ever since.

After languishing in the margins of core economic concerns of regional economists and policy scholars who were preoccupied with neo-classical economics and the formulation and implementation of science, technology, and innovation policies at the national level (where regional disparities were dismissed as temporary economic disequilibria), there has been a resurgence of interest in the relationship between productive and innovative activity and geography (Becattini, 1978; Piore and Sabel, 1984; Storper, 1989; Krugman, 1991; Porter, 1990; and many others). Traditional agglomeration theory in the late 80s and early 90s had given way to the New Economic Geography, a term coined by Paul Krugman (1991).

Can location be a stimulus of innovation and competitive advantage at the firm, local, regional, and even national level? Evidence suggests that location can be an impetus to innovation. Economic geographers have studied the location of innovative activity (Malecki, 1980; Sweeney, 1987; Feldman, 2000; Audretsch and Feldman, 1996; Feldman, 1993) - and found innovative activity to be even more spatially clustered than productive activities- the location of knowledge-intensive industries (Hall and Markusen, 1985; Saxenian, 1994) in regions with high R&D expenditures, and the importance of university spillovers to new firm location (Audretsch et al, 2005).

A primary source of new and economically useful knowledge is R&D. However, not all types of knowledge produced by formal or informal R&D activities are alike. Some aspects of knowledge are very difficult to encode in text-based instructions, blueprints or other symbol-based expressions and require close interaction between knowledge agent and recipient in order to realize an efficient transfer of this type of knowledge. Polanyi (1958) termed this particular type of knowledge, tacit knowledge. Tacit knowledge is often the result of informal R&D activities and comes about through e.g. learning by doing (Arrow, 1962). A growing body of research indicates that tacit knowledge, produced and exchanged by knowledge workers, constitutes the most important ingredient for an innovation-based firm strategy (Pavitt, 2002).

Firm innovation in general, and small firm innovation in particular, in knowledge-intensive and even ‘traditional’ industries are expected to exhibit strong geographic clustering patterns because the innovation process rests in large part on the exchange of tacit knowledge. The exchange of tacit knowledge occurs in a process that - when taking a systemic perspective of innovation - entails many participants and is greatly facilitated when these participants are in close geographic proximity to each other (Nelson and Winter, 1982; Lundvall, 1992; Feldman, 1993).

The focus of this dissertation is small, highly innovative technology-based firms and their relationship to a specific external environmental variable- the geographical location of these firms relative to industrial clusters (and research universities) and the potential impact of spatial agglomeration on the innovative and commercial performance of these firms. These problems will be examined using a *population* of unusually distinguished technology-based firms, the best in class when it comes to inventive performance, which have been selected independently of their geographical location. Technology-based firms are defined as firms that in one way or another (product and/or process-wise) are reliant on advanced technology to exploit business opportunities (Granstrand, 1998). They may or may not patent the technologies they develop. Small firms that are not technology-based are therefore not reliant on advanced technology to conduct business.

The firms studied are a subset of the larger population of technology-based firms and are unique in several ways. First of all, these firms are small[1] in the sense that they employ 500 or fewer employees and have remained small for all of their existence. Secondly, these firms are long-lived in the sense that they have operated through at least one full economic cycle in fast changing markets, experiencing rapid technological change. Thirdly, the firms exhibit very high levels of patenting activity, at least 15 patents have been granted to them in a five-year period from 1998 to 2002, which is very unusual among small firms that are rarely found to be patenting at all (NFIB, 2005). Fourthly, these firms are independent and are therefore not majority-owned by a larger

[1] I adopt the definition of a 'small business' from the Small Business Administration Agency as a business organization with 500 or fewer employees

business or a subsidiary of a large American or a foreign company operating in the United States. Finally, these firms are going concerns and are not bankrupt at the time data collection efforts were initiated in late 2006. To put in perspective how unique these firms are, the population of firms of interest in this study make up less than 100th of a percent of the total population of small firms in the United States.

Moreover, these firms have not been founded based on a particular business model, market opportunity or a product or range of products (although these elements are certainly of great importance), but rather around a core technology that was invented by the firm and on which further technological improvements or even breakthroughs have been realized and subsequently commercialized. One of the key distinguishing characteristics of these elite firms that set them apart from all other small technology-based firms is that they patent their technologies and adopt intellectual property protection as a key element of their technology strategy.

A good description of such firms was proposed by Leigh Buchanan, a journalist formerly with *Inc.* magazine, who labeled them "serial innovators."[2] She makes a clear distinction between serial innovators and serial entrepreneurs. Small firms are usually founded based on a great market opportunity that has been recognized by the entrepreneur and for which he or she or a close associate developed an innovative solution. The firm strategy coalesces around the exploitation of the opportunity, and the subsequent commercialization of the product or service embodies the innovative solution that addresses this business opportunity. If the commercialization fails the firm

[2] The August 2002 issue of Inc. magazine contains profiles of some of these firms and shows how they sustain their innovative edge. The profiles can be consulted at http://www.inc.com/magazine/20020801/24453.html

dissolves; if it is successful the entrepreneur may sell out. Even if the idea and its embodiment proves successful in the marketplace and the firm is not sold, the next idea, or a process to generate more ideas becomes more challenging, and often the small firm disappears after the first idea has run its course. Regardless of the outcome, in the United States the entrepreneur is inclined to go on and start another firm, and there are many "serial entrepreneurs."

Serial innovators are firms that have a unique ability to sustain innovation around the first idea while maintaining or even strengthening their innovative edge (Libaers et al, 2007). They furthermore develop technology that is of high quality, broad-based, quite basic, and often operate in the markets for technology as specialized technology suppliers to other, often large firms (Hicks and Hegde, 2005). In this dissertation a comparative analysis is conducted between serial innovator firms and non-serial innovator firms. Non-serial innovator firms are small, technology-based firms comparable to serial innovators in terms of age, size, market segments targeted, and products marketed that may or may not patent their technologies, but certainly not at the rate of a serial innovator firm are. In addition, non-serial innovator firms cannot sustain their innovative edge over time and therefore resort to the development of more incremental technologies or produce imitative products without infringing the patents on which the original technologies are based.

In sum, taking into consideration all of the characteristics that distinguish this elite set of firms from the larger population of technology-based firms one may expect different locational and firm performance outcomes from serial innovator firms vis-à-vis a sample of non-serial innovator firms. In this dissertation study I will primarily focus on technological and innovative performance, although one measure of commercial performance will be examined to assess the role of clustering in the internationalization of these firms.

Research Questions

The overarching question of this study seeks to explore whether geographical location, more specifically location in a geographic area with high levels of firm agglomeration in a particular industry, is one factor that may explain the exemplary invention record and innovative prowess of serial innovator firms. I divide this larger question into three temporally related sub-questions. First, are there any systematic differences in the location of serial innovator firms with respect to both research universities and industrial clusters compared to non-serial innovator firms? Second, if regional technology and industrial clusters do play a role in the location of serial innovators, do they lead to any *upstream* innovation performance differentials (number of new product announcements and pace of technology development) for these firms as a consequence of varying levels of agglomeration? Third, do elevated levels of agglomeration matter for the *downstream* innovation process (technology commercialization phase), more specifically export performance? And can any export performance differentials be observed between serial and non-serial innovator firms

Serial innovator firms by definition have an exemplary record of technological inventiveness compared to other small firms, as evidenced by their outsize patent estate[3]. As previously indicated, the broad question addressed in this study is whether

[3] Hicks, D., A. Breitzman, M. Albert & Thomas P. (2003). *Small firms and technical change*. Report to Office of Advocacy, Small Business Administration. (CHI Research, Inc., Haddon Heights, NJ)

geographical location and more specifically location in MSA (Metropolitan Statistical Areas) areas with high levels of industry clustering, is one factor that may or may not be associated with the stellar invention record and innovative performance of serial innovator firms. In other words, can industry clustering help explain why serial innovator firms are so successful in technological innovation? Does regional industry clustering influence these firms' commercialization processes? Each essay will examine part of the overarching question in a logical and sequential fashion.

Essay 1 will address the following question:

1. Are there significant systematic differences between firms with differential levels of innovative prowess in their geographical location vis-à-vis research universities and industrial clusters? The status quo (null hypothesis) holds that no systematic differences exist between the spatial location of serial innovator (high levels of innovative prowess) and non-serial innovator firms (low levels of innovative prowess).

Essay 2 will explore these questions:

2. Are there increasing returns to upstream innovative activity (number of new product announcements) to locating in MSA areas with high levels of industry clustering even within the population of proven innovators? The null hypothesis states that the returns are independent of location.
3. Are technologies being developed by serial innovator firms in MSA areas with high levels of industry clustering progressing faster than those developed by serial innovator firms in MSA areas with low or no industry clustering? Again, the null

hypothesis holds that there is no significant difference in the pace of technology development between firms, regardless of clustering levels within the MSA areas.

Finally, Essay 3 examines:

4. Whether serial innovator firms located in MSA areas with higher levels of industry clustering are expected to internationalize their commercialization process more than serial innovator firms in MSA areas with lower or no industry clustering? The baseline assumption (null) here is that industry clustering does not make a difference in terms of export performance for firms. A related sub-question asks whether serial innovator firms benefit more from industrial clustering than their non-serial innovator firm counterparts in their effort to internationalize their commercialization processes.

Organization and purpose of the study

This study, as previously indicated, contains three essays on the relationship of an unusual set of technology-based firms and their spatial context. The three essays are related both in sequence and in topic. At a high level of abstraction, the primary objects that will be examined are a special set of technology-based firms which have been selected precisely for their innovative prowess but independent of their geographic location.

Why is it important to study these firms? These firms possess rare qualities as evidenced by their outsize patent estate, an indication that they excel at technological learning, have very strong specialized technological capabilities, and have an exemplary ability to transform ideas into technological artifacts that are subsequently patented and commercialized. The strength of their *technological competencies* and the *ability to* *sustain* them differentiates these firms from their less innovative *peers* who operate in the same industry and perhaps even in the same spatial context. This unique set of firms will be studied in their spatial context because they may or may not rely on the external environment to build and exploit such strong technological capabilities.

The behavior, attributes, and strategies of these firms are poorly understood since the extant literature reports very few findings on this group (collectively) in a cross-industry setting. This set of firms are key contributors to technological change and from a policymaker's perspective may be economically important, not so much for the modest number of jobs they create, but for the potentially groundbreaking technologies they develop and market. These technologies may have implications for many different industries (Hicks and Hegde, 2005) as well as the individual customer in the street. Serial innovator firms are likely a potential source of disruptive technologies that initiate new technological trajectories or paradigms of great economic and social consequence[4].

Serial innovator firms can offer both intermediate or finished products and many of them operate in the markets for technology (Hicks and Hegde, 2005; Libaers et al, 2007). Furthermore, these firms often serve as a key technology supplier to much larger, established firms that integrate the technology in their products and services[5]. Prior analyses by the author indicated that they are attractive targets for acquisition by other (larger) firms that are keenly interested in the serial innovator's technological and human capital. As such, these fulfill an important social and economic role that has yet to be

[4] Christensen, Clayton M. (1997). *The Innovator's Dilemma*. Harvard Business School Press
[5] Libaers, D., Hicks, D. and Porter, A.L. (2007)' A taxonomy of small firm technology commercialization' Working Paper, School of Public Policy, Georgia Tech

fully illuminated in the academic literature. A typical example of a serial innovator firm is MIPS Technologies,[6] a firm located in the heart of Silicon Valley and established by a Stanford University professor in 1984. The firm was the first to develop the RISC processor technology based on a research project at Stanford University. The technology instantly revolutionized the microprocessor market and placed Silicon Valley firmly on the map as a technology cluster of semiconductor firms based on a new paradigm technology. More examples of serial innovator firms will be provided in the final chapter of this dissertation.

The presence and impact of these firms may have implications for policy making at different levels, e.g. the regional, state, or national level. It might highlight the disproportional importance of universities and technology clusters for this special set of firms which make up a tiny fraction of all small firms (roughly 400 firms out of a total of nearly six million small firms). Secondly, the presence of one or more of these firms may serve as evidence policymakers can use to showcase the innovative potential of their jurisdiction, or as a 'recruitment' tool to attract other innovative firms, both small and large. Besides creating a business environment that is conducive to innovation and export promotion, policy- makers at different levels of government may develop entrepreneurial policies that favorably impact input factor and/or output markets for serial innovator firms. They need to exercise caution however, in the sense that these policies ought not to be perceived as a sign of favoritism towards these elite firms. The policy implications of this study will be elaborated upon in the final chapter of this dissertation.

[6] For more information on MIPS Technologies Inc., see http://en.wikipedia.org/wiki/MIPS_Technologies

The *first* essay examines the location of firms with varying levels of innovative prowess relative to research universities and technology clusters - spatial agglomerations of interconnected firms and associated institutions in a particular industry, linked by commonalities and complementarities[7]. The study makes use of two distinct matched datasets, the first one containing our focal serial innovator firms, and the second comprising non-serial innovator firms that are of similar size, similar age and operate in the same market segment/industry. Can one observe any systematic differences in the location of firms with differing levels of innovative prowess relative to research universities and industrial clusters? This is a non-obvious question since one can reason that because of the internal technological competencies and existence of various technology commercialization modes[8] of varying levels of location- specific sensitivities, geography may not matter for these firms. Conversely, serial innovator firms are known to develop technologies with a high 'science' content (Hicks and Hegde, 2005). This might imply that proximity to sources of new knowledge creation, i.e. universities, might be important for them.

The *second* essay examines whether higher levels of industry clustering influences two specific dimensions of the upstream innovation process. The first dimension of innovation performance is actually the final outcome of the upstream innovation process, the rate of new product announcements. The second dimension of

[7] Porter, M. (2000) 'Location, competition, and Economic Development: Local Clusters in a Global Economy' *Economic Development Quarterly*, 14(1), pp. 15- 34
[8] David Teece's framework and the Markets of Technology framework developed by Aurora, Gambardella, & Fosfuri

innovation performance is an intermediate outcome of the technological learning (innovation) process, namely the speed whereby invention progresses.

Finally, the *third* essay examines how geographic location, more specifically increasing levels of industry clustering, may influence the downstream innovation activities - in essence the commercialization process - of these serial innovator firms. One specific dimension of the commercialization process will be examined, namely the export performance of serial innovator firms. The question to be answered is whether higher levels of industrial clustering may or may not increase the average export performance level in the population of serial innovators. This essay in a sense will complete the second leg of the examination of industry clustering and its impact on the innovation process, the first one being examined in the second essay. Moreover, the third essay will also address the question as to what extent firm type (serial innovator or non-serial innovator firm) moderates the relationship between industrial clustering and the focal firm's export performance.

The contributions of the study

The literature has noted significant differences in firm location along a number of dimensions, including industrial sectors, high technology and low technology regimes, large and small firms, and levels and composition of human capital. Mainstream management theories explain differences in firm performance as a result of firm-specific resource endowments and capabilities (Wernerfelt, 1984; Barney, 1991; Leonard-Barton, 1992; Teece et al., 1997). These frameworks do not include the geographical location of the firm as a key explanatory variable. The rich literature in the economic development and planning fields on industrial districts and clusters does explain to different degrees firm performance differentials as a function of firm location, but still exhibits gaps. In my review of that literature I observed that small firms in knowledge-intensive and innovative industries have always been assumed to be homogenous and seen as behaving in similar ways- at least when it comes to their location behavior. Furthermore, none of the extant studies examine a set of small, elite firms that operate at the technological frontiers in their respective markets and industries in their spatial context. This study challenges the notion that small, technology based firms in knowledge-intensive industries are alike in their locational preferences, and that the impact of location may have systematically differential impacts on serial and non-serial innovator firms.

Several contributions to the study of entrepreneurship in a spatial context and their policy implications can be noted. These three essays respond to a significant gap in the literature regarding the role of small, elite firms and their relationships to research universities and industrial agglomerations for their location and firm performance. First of all, they aim to demonstrate that for the most innovative small firms operating in a vibrant and dynamic economy such as that of the United States, location may still matter. This contribution is made in all essays.

The concept of innovative prowess will be introduced in the first essay as a measure of firm heterogeneity testing whether the innovative orientation of the firm – even within a population of technology-based firms – will influence the decision to site the firm in a specific location.

The theoretical framework applied in the second essay explicates how geographical attributes may impinge on technological learning and innovation processes and outcomes. Dominant theories in industrial organization or strategic management (save Porter's diamond theory of firm competitiveness) like the resource-based view, transaction cost economics, and evolutionary theory do not acknowledge the role of location on business performance but the framework proposed here integrates a mainstream management theory with a dominant economic theory of agglomeration.

The second essay also makes use of a novel construct representing the speed whereby innovation processes in a specific technology domain develop. It also assesses whether differences in the pace of technology development can be observed in a spatial context, a unique contribution that has to date been assumed but never empirically tested. In addition, a second contribution in the second essay will assess whether innovation performance differentials can be found within a population of proven innovators as a consequence of their geographical location.

The third essay seeks to examine the importance of geographical location as an external source for internationalization of serial innovator firms. It aims to illustrate whether the ecology of the local environment may serve as a determinant of commercial performance, more specifically export performance. The theoretical frameworks used for the second and third essays provide conceptual lenses where external resources and conditions explain differences in firm performance in general and innovative and commercial performance in particular. Furthermore, the last essay seeks to examine whether some firms, more specifically serial innovator firms, benefit more from industrial clustering than their non-serial innovator counterparts.

Finally, the last chapter of the dissertation discusses the policy implications of the empirical results that could serve as guidance for policymakers at different levels of the government.

REFERENCES

Arrow, K. 1962. ‘The economic implications of Learning by Doing’ *The Review of Economic Studies*, 29(3), pp. 155-173

Audretsch, D., and Feldman, M.P, 1996. ‘R&D spillovers and the Geography of innovation and production’ *American Economic Review*, 86, pp. 630-640

Audretsch, D., Lehmann, E., Warning, S. 2005. ‘University spillovers and new firm location’ *Research Policy*, 34, pp. 1113-1122

Barney, J. 1991. ‘Firm resources and sustained competitive advantage’ *Journal of Management*, 17(1), pp. 99-120

Becatinni G. 1978. ‘The development of light industry in Tuscany: an interpretation’ *Economic Notes* 3, pp. 107- 23.

Feldman, M.P. 1993. ‘An examination of the geography of innovation’ *Industrial and Corporate Change*, 2(3), pp. 417-437

Feldman, M. P. 2000. ‘Where Science Comes to Life: University Biosciences, Commercial Spin-offs and Regional Economic Development’ *The Comparative Journal of Public Policy*, 2, pp. 345-36.

Feldman, M.P. 2001. ‘The entrepreneurial event revisited: firm formation in a regional context’ *Industrial and Corporate Change*, 10 (4), pp. 861-891

Grandstrand, O. 1998. ‘Towards a theory of the technology-based firm’ *Research Policy*, 27, pp. 465-489

Hall, P., and Markusen, A. 1985. *Silicon Landscapes*. Boston. Allen and Irwin

Hicks, D., and Hegde, D. 2005. ‘Highly innovative small firms in the markets for technology’ *Research Policy*, 34, pp. 703-716

Krugman, P. 1991. *Geography and Trade*. Cambridge: MIT Press.

Leonard-Barton, D. 1992. ‘Core capabilities and core rigidities – a paradox in managing new product development’ *Strategic Management Journal*, 13, pp. 111-125

Libaers, D., Hicks, D. and Porter, A.L. 2007. ‘A taxonomy of small firm technology commercialization’ Working Paper, School of Public Policy, Georgia Tech

Lundvall, B.A (Ed.) 1992. *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. London: Pinter

Malecki, E. 1980. ‘Dimensions of R&D location in the United States’ *Research Policy*, 9, pp. 2-22

Marshall, A. 1920. *The Principles of Economics*. London: McMillan

Nelson, R. and Winter, S. 1982. An Evolutionary Theory of Economic Change. Cambridge, MA. Harvard University Press.

NFIB. (2005). National small business poll – innovation. *NFIB Voice of Small Business Report* 5(6) (NFIB Research Foundation, Washington DC)

Pavitt, K. 2002. ‘Knowledge about knowledge since Nelson & Winter: a mixed record’ *SPRU Electronic Working Papers* n° 83.

Piore, M., and Sabel, C. 1984. *The second industrial divide: Possibilities for prosperity*. New York: Basic Books

Polanyi, M. 1958. *Personal Knowledge. Towards a Post Critical Philosophy*. London: Routledge.

Porter, M.E. 1990. *The Competitive Advantage of Nations*. New York: Free Press

Saxenian, A.1994. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.

Smith, A. 1776. *An Inquiry into the Nature and Causes of the Wealth of Nations*. London: Methuen and Co. Ltd.

Sorenson, O., and Audia, P. 2000. 'The Social Structure of entrepreneurial Activity: Geographic concentration of footwear production in the US, 1940- 1989' *American Journal of Sociology*, 107 (2), pp. 424 –459

Storper, M. 1989. 'The transition to flexible specialization in industry: External economies, the division of labor and the crossing of industrial divides.' *Cambridge Journal of Economics*, 13, pp. 273-305

Stuart, T., and Sorenson, O. 2003. 'The geography of opportunity: spatial heterogeneity in founding rates and the performance of biotechnology firms.' *Research Policy*, 32, pp. 229-253

Sweeney, P. 1987 *Innovation, Entrepreneurs and Regional Development*. New York, St Martin's Press.

Teece, D., Pisano, G., Shuen, A. 1997. 'Dynamic capabilities and strategic management.' *Strategic Management Journal*, 18(7), pp. 509-533

Wernerfelt, B. 1984. 'A resource-based view of the firm.' *Strategic Management Journal*, 5(2), pp. 171-180

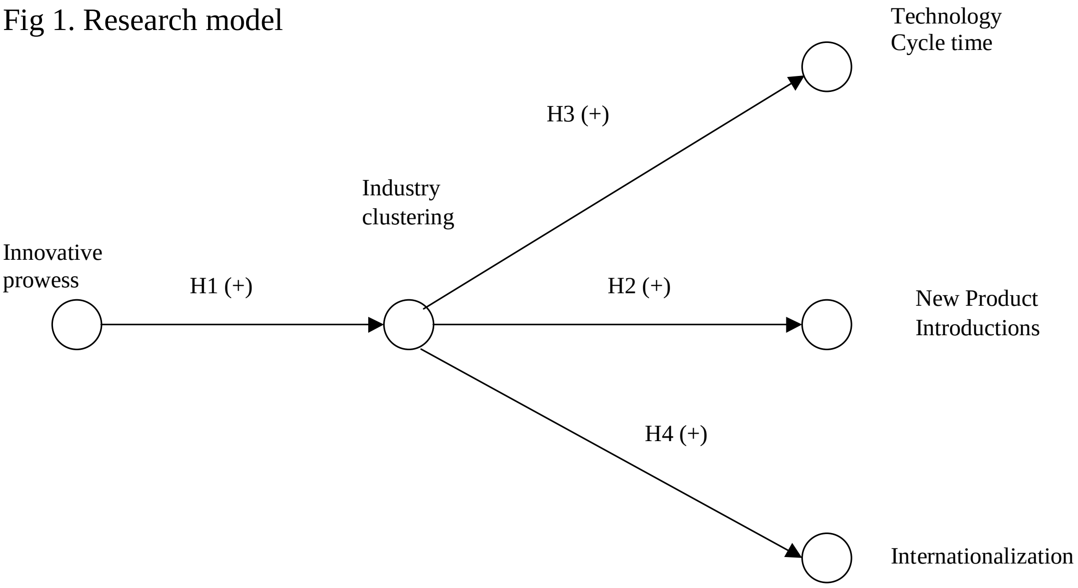
2. MODEL, RESEARCH ASSUMPTIONS, AND LIMITATIONS

The model that will be analyzed and tested in this dissertation is a two-step path model with the first step examining where serial innovators are likely to be located vis-à-vis research universities and technology clusters and the second step examining the relationship between industry clustering and firm performance.

Both the simplified and the complete model are presented below:

Serial innovator → Geographic clustering → Firm Performance

Fig 1. Research model



As mentioned in the introductory chapter, the first leg of the path model will be discussed in the second and third essays. Industry clustering is a key element in the conceptual model sketched above, and in the last two essays it will be argued that pecuniary advantages and/or knowledge spillovers will play a role in the firm-level performance outcomes on the right-hand side of the model. Before moving on to the substantive part of this study- the essays proper- it is important to state the research assumptions made and the limitations envisaged for this study as a whole.

Research Assumptions

A number of research assumptions apply to all three essays here while others are specific to the essay in question. These assumptions are important because they will determine the nature and extent of the limitations imposed on the research design in each of the three essays. I will enumerate and discuss them separately below.

Throughout this study I *assume* that the innovative capabilities of these small, technology-based firms can be characterized by their public invention track record as evidenced by the size of their patent estate over a specified period of time (from 1998 to 2002). The population of interest in this study comprises firms that developed prominent positions in the technology space, in the sense that they operate at the technological frontier of their respective product markets. It is important to note that this population is only a subset of the larger population of small, innovative firms that may or may not use utility patents to provide protection for its intellectual property assets.

A *second assumption* that applies across the board is the fact that each essay contains unobservable variables that will be proxied by measures that correlate satisfactorily with these variables. This is common practice in the social sciences, including public policy. The validity of these measures has been tested in many other scholarly works and in a variety of different contexts as will be cited throughout this work. An example of an unobservable measure is the level of agglomeration in a specific region at a specific time and will be used throughout this dissertation. Another example is a novel measure of technological progress that will be introduced in the second essay.

A *third general research assumption* is that serial innovator firms are *unrepresentative* of the larger population of small firms in these industries and are uniquely technology-based. The first reason they are unrepresentative of the larger population of small firms is their ownership of a large number of patents. In addition, Hicks and Hegde (2005) provided other reasons why these firms are different from their peers: serial innovator firms develop mostly general purpose technologies (GPTs), which are radical in nature and commonly built on knowledge originating from the science base. Hicks and Hegde further argue that the innovative efforts of these firms mimic best R&D practices in large firms as they have adopted 'large firm' routines. These routines include formal R&D groups, product and technology vetting and selection committees, and goals such as a certain percentage of sales should come from new products.

A *simplification* made throughout this study is that the phenomenon of industry agglomeration, a very complex phenomenon, is reduced to single, uni-dimensional variable, the cluster location quotient. A more detailed discussion of this proxy variable will be provided in the first essay.

In terms of *essay-specific research assumptions* it is worth noting that the second essay uses the number of new product announcements as a measure for innovative performance. Simple counts are taken, and no distinction is being made between incrementally improved products or new-to-the-world products. In addition, a new electronic component, a new drug, and a new piece of communications equipment are given equal importance in counting new product introductions, but industry differences in performance will be captured by the industry dummy variables. Furthermore, the second essay assumes that innovation speed can be satisfactorily gauged by examining a patent-level variable, Technology Cycle Time, a proxy variable that measures how quickly each new invention is being replaced by a successive invention.

Limitations of the research

For the study overall and in each essay individually, a number of limitations can be identified since the three essays share a common dataset. These limitations will have implications for the research design and the conclusions that one can draw from the results.

A *first limitation* is the criterion used to define a population of small, highly innovative firms and prominently among them the requirement of small firms to have been granted at least 15 United States utility patents in a five-year period preceding 2002. The number 15 is somewhat arbitrary but was chosen as a cut-off value to ensure that these firms are unusually active patentees. A higher cut-off value would further shrink the population and make statistical analysis of the dataset more troublesome and unreliable. A lower cut-off number would expand the population but make the firms progressively less unique and look more like their less innovative peers.

Furthermore the focus on patents implies that technology-based firms are assumed to be highly innovative when they have high rates of patenting, although Mansfield (1986) has provided empirical evidence indicating that the relationship between patents and innovation is complex, and that many inventions in traditional industries would have been commercialized even in the absence of a patent system. However, he showed that most inventions made by science-based firms (pharmaceuticals, medical devices, chemicals, semiconductors etc.) require patent protection in order to enable these firms to appropriate a fair return to the sizable investment they make in R&D activities. The total population of innovative firms therefore comprises entities that may or may not own patents.

Serial innovator firms operate in both science-based and traditional industries, although the distribution of these firms is heavily concentrated in science-based industries (Libaers, Hicks, and Porter, 2007). Following Mansfield's logic these firms do indeed engage intensively in patenting their inventions. The propensity to patent also varies across industries and countries (Evenson, 1993). However, the population of innovative firms comprises companies that do not own patents and protect their intellectual assets through other means. Firms use other means of *intellectual property protection*[9] that are often more effective than patenting under the right circumstances i.e. under conditions where knowledge codification is hard (or expensive) to achieve.

However, patents as tools to protect intellectual property embodied in technological artifacts are often far superior than copyrights, trademarks, and trade secrets, provided diligent and permanent market monitoring is undertaken to detect potential patent infringement. Teece (1986) argues that profits from innovation depend upon the interplay of three sets of factors, namely, appropriability regimes, (specialized) complementary assets and the presence of a dominant technological paradigm. Appropriability conditions comprise in addition to patent and copyright protection, secrecy, time to market, costs and time required for re-engineering, technological learning, and commercialization assets such as sales forces and service personnel. Furthermore, as Teece stresses, such appropriability regimes are primarily dictated by the

[9] Alternative 'intellectual property' strategies are: 1. first mover advantage, 2. secrecy, 3. very high levels of tacit knowledge, know how that is hard to codify, 4. trademark or copyrights

nature of technological knowledge (Teece, 1986). In a sense, the population of serial innovator firms is a subset of the larger population of small, innovative firms and the conclusions drawn here should not be extended to the entire population of small innovative firms.

A *second limitation* is the time span over which the research problem can be examined, essentially limiting the study to a *cross-sectional* analysis. The implication of this limitation is that no causal inferences can be made about the relationships being tested and that one can't control for unobserved heterogeneity among the firms.

A *third limitation* is that this analysis pertains to *public* firms, leaving out the equally interesting subset of private serial innovator firms. Being a public firm brings a different set of external pressures to bear on the performance and management of the firm that are absent or not as pronounced in private firms and hence may lead to different behaviors and performance outcomes. The resulting population thus consists of an elite survivor set of actors, as longevity is one of the defining attributes of serial innovator firms. Public firms have been chosen primarily for reasons of data availability since these firms have extensive reporting requirements mandated by the Securities and Exchange Commission, a federal regulatory agency charged with enforcing federal securities regulations and regulating the securities industry and stock markets.

A *fourth limitation* is the size of the population and the control sample of equal size, just below 200 firms, which is sufficient for maximum likelihood and OLS regressions but requires caution for the within serial innovator population analyses. It precludes within industry analyses since the number of observations become too limited to draw strong statistically valid results.

Moreover, each essay has limitations associated with its research design and the way the variables are operationalized. The specific limitations will be cited in the essays and I will restrict myself to briefly discussing one variable operationalization that is central to all three essays. The variable in question is the cluster location quotient, which is a one-dimensional measure seeking to represent a very complex phenomenon (industrial agglomeration). To complicate matters further, there are different definitions and operationalizations possible for cluster location quotients. No clear, theory-driven cut off mark exists to decide where clustering effects start to truly manifest themselves. Some authors, use 1.2, others 1.25 (Miller et al, 2001), and still others 3 (Isaksen, 1996).

Another disadvantage of traditional location quotients is the fact that these measures do not provide information on the absolute size of local industries. One may therefore obtain high location quotients for industries that have small workforce sizes (O'Donoghue and Gleave, 2004). An attempt to overcome this limitation is the HC (Horizontal clustering) quotient but again, this measure suffers from no commonly accepted cutoff value for defining a cluster.

Throughout the dissertation, I decide to sidestep the vexing issue of a cut off mark for the location quotient by treating clustering phenomena as occurring across a continuous scale, with *no particular cut-off value* for the location quotients being defined.

REFERENCES

Evenson, R. 1993. ‘Patents, R&D, and Invention potential: International Evidence.’ *American Economic Review*, 83(2), pp. 463-468

Hicks, D., and Hegde, D. 2005 ‘Highly innovative small firms in the markets for technology’ *Research Policy*, 34(5), pp. 703-716

Isaksen, A. 1996. ‘Towards increased regional specialization? The quantitative importance of new industrial spaces in Norway 1970-1990, *Norsk Geografisk Tidskrift*, 50, pp. 113-123

Libaers, D., Hicks, D., and Porter, AL. 2007. ‘A taxonomy of small firm technology commercialization’ *Working Paper*, School of Public Policy, Georgia Institute of Technology

Mansfield, E. 1986 ‘Patents and innovation – an empirical study’ *Management Science*, 32(2), pp. 173-181

Miller, P., Botham, R, Gibson, H, Martin, R, and Moore, B 2001. *Business Clusters in the UK – A first assessment*. Report for the Department of Trade and Industry, London, UK.

O’Donaghue, D., and Gleave, B. 2004. ‘A Note on Methods for Measuring Industrial Agglomeration’ *Regional Studies*, 38(4), pp. 419-427

Teece, D. 1986. ‘Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy’ *Research Policy*, 15, pp. 285-305

ESSAY 1: LOCATION OF SERIAL INNOVATOR FIRMS

Introduction

The first essay will address the following research question: Are there significant systematic differences between firms with differential levels of innovative prowess in their geographical location vis-à-vis research universities and industrial clusters? The null hypothesis holds that, on average, no such differences exist. All technology-based firms, even in the same industry, may not be alike in their choice of geographical location and attributes and knowledge bases may in some cases have been built with the help of the immediate environment, more specifically location-specific resources and their interrelationships. The differences posited refer to different levels of industrial clustering at the MSA (Metropolitan Statistical Area)[10] level and differences in the number of research universities in the MSA, respectively.

In essence what is argued in this essay is that firm heterogeneity in terms of technological capabilities might lead some firms to behave differently-at least in their locational preferences – than similar-sized firms in the same industry. The concept of 'innovative prowess' will be advanced as the single most important form of heterogeneity between the two types of firms considered in this study. This essay seeks to explore the link between knowledge spillovers and location choice and how firm-specific heterogeneity may influence where a firm is located.

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[10] The Office of Management and Budget (OMB) defines Metropolitan Statistical Areas as areas that have at least one urbanized area of 50,000 or more population, plus adjacent territory that has a high degree of social and economic integration with the core as measured by commuting ties.

Since the 1990s scholars in regional and local innovation systems literature rediscovered the importance of the regional dimension and the key role of specific and regional resources in fostering the innovation capability and competitiveness of firms and regions (Asheim et al., 2003; Cooke, 1992; 2001; Saxenian, 1994; Malmberg and Maskell, 2002). In a sense, what these scholars argue is that firm-specific competencies and learning processes can lead to regional competitive advantage if they are based on localized capabilities such as specialized resources, skills, institutions, and shared social and cultural values with other firms in a specific locale (Maskell and Malmberg, 1999). In other words, regional development ensues as competitiveness occurs in geographical locations where localized capabilities such as institutional endowments, infrastructure, knowledge, and basic and advanced skills co-exist.

A similar line of reasoning, but taking an industrial organization perspective, was introduced in the early 90s by Michael Porter who argued that local factor conditions such as skill levels, sophistication of demand, and competitive dynamics within a region would enhance firm capabilities and the competitive edge of firms located in that region (Porter, 1990). The literature on regional innovation systems has provided ample descriptive evidence and analysis of the complex relationships between (technological) learning, innovation and economic performance in particular regions.

Other studies contradict the received wisdom regarding the benefits provided by the 'economies of agglomeration school of thought' and found empirical support suggesting that firms with the best technologies, human capital, and other favorable firm-specific capabilities have little to gain by locating in a technology cluster (Shaver and Flyer, 2000) or that there are even negative returns associated with locating in an industry cluster due to congestion costs (Pouder and St John, 1996; Prevezer, 1997; Beaudry and Swann, 2001). Increased competition for valuable inputs- especially for technology-based firms (Zucker et al, 1999), an increased risk for knowledge expropriation by geographically proximate rivals (Flyer and Shaver, 2003), or lock-in due to path dependency (Arthur, 1990), are additional negative returns

Previous studies indicated that some small, highly innovative firms – especially those operating in science-based industries - locate near academic institutions or government laboratories in order to capture the benefits of knowledge spillovers or to have access to a supply of new knowledge workers, including star scientists (Audretsch et al, 2005; Kauffman et al, 2003; Furman, 2003; Zucker and Darby, 1997).

No study, however, has examined one important dimension of firm heterogeneity – innovative prowess – as a distinguishing trait in a set of small high technology firms, and its impact on the location of firms vis-à-vis research universities and technology clusters. This study aims to illuminate the role of *innovative prowess* as a potential determinant of small firm location. *Innovative prowess - refers to the deployment, refinement and management of superior technological capabilities that enable a small firm to sustain its technological edge over time.*

The innovative prowess of small, high tech firms is directly related to their public record of sustained technical invention, expressed as the number and quality of patents owned by these firms and is built over time and is path-dependent (Dierckx and Cool, 1989; Schendel, 1994). Such a record could not have been built without possessing extraordinary technological capabilities that are continuously refined, maintained and upgraded. As such, the definition of the term innovative prowess is rather narrow and does not include other aspects important to innovation such as managerial capabilities, marketing and other non-technological capabilities. Small, high tech firms with high levels of innovative prowess are labeled serial innovator firms throughout this dissertation. A precise definition of such a firm will be provided later on in the section that describes the dataset.

The essay is structured in four sections. The first section will develop the theoretical framework and principal hypotheses that addresses the research question along with a brief review of the extant literature. The second section will describe the dataset, the sampling strategy and the way the variables have been operationalized. The third section discusses the descriptive statistics, the analysis of the results, and provides an elaboration on the findings. The fourth and final section includes a conclusion and a discussion on future related topics that can be explored.

Theory and Hypothesis development

Traditional agglomeration theory as described by Marshall (1920) seeks to explain proximate economic activity in terms of mutually reinforcing external economies of scale and scope. Marshall theorized that agglomeration advantages arise from three distinct sets of localization economies, namely a skilled pool of workers with specialized expertise, the expansion of supporting firms, and the specialization of firms in parts of the production process. Knowledge spillovers result from the dynamic interplay of these three factors. This triad of localization factors contributing to an agglomeration advantage first suggested by Marshall has been at the center of the debate on industry clustering ever since. Michael Storper (1997: p.35) makes a clear distinction between traded dependencies – represented by the common labor pool and the presence of relevant suppliers and related services – and un-traded ‘soft’ interdependences such as ideas, knowledge and social and professional relationships. Traded dependencies have traditionally played a major role in instigating and maintaining industrial agglomeration as they lead to measurable economic advantages such as a reduction in transportation costs, transaction costs in both input and output markets, and access to capital (Storper, 1997; Porter, 2000). Un-traded interdependencies have variously been labeled as technical, knowledge, or research spillovers and are often complex, intangible and resist codification. These un-traded interdependencies will hereafter be referred to as knowledge spillovers.

In the past two decades increasing attention has been paid to the existence, conceptualization, measurement, and diffusion of knowledge spillovers and Jaffe et al. (1993) provided evidence of a close relationship between spatial proximity and the existence and diffusion of knowledge spillovers. Jaffe et al. specifically demonstrated that inventors are more likely to cite other inventors who are geographically proximate. Adams and Jaffe (1996) measured knowledge spillovers and offered evidence that intra-firm knowledge transfer decreases with distance even within a multi-plant firm with geographically dispersed plants. Further evidence that agglomeration economies and more specifically knowledge spillovers dissipate rapidly across space was provided by Rosenthal and Strange (2003, p. 387) and Anselin et al (1997).

One of the key benefits provided by knowledge spillovers is the fact that they inform the recipient(s) of the knowledge spillover about the technological direction, sophistication and level of progress of the spillover originator (Brown and Duguid, 2000). Furthermore, knowledge spillovers contain non-technical data on new market opportunities, emerging trends, and changing customer preferences (Audretsch and Keilbach, 2004). Lastly, knowledge spillovers have a cost saving effect for the recipient(s) since spillovers are 'free' and this is knowledge that does not need to be produced by the recipient (Harhoff, 2000).

However, knowledge spillovers may also have negative or unintended effects on the creator of the knowledge. Specifically, knowledge spillovers are not always voluntary as in the case of expropriation of ideas or knowledge assets from a technologically advanced firm by a co-located (less sophisticated) competitor (Flyer and Shaver, 2003). Recent research however, has cast doubt on the existence of intra-national localized spillovers at different levels of geographic agglomeration (national, state, and at the MSA level) because of knowledge spillover measurement problems (Thompson and Fox-Kean, 2005). More specifically, Jaffe et al. (1993) proposed a matching method to study the localization of knowledge spillovers using patent citations and found a strong localization effect. However, Thompson and Fox-Kean(2005) using a more accurate matching method of original, citing, and control patents found no such localization of knowledge spillovers. This issue will be addressed in the section that describes the dataset and the methodology used in this paper. Knowledge spillovers may serve a particularly important role with regard to the type of firms studied in this essay.

This essay argues that a firm's distinct quality and level of technological capabilities - represented by the level of *innovative prowess* - may influence its ability to acquire knowledge from proximate firms and universities, its willingness to serve as a source of knowledge spillovers, and ultimately where the firm is located. The theoretical analysis presented in this essay incorporates and synthesizes an array of theoretical arguments drawn from the economics, innovation, and strategy literature. The focus is on firm location strategy - a pre-condition for knowledge spillovers- as opposed to the identification, measurement and impact of knowledge spillovers. The existence of knowledge spillovers is assumed and has been documented in numerous other studies in the literature.

Two competing hypotheses will be developed that provide alternative explanations for the geographical location of firms with differing levels of innovative prowess vis-à-vis industrial clusters. Subsequently a third hypothesis will be developed that provides an explanation for the location of firms with differing levels of innovative prowess relative to research universities. The hypotheses are grounded in theoretical concepts that explain the heterogeneity of sources of knowledge spillovers and the differing abilities of firms to benefit from this heterogeneity.

Heterogeneity of sources for knowledge spillovers

Innovative activity is not evenly distributed across space and critically depends on differences in initial endowments, the nature and number of actors engaged in R&D, and their interconnectedness, in addition to the institutional setting in which these actors operate (Nelson, 1993; Lundvall, 1992; Cooke, 2001; Harrison, 2007). Some areas will exhibit stronger knowledge-generating abilities than others as a result of localized R&D spending (Jaffe, 1989) or a tighter fit between private firms and public research organizations (Cohen et al, 2002). More R&D activity in a specific location or region implies that the likelihood for knowledge spilling over to other entities increases.

The innovation literature highlights two key aspects of technological innovations: basicness, defined as the innovation's reliance on results from scientific exploration, and appropriability, the ability of inventors to reap the benefits from their investment in R&D (Jaffe and Trajtenberg, 2002: p.83). The dual character of technological innovations lies at the heart of the concept of division of labor in the sense that public research organizations dedicate themselves to the performance of mostly basic research (the basicness dimension) whereas private firms primarily conduct applied research and engage in technology development and commercialization activities. Private firms also seek to protect their ideas from competitors (the appropriability dimension) through formal or informal means. Since the passage of the Bayh-Dole legislation, universities have also become major participants in the market of ideas (Mowery et al, 2001).

Technological innovations differ in terms of basicness and technological domains (Trajtenberg et al, 2002) i.e. university patents are more basic than private firm patents and cover a more limited number of technological domains. Patents produced by serial innovators are more like university patents than like pure private firm patents (Hicks and Hegde, 2005) and rely in part on different bodies of knowledge originating from different institutional environments. More specifically Hicks and Hegde (2005) empirically demonstrate that technologies developed by serial innovators – firms with very high levels of innovative prowess - have a stronger link to the science base, are broad-based and have less immediate precedents in its patent technology class and can therefore be considered more radical than those of other firms. In addition, Hicks and Hegde found that many serial innovator firms provide specialized technologies that are traded in markets of technology as General Purpose Technologies (GPT) (Bresnahan and Trajtenberg, 1995; Arora et al, 2001; Goldfarb, 2005). Basically in this essay one can distinguish two sources of knowledge spillovers: private firms and public research organizations i.e. research universities. The next section will discuss how firms differ in their abilities to capture and consequently benefit from the two sources of knowledge spillovers introduced in this section

Heterogeneity in firm's abilities to benefit from spillovers

Firms, as recipients of knowledge spillovers will differ in their ability to benefit from this 'free' knowledge. The word free is between quotation marks because firms need to invest in their own innovative activities to effectively take advantage of spillovers (Leahy and Neary, 2007). The primary source of differences in the ability of firms to capture and exploit knowledge spillovers is the level of absorptive capacity of firms (Cohen and Levinthal, 1990) which will be determined by the firm's relative level of technological capabilities, conceptualized as the level of *innovative prowess* of the firm. Firms with sophisticated technological capabilities will be able to recognize, capture, assimilate and exploit knowledge spillovers to a much higher degree than firms with much weaker capabilities.

Firms play a dual role in the sense that they can serve both as recipient and source of knowledge spillovers. Technologically advanced firms – such as serial innovators – do serve as a source of knowledge spillovers for much less advanced firms and Shaver and Flyer (2000) suggest that spillovers from sophisticated firms with strong technological capabilities may affect the net contribution firms make to the level of agglomeration economies and the ultimate decision to locate in a cluster. Small firms with high levels of innovative prowess may not find it beneficial to locate in dense clusters of firms in the same industry. Moreover, they may not have a need for knowledge spillovers since most other firms do not operate at the technological frontier as serial innovator firms do. The next section will theorize on the net balance of benefits from knowledge spillovers and its potential impact on firm location.

Net knowledge spillovers and firm location

Rationally acting firms – in search of competitive advantage – seek to maximize the net amount of knowledge spillovers by favoring locations abundant with relevant knowledge sources subject to two constraints (Alcacer and Chung, 2007). The first constraint is the firm's ability to benefit from and leverage the knowledge sources resident in a particular location. The second constraint is the firm's ability to minimize knowledge leakage.

Spillover-seeking firms may favor some geographical areas over others. For small firms, ease of commercialization is likely to be an important consideration. Technology clusters invariably feature large firms, business services, and other firms in related industries (Porter, 1990), all complementary assets that small firms can access and employ to facilitate the commercialization of their products (Teece, 1986). So the presence of high levels of industrial activity in general and of similar firms in particular is favored (pecuniary advantages of agglomeration).

The level of innovative prowess in part determines to what extent the firm can benefit from private firm and academic knowledge spillovers. Technologically lagging firms will experience more trouble benefiting from knowledge sources that are less commercially oriented (academic spillovers) and will be more inclined to seek knowledge spillovers generated by private firms, which often comprise a high marketing content (Audretsch and Keilbach, 2004; Alcacer and Chung, 2007). Technology pioneers -like the set of serial innovator firms- are the first firms to develop novel technologies, operate at the technological frontier in their respective markets, and have typically much higher levels of absorptive capacity to interpret, acquire, and synthesize knowledge spillovers into their existing knowledge base, subsequently benefitting from this external source of knowledge. Because these firms operate at the technological frontier and are first movers in their respective product markets, they face much higher levels of market and technological uncertainty than follower firms (Lieberman and Montgomery, 1988). The need for knowledge spillovers with both up-to-date market and technology content is therefore much more important for firms with high levels of innovative prowess than for other firms, spillovers that can be found and accessed by locating in geographical clusters (that may comprise other serial innovators and large, technologically-sophisticated firms).

Firms with high levels of innovative prowess by definition own very sizable portfolios of patents, a key legal mechanism of protecting their intellectual property. Once granted, patents are in the public domain and the tacit knowledge not reported in patents can still 'slip out' of the firm through e.g. employees that leave the firm. Serial innovator firms, through their innovative prowess, are nevertheless in a strong position to benefit from knowledge spillovers (originating from other private firms) in technology clusters while at the same time being able to minimize leakage from the firm (through patents). In addition they can deploy strong monitoring and enforcement mechanisms to ensure that none of their intellectual property assets are being infringed upon. The possession of a strong portfolio of patents signals to others that the firm is serious about intellectual property protection and that every attempt to infringe upon the firm's technology assets will be met by a legal response (Arora and Merges, 2004). Hence I expect that:

Hypothesis 1a: Metropolitan firms with high levels of innovative prowess are located in MSAs with higher average levels of industrial clustering compared to firms with much lower levels of innovative prowess

Two arguments can be made that firms with high levels of innovative prowess do not have a need for knowledge spillovers originating from other private firms. Indeed, such firms are pioneering novel technologies and often operate in the markets for technology (Hicks and Hegde, 2005).

First, technologically advanced firms may suffer from knowledge leakage when knowledge is inadvertently spilled over to technologically less sophisticated firms in the same area (Shaver and Flyer, 2000). Serial innovator firms, because of their innovative prowess, are among the most technologically advanced small firms in the country and can be conceived as net spillover generators in the sense that codified (patents) as well as tacit (e.g. employees) knowledge may leave the firm and be absorbed by geographically proximate firms in the same or related industries. The existence of knowledge leakage is a major disincentive for technology pioneers to locate in clusters where many weaker firms congregate and benefit from the localized leaked knowledge, and is an incentive to locate in areas where the risk for unintentional knowledge spillovers is limited and knowledge sources are predominantly non-commercial (e.g. universities). That said, serial innovator firms may also benefit from knowledge flowbacks and links (e.g. recruiting the best technical minds that are always eager to work for firms operating at the cutting edge of their field) that could mitigate some of the negative consequences of knowledge leakage. In addition, nowadays, leading universities and the business incubators and/or science parks affiliated with them house innovative firms that may benefit from knowledge leakage from serial innovator firms.

Second, firms with high levels of innovative prowess often operate in the markets for technology and may or may not find locating in a specialized industrial cluster beneficial. They may be motivated to locate in a cluster because of the presence of complementary assets that they need access to in order to commercialize their technologies and for ease of transfer of the (tacit) knowledge associated with the technology (Teece, 1986; Von Hippel, 1994). However, given the globalization of the markets for technology these very innovative firms may not be bound to particular geographic locations (Arora et al, 2001).

Arora and his co-authors develop a simple typology for different transactions of trade-able technology in technology markets. One dimension refers to horizontal (licensing to rivals) or vertical transactions (licensing to non-rivals) whereas the second dimension indicates whether the technology is existing and mature or new. An example of a horizontal trade of technology in the market is that of SUN licensing JAVA to IBM. The licensing of tools for combinatorial chemistry by Affymax to numerous geographically dispersed biotechnology firms would constitute a vertical technology transaction. A typical example is that of small semiconductor design houses who license blueprints for ASICs (Application Specific Integrated Circuits) to large foundries often located in the Far East (Hall and Ziedonis, 2001). Licensing allows small firms focused on technology development to appropriate the returns to innovation since access to critical complementary assets may be too costly. Markets for technology are also extensively used in the medical device industry where many small development stage firms specialize in the early stages of the product development process and license their intellectual property to large established medical device firms that possess expertise in the later stages of product development and own distribution and marketing networks with wide coverage (Rosenberg, 2000). Therefore I expect that:

Hypothesis 1b: The level of a metropolitan firm's innovative prowess is not related to the level of industrial clustering of the MSA in which the firm resides.

Innovative prowess and proximity to research universities

Firms with high levels of innovative prowess such as serial innovators develop and control technology assets that are more basic than that of an average technology-based firm, implying that their innovative prowess rests in significant part on research results originating from the academic community (Hicks and Hegde, 2005; p.713). A strong science linkage indicates that the firm is developing technology based on advances in science. One reason to locate in close proximity to a major research university is access to a pool of new scientists and engineers, a pecuniary advantage of agglomeration. Earlier research indicated that higher intensities in academic R&D expenditures provide a comparative advantage for the local industry - although one can observe strong disciplinary effects (Nagle, 2007) - and play a significant role in the location decisions of high technology firms (Woodward et al, 2006; Anselin et al, 1997). Additional reasons why innovative firms may locate near research universities can be related to factors such as quality of life, reputational or prestige effects or access to graduate labor pools. While these factors do play a role, I argue that research-related knowledge links plays a primary role in the location decision of firms with elevated levels of innovative prowess.

The university-firm dyad is a unique mechanism for cross-boundary organizational/technological learning since the incentive, reward, and decision-making structures of these two entities are so different (Bercovitz and Feldman, 2007) and concerns surrounding knowledge expropriation by a university from an innovative firm are not present. The interaction of firms with high levels of innovative prowess with the science base will be framed in the exploration/exploitation dichotomy, a framework that has been extensively used to explain organizational learning (March, 1991). Every firm's innovation strategy rests on both exploratory and exploitative activities in order to remain viable. Exploration is defined as the set of routines associated with the search, discovery and development of new knowledge whereas exploitation represents the refinement and utilization of existing knowledge and capabilities (March, 1991; Levinthal and March, 1993).

While firms with high levels of innovative prowess expend significant resources on internal R&D, external alliances for both explorative and exploitative activities are important to access knowledge and other resources residing in other organizations such as universities, government laboratories and private firms (Leonard-Barton, 1995). External alliances with organizational entities have been shown to be crucial for successful exploration strategies (Rosenkopf and Nerkar, 2001; Von Hippel, 1988; Mowery et al, 1996) and provide firms with new knowledge that can be integrated into the firm's technology portfolio (Lane and Lubatkin, 1998; Dussauge et al, 2000).

The innovation strategy of firms with high levels of innovative prowess is tilted towards exploratory research, initially around the first idea to tackle a technical problem and later branching off from the first solution to this problem to related or unrelated challenges (Hicks and Hegde, 2005). The theory of organizational learning suggests that firms seeking to tap expertise through interactions with universities pursue innovation strategies with a relative emphasis on exploratory research (Cyert and March, 1963; March 1991; Cohen and Levinthal, 1989). Exploration is also enhanced by increased diversity and variation in the sense that collaborating with a university partner (or partners) with a distinctly different knowledge base will yield know-how that is unique to the firm. Earlier research by the author reported in the fourth chapter of this dissertation indicates that a sizable number of serial innovator firms are actually spinoffs from universities and conceivably maintain formal and informal ties with their parent organization long after the spin-off event.

The organizational learning literature also indicates that internal exploratory research will result in further upgrading and development of a firm's absorptive capacity and implies a complementarity between internal exploration and external university research. Specifically, the more the firm's internal R&D activities are oriented towards exploratory research, the higher the share of the firm's R&D budget that will be allocated to university-based research contracts (Bercovitz and Feldman, 2007).

With regard to public research organizations, prior research indicated that the bond between academia and industrial research is strong although differences can be observed by scientific discipline (Cohen et al, 2002). Moreover, this link between academic and industrial research is stronger than the one between government research –

performed in federal laboratories – and private firm R&D. Interesting patterns can be observed in the interaction between private firms and universities. The pharmaceutical, biotechnology, and medical device sectors have traditionally been at the forefront in collaborating with universities with strengths in the life sciences (Blumenthal et al, 1996; Blumenthal et al, 1997). Industry funding for academic research favor areas such as biotechnology, computer science, materials science, and nanotechnology (areas with great commercial potential) as opposed to disciplines such as astrophysics, mathematics or archeology (Geuna, 1999; Mowery et al, 2001). Usage patterns of academic research by different industries are also pronounced (Mansfield, 1998).

Ideas and cutting-edge scientific knowledge have a strong tacit character (Nelson and Winter, 1982). Mowery and Rosenberg (1989) observe that a new technology embodies both codified knowledge and a more amorphous, tacit form of knowledge which they label 'know-how.' For effective transmission of this tacit knowledge interactive face-to-face communication with university-based scientists is indispensable (Teece, 1985; Kogut, 1988; Von Hippel, 1994) to facilitate organizational and technological learning. Furthermore, a strong and direct link between the intensity of research efforts at research universities and the innovative potential in the university's MSA have been clearly demonstrated in previous studies (Jaffe, 1989; Anselin et al, 1997). Hence I expect that:

Hypothesis 2: Metropolitan firms with high levels of innovative prowess are located significantly closer to a research university than metropolitan firms with low levels of innovative prowess.

Dataset

The dataset employed in this essay comprises a defined population of serial innovators[11] – firms with 500 or fewer employees with a portfolio of a minimum of 15 utility patents granted in the five-year period preceding 2002, who are independently owned, not bankrupt at the time of this study (2006), and are long-lived in the sense that these firms have operated through at least one complete economic cycle – a unique set of strong technology-based firms that have built a competitive advantage around a strong proprietary technology and have sustained or strengthened its competitive position while remaining small in size (Hicks and Hegde, 2005). The serial innovator firm is the unit of analysis throughout this study. This set of serial innovator firms is a population since we include all U.S. firms in the 1998-2002 time frame that meet the criteria indicated above to specify what a serial innovator firm is.

According to Buchanan[12] these small firms invest substantial time and money in technological innovation. They furthermore adopt or at least mimic best R&D management practices used in large firms and most of them have a formal R&D department or group with formal structures, committees for assessing new ideas and approving funds. Compensation of senior management personnel is often tied to the granting of patents or completion of prototypes, in the form of bonuses. She found that these firms tend to set a measurable goal that a certain percentage of their revenue should come from new products or be allocated to R&D activities. Again, these are organizational routines often encountered in much larger firms and this may well be

[11] The initial dataset on serial innovators was collected under SBA contract SBAHQ-01-C-0149 by Dr. Diana Hicks

[12] Buchanan profiled a number of serial innovator firms in the August 2002 issue of Inc. Magazine, http://www.inc.com/magazine/20020801/24453.html

another feature that sets these serial innovator firms apart from the much larger population of small technology-based firms.

The procedure used to define the population of serial innovators can be summarized as follows: firms are labeled serial innovators if they meet the following criteria.

1. have 500 or fewer employees, in line with the Small Business Administration definition of a small firm
2. have been granted 15 or more U.S. utility patents in the period 1998-2002
3. are independent, i.e. not majority owned by a large firm, not a joint venture, and not a subsidiary of a large U.S. or foreign firm
4. are a going concern, not bankrupt in 2006
5. are long-lived, i.e. have survived at least one full economic cycle

It is important to note that this population has been restricted to public firms because of the greater availability of non-patent firm-level data critical to test the propositions put forth earlier. After cleaning for firms that are defunct, have merged, or have changed names, the total number of serial innovators in the population dataset numbers 401, that is, 203 are privately owned and 198 firms are public.

The author added to the original serial innovator data additional information derived from COMPUSTAT, the firms' Web sites, Hoover Database, the Lexis Nexis database and SEC 10-K annual reports. Cluster data is gleaned from the Cluster Mapping Project at Harvard Business School and cross-checked with location quotient data available from the Bureau of Labor Statistics (BLS). The section on variables and their operationalization contains specific data on the data sources used per variable.

However, in addition to the population of serial innovator firms used in the analysis, a matched sample comprising non-serial innovator firms was created to enable a comparative analysis between serial and non-serial innovator firms. The non-serial innovator firms constitute a random sample drawn from the population of small, technology-based firms (that do not meet the criteria used to define a serial innovator firm). This matched sample therefore comprises firms of similar size (measured as the number of employees) as the serial innovator firms described above and was constructed using the following procedure:

1. For each serial innovator firm I consulted the Hoover's Company & Capsules Database that provides brief information on 40,000 public and non-public companies (Capsules) and 225,000 key executives, to identify a matched non-serial innovator firm. The Hoover's database of firm profiles includes an overview and history of company operations as well as: key officers, competitors, number of employees and selected historical financial data (seven years).

2. For each serial innovator firm, Hoover's yielded a list of direct competitors, along with their HQ location and work force size – that constitute potential non-serial innovator firms. Serial innovator firms are niche players and compete with one or two other small firms in their chosen 'niche' market segments.

3. From the list of direct competitors operating in the relevant niche market, I selected one incorporated and headquartered in the United States, and having a workforce of 500 employees or less. An appropriate non-serial innovator

must therefore be of similar size and operate in the same market segment/ industry as the serial innovator firm. Furthermore care was taken that serial and non-serial innovator firms market close product substitutes. This step therefore results in the selection of a matched non-serial innovator firm.

4. In case the list of competitors did not yield a non-serial innovator firm that met these two criteria, a list of competitors from a competing firm was checked; i.e. a competitor of a competitor, often termed "indirect competitor." The same procedure was followed and care was taken that the resulting non-serial innovator firm met the criteria outlined in point three. The problem with indirect competitors is that the strategic focus of these firms may deviate significantly from the focal serial innovator firm. The danger exists that one starts to compare firms with distinctly different knowledge- and technology bases and product portfolios.

5. The procedure highlighted in points 2, 3, and 4 was repeated for each of the serial innovator firms, resulting in a matched sample of non-serial innovator firms.

To test the robustness of our results, a second matched sample of non-serial innovator firms will be developed using the same procedure outlined above.

Measures

Dependent variable 1 - The dependent variable to test Hypothesis 1a and 1b is the *Cluster Location Quotient (***CLQ***)*, an index which indicates the degree to which a given metropolitan area has a higher, lower, or equivalent representation of cluster employment than what exists in the United States at large in 2002, in a particular industry. Location quotients are relatively simple measures of regional specialization to detect, identify, and to a certain extent characterize industrial clusters (Feser and Bergman, 2000; Bergman and Feser, 2002) although Porter (2000) explicitly states that more than single industries, clusters encompass an array of linked industries and other entities important to competitive advantage. It is therefore important to account for these ‘linked’ industries in the calculation of location quotients.

Linked industries are often situated in the upstream and downstream section of the ‘core’ cluster e.g. component and machinery suppliers (upstream), or distribution and customer-facing activities such as sales and service (downstream). It is important to note up front that the term cluster means different things to different researchers and policy-makers (Feser and Bergman, 2000; Martin and Sunly, 2003). In this study a Porterian view of industrial clusters will be adopted and defined as: ‘A cluster is a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities.’ (Porter, 2000).

The mechanics of location quotients are fairly simple. For example, a given metropolitan location whose proportion of cluster employment in a given industry is equivalent to that of the United States as a whole would have a cluster location quotient of 1. Metropolitan areas with a cluster location quotient greater than 1 have a higher concentration of employment than that which exists in this country, while those with a cluster location quotient less than 1 would be less concentrated than the United States as a whole. This is a continuous variable.

Several methodological issues and shortcomings are associated with using location quotients as a measure for the degree of agglomeration. It is fair to say that the most widely used measure to spatially delimit agglomerations is the location quotient (LQ) (O'Donoghue and Gleave, 2004). The LQ measures the ratio between the local and national percentage of employment in a specific industrial sector in a particular year in a predetermined geographical unit (MSA, county, state, etc). The question is, at what level for the LQ do we consider the geographical unit do be a cluster. No *theoretically grounded cutoff values* exist for LQ to distinguish between cluster and non-clusters, and values have been chosen somewhat arbitrarily in the literature. Miller et al (2001) used a cut-off of 1.25 and many other studies use 1.2, although some scholars have used LQ cutoff values of 3 to define an agglomeration (Isaksen, 1996). I sidestep this gray area by using a continuous variable for the LQ and arguing that the degree of industrial clustering is a relative concept. A further disadvantage of LQ's is the fact that this proxy for industry agglomeration does not provide information on the absolute size of local industries.

Fingleton et al (2002) has devised a measure in an attempt to overcome this limitation and labeled it HC (horizontal clustering). This is computed as the number of jobs in a local industry that exceeds the number of expected jobs for that industry. The expected number of jobs for that industry is defined by the number of jobs in the industry that would correspond to the area having the national average share of that industry, in other words produce a LQ of 1. The HC measure therefore accounts for both the relative concentration of an industry in a particular geographical unit, and the size of the industry in absolute terms. A major problem with this measure is its property to take very high absolute values when the proportional representation is marginally above the national average. The measure clearly fails to identify clusters as places that are somewhat exceptional (O'Donaghue and Gleave, 2004). In addition, like with the LQ, the HC measure has no commonly accepted cutoff value associated with it to distinguish clusters from non-clusters. The industry data on employment levels in specific MSA's used to compute location quotients does make no mention of whether MSAs can be labeled clusters or not in a particular industry.

The Cluster Mapping Project at Harvard Business School provides employment data on *traded clusters*, *local clusters* and *natural endowment dependent clusters*. Local industry clusters are those present in most, if not all geographic areas, are evenly distributed, and hence primarily sell locally. They serve as an excellent proxy for mainstream and supporting employment to the 'core' traded cluster. Traded clusters in a particular industry are those that are concentrated in a subset of geographic areas and sell to other regions and nations. These are the clusters of interest to this study. The natural endowment cluster employment figures are very marginal in most if not all cases. To fully capture the essence of the industrial clustering phenomenon I intend to include in the measure for clustering the national share of employment for mainstream and supporting industries in a given MSA in 2002.

In terms of industries, the Cluster Mapping Project is very detailed and provides detailed data for each sub-sector in a particular industry. For instance, the biopharmaceuticals industry consists of biopharmaceutical products; containers; and health and beauty products. The medical devices industry is comprised of the following sub-segments: biological products; dental instruments and supplies; diagnostic substances; medical equipment; ophthalmic goods and instruments; and surgical instruments and supplies. The Information Technology sector is composed of:

communications services; computers; electronic components and assemblies; peripherals; and software. The telecommunications equipments industry is equally well disaggregated and consists of 3 segments: communications equipment; electrical and electronic components; and specialty office machines. All other industries are being analyzed at the same level of dis-aggregation. The cluster location quotient is determined by the following formula: CLQ = $(e_{i,MSAj,2002}/e_{MSA, 2002})/(E_{i, 2002}/E_{2002})$ where $e_{i,MSAj,2002}$ is the local employment in industry i, in MSA j in 2002; $e_{MSA, 2002}$ is the total employment in the MSA in 2002; $E_{i, 2002}$ is the national employment in industry i in 2002, and E_{2002} is the total national employment in 2002. The SIC classification is used for industries. I compared the computed figures of the CLQ with those reported by the Bureau of Labor Statistics and found almost a perfect correlation.

Dependent variable 2 – The dependent variable for Hypothesis 2 is *the number of research-intensive universities in the MSA of the focal firm*. This is basically a non-negative count of research universities (Carnegie 1) in the focal firm's MSA. If the MSA is a stand-alone unit than the number of research universities in that MSA is the relevant count. In case the MSA is part of a CMSA (Combined Metropolitan Statistical Area) then the relevant count is the number of research universities in the CMSA. Alternative specifications for this variable could be used such as the amount of research expenditures at the universities but this could bias the results as some large research-based universities are located outside of MSAs or in stand-alone MSAs.

Data source: Carnegie classification of universities.

Independent variable: The independent variable of interest for both hypotheses is a dummy variable that takes on the value of 1 if the firm has a high level of innovative prowess and 0 in case the firm has a low level of innovative prowess. It is labeled *Innov_Prowess*. This variable is directly related to whether the firm can be considered a serial innovator or not.

Control variables:

Besides 'innovative prowess' other variables may predict whether firms may be more or less likely to locate in MSAs with higher levels of industrial agglomeration in a particular industry in 2002.

1. *Employ* - continuous variable, average number of employees of firm in the period 1998 to 2002. This variable serves as a proxy for both serial innovator and control firm size. Smaller firms in those new industries are more likely to be located in technology clusters than firms of similar age in traditional industries (Campi et al, 2004). Others have found that firm size is a main determinant of industrial location and concluded that the impact of this variable differs across industries (Carod, 2005) although a firm conclusion on this issue has yet to be established. Serial innovators may grow over the period studied, but not to the extent where they are no longer considered a small firm (500 employees). The data source for this variable is the 10-K SEC annual reports, as all the firms in the dataset are public.

2. *Age* - continuous variable of firm age in 2002

This is the age of firm in years since inception. Firm age is a differentiating factor in many industries. This may be true even within the range of workforce size (0 –500) chosen by the Small Business Administration to define a small business. Firms of similar age and size, draw on similar pools of resources, and likewise employ similar strategies and administrative routines. They may react to environmental changes in a similar way, and may possess and exert comparable market power (e.g., Aldrich and Auster, 1986; Chen and Hambrick, 1995; Hannan and Freeman, 1977; Haveman, 1993; Pfeffer & Salancik, 1978; Stinchcombe, 1965).

Their similarities in size and age are so striking that they identify with each other and share experiences more effectively (e.g., Baum, Li and Usher, 2000; Davis and Greve, 1997; Haveman, 1993; McKendrick, 2001). Young firms typically suffer from a liability of newness (Stinchcombe, 1962) and this effect is exacerbated in agglomerations where there is on average more intense competition among similar firms (Sorenson and Audia, 2000). Data for this variable originates from the 10 K SEC Annual report and if no mention is made about the founding data, other sources such as the firm’s website or the COMPUSTAT database were used.

3. *R&D Expend9802* **-** The average expenditures on R&D in a firm in the period 1998 to 2002. Annual R&D expenditures of serial innovator and control firms. Knowledge production and the R&D efforts that create new, economically useful knowledge are spatially clustered (Audretsch and Feldman, 1996; Moreno et al, 2005), and the more firms spend on R&D the more likely they will be located in a technology cluster. Data on R&D expenditures are sourced from the firm’s 10 K SEC annual reports or the COMPUSTAT database as all the firms in the dataset are public.

4. *Industry dummies* **-** dummy variables for 11 industries that have been defined using the three digit SIC (Standard Industry Classification) classification will be included. As indicated earlier, industries for which new economically useful knowledge is important have a tendency to cluster more in space than do industries where new

knowledge is less important (Audretsch and Feldman, 1996). The SIC codes are provided by the COMPUSTAT database and the firm's 10 K SEC annual report.

5. *Regional dummies* – dummy variables for four regions (CA = California; MA = Massachusetts; REST = all other states) as firms with higher levels of innovative prowess can be found primarily in areas with a tradition in high tech manufacturing.

Since the dependent variables are either continuous or count measures and provided that all the model identification conditions are satisfied the econometric models to be tested are:

For Hypothesis 1a & 1b:

E [CLQ | $X_{i,s}$] = f(Innov_Prowess, Employ, Age, R&D9802, Industry fixed effects, Regions)

An OLS specification will be used to test this hypothesized relationship.

The corresponding model to test Hypothesis 2 is:

P [# Research Universities | $X_{i,s}$] = f(Innov_Prowess, Employ, Age, R&D9802, Industry fixed effects, Regions)

which will be tested using a zero-truncated negative binomial specification (which makes the assumption that each MSA in the dataset is home to at least one research university). The hypothesized relationships are depicted in Fig 2.

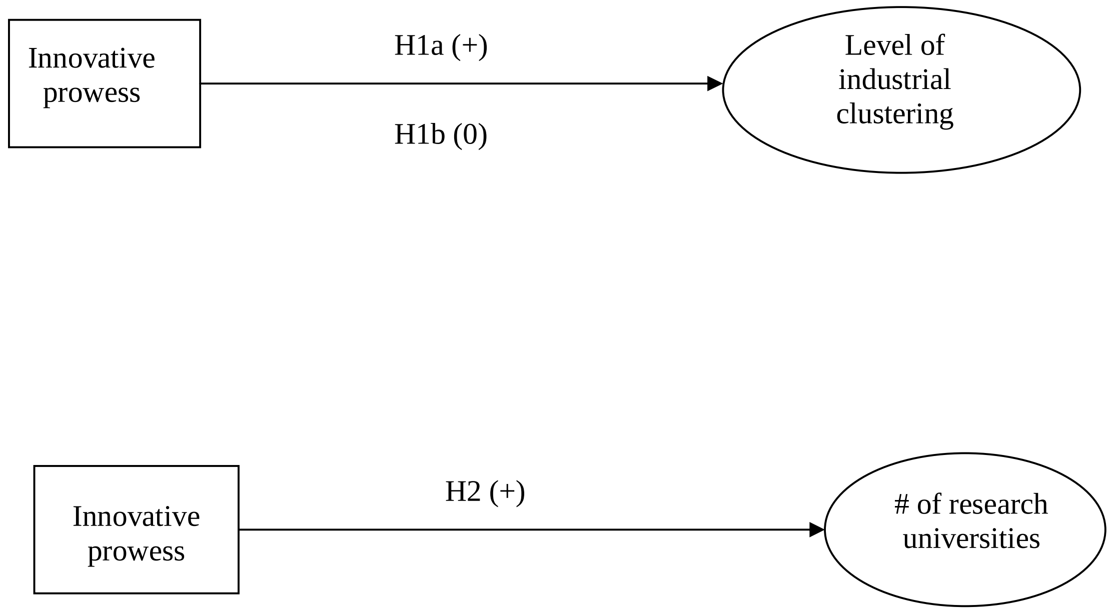


Fig 2. Innovative prowess and spatial outcome variables

Descriptive Statistics

Table 1 shows the descriptive statistics for the full sample (serial innovators plus non-serial innovators) while Table 2 provides descriptive statistics for the serial innovator population (firms with high innovative prowess) and non-serial innovator (firm with low innovative prowess) sample, respectively. The descriptive statistics shed light on some important characteristics and attributes of the total dataset and the subsets, one of which constitutes a population (the serial innovator firm subset).

Table1. Descriptive statistics – Total dataset

Variable	Obs	Mean	SD	Min	Max
Employees02	396	200.12	145.67	2	500
Patents9802	394	22.31	33.22	0	451
R&Dexpend9802	394	14.08	14.97	0.02	98.6
Age	396	16.27	11.27	4	117
Chemicals	396	0.01	0.10	0	1
Machinerymfg	396	0.01	0.12	0	1
Computermfg	396	0.06	0.24	0	1
Communicatequip	396	0.07	0.26	0	1
Semiconductor	396	0.13	0.33	0	1
Navigationinstrum	396	0.03	0.17	0	1
Surgicalandmedical	396	0.13	0.34	0	1
Electricalequipm	396	0.03	0.16	0	1
Transportation	396	0.01	0.10	0	1
Pharmaceutical	396	0.39	0.49	0	1
Software	396	0.06	0.24	0	1
Miscellaneous	396	0.04	0.21	0	1
Packaging	396	0.01	0.07	0	1
Number of patent ref.	396	20.4	26.10	0	312.4
Number of science ref.	396	11.41	20.71	0	148.25
Cluster location quot.	396	4.17	7.10	0	69.41
# R1 Univ	396	1.24	0.37	0	4
CA	396	0.39	0.23	0	1
MA	396	0.11	0.31	0	1

Table2. Descriptive statistics – Serial innovator and non-serial innovator firms

Variable	Obs	Mean SI	Obs	Mean Non-SI	Difference	Sig (two tail)
Employees2002	198	199.76	198	200.48	0.72	ns
Patents9802	198	39.54	198	4.89	34.65	***
R&Dexpend9802	197	17.11	197	11.06	6.05	***
Age	198	14.71	198	17.83	3.12	*
Chemicals	198	0.01	198	0.01	0	
Machinerymfg	198	0.01	198	0.01	0	
Computermfg	198	0.06	198	0.06	0	
Communicatequip	198	0.07	198	0.07	0	
Semiconductor	198	0.13	198	0.13	0	
Navigationinstrum	198	0.03	198	0.03	0	
Surgicalanmedical	198	0.13	198	0.13	0	
Electricalequip	198	0.03	198	0.03	0	
Transportation	198	0.01	198	0.01	0	
Pharmaceutical	198	0.39	198	0.39	0	
Software	198	0.06	198	0.06	0	
Miscellaneous	198	0.04	198	0.04	0	
Packaging	198	0.01	198	0.01	0	
# of patent references	198	25.91	198	14.88	11.3	***
# of science references	198	12.87	198	9.94	2.93	**
Cluster Location quot	198	4.799	198	3.54	1.25	**
# R1 Univ	198	1.62	198	1.12	0.50	**
CA	198	0.46	198	0.32	0.14	**
MA	198	0.10	198	0.12	0.02	ns

* 10%, ** 5%, *** 1%

In total, 396 analytically useful public firms are available for further analysis as can be seen from Table1. The average firm in the total dataset employs 200 people (Employees2002) over the five year period studied. Average R&D expenditures (R&Dexpend9802) are just over $14 million over the period of five years and the average firm is of adolescent age (16) and has had granted 22 patents in the period studied. Most firms in the dataset operate in just a handful of industries typically characterized as knowledge-intensive - Pharmaceutical (38.8 %), Surgical & Medical devices (13.2 %), Semiconductors (12.7 %) – with smaller representations of firms in both high technology and more traditional industries. Half of the firms are located in only two states, California (39%) and Massachusetts (11%). Table 2 indicates that there are significant differences between serial and non-serial innovator firms in terms patents (Patents9802), R&D expenditures (R&DExpend9802), Age. In addition, serial innovator firms have patents that have significantly more references to other patents (# of patent references) and the scientific literature (# of science references) than non-serial innovator firms. The state of California (CA) is also home to more serial innovator firms than non-serial innovators.

Table 3 provides a geographic summary of the location of serial and non-serial innovator firms. Serial innovator firms exhibit strong geographical concentration patterns with three US states (CA, MA, NY) playing host to almost 60 percent of all serial innovator firms. Their non-serial innovator industry counterparts appear slightly less concentrated in the same three states (53 per cent). Once again confirming previous studies (Audretsch and Feldman, 1996, Rosenbloom, 2007 and others) the pre-eminence of three states, California, Massachusetts, and New York in terms of innovation and innovative activities is reflected in both tables although more so in terms of concentration in the serial innovator firm dataset than in the non-serial innovator dataset. These states, especially CA and MA coincidentally house the nation's premier research universities as well as existing concentrations of high tech activity.

Table3. Geographic summary – by Firm Type

Metropolitan Statistical Area	SI firms	Non-SI firms
San Jose-Sunny Vale-Santa Clara, CA	46	24
San Francisco-Oakland-Fremont, CA	20	12
Boston-Cambridge-Quincy, MA	18	25
San Diego-Carlsbad-San Marcos, CA	14	11
New York-Northern New Jersey-Long Island, NY-NJ	13	19
Los Angeles-Long Beach-Santa Ana, CA	8	14
Minneapolis-St. Paul-Bloomington, MN	8	8
Philadelphia-Camden-Wilmington, PA-NJ-DE	6	5
Austin-Round Rock, TX	4	4
Seattle-Tacoma-Bellevue, WA	4	6
Salt Lake City, UT	4	0
Chicago-Naperville-Joliet, IL	4	4
New Haven-Milford, CT	3	3
Dallas-Forth Worth-Arlington, TX	3	5
Houston-Sugarland-Baytown, TX	3	1
Durham, NC	3	1
Bridgeport-Stamford-Norwalk, CT	3	1
Worcester, MA	3	0
Miami-Fort Lauderdale-Miami Beach, FL	2	5
Washington-Arlington-Alexandria, DC-VA	2	8

Las Vegas-Paradise, NV	2	1
Santa Barbara- Santa Maria, CA	2	0
Madison, WI	2	0
Fort Collins-Loveland, CO	2	0
Palm Bay Melbourne-Titusville, FL	1	1
Youngstown-Warren-Boardman, OH	1	0
Richmond, VA	1	0
Vallejo-Fairfield, CA	1	0
Orlando-Kissimmee, FL	1	2
Trenton-Ewing, PA-NJ	1	1
Atlanta-Sandy Springs-Marietta, GA	1	3
Santa Rosa-Petaluma, CA	1	0
Omaha-Council Bluffs, NE	1	0
Portland-Vancouver-Beaverton, OR	1	3
Boulder, CO	1	2
State College, PA	1	0
Albany-Schenectady-Troy, NY	1	2
Manchester-Nashua, NH	1	0
Colorado Springs, CO	1	0
Burlington, NC	1	0
Detroit-Warren-Livonia, MI	1	0
Rural	1	0
St Louis, MO	1	1
Phoenix-Mesa-Scottsdale	0	3
Denver-Aurora	0	3
Gainesville	0	3
Oxnard-Thousand Oaks-Ventura, CA	0	2
Grand Rapids-Wyoming, MI	0	1
Lansing-East Lansing, MI	0	1
Providence-New Bedford-Fall River, RI	0	1

Pittsfield, MA	0	1
Sacramento-Arden Arcade-Roseville, CA	0	1
Syracuse, NY	0	1
Chattanooga, TN	0	1
Hartford-West Hartford-East Hartford, CT	0	1
Tampa-St Petersburg-Clearwater, FL	0	1
San Antonio, TX	0	1
Cape Coral-Fort Myers, FL	0	1
Birmingham-Hoover, AL	0	1
Evansville, IN	0	1
Hudson, NY	0	1
Total	198	198

Significant differences can be noted in the rate of patenting across industries and between the population of serial innovators and the corresponding sample of non- serial innovator firms as could have been expected based on our selection procedure for firms (see Table 4). Not surprisingly, since this was an important sample selection criterion, serial innovator firms patent at much higher rates than an average firm in the full dataset. Noteworthy is that the Electrical Equipment industry is the most patent-intensive industry closely followed by the Navigation & Detection industry and at a larger distant the Pharmaceutical industry, at least in the serial innovator population.

It is a surprising pattern, all the more since the Electrical Equipment and Navigation & Detection industries do not receive the same amount of academic examination as the more well-known and heavily researched Semiconductor, Pharmaceutical & Biotechnology and IT (Computer & Electronic Manufacturing, Software Services, and Communications Equipment) industries. In the non-serial innovator sample we observe a pattern that holds fewer surprises with the most active patentees in the Communications Equipment, Semiconductor, Navigation & Detection, and Computer & Electronic product manufacturing, closely followed by the Pharmaceutical industry. Across all industries we note significant differences (at least at the 5 % confidence level) in the number of patents (in favor of the serial innovator firms) often approaching or exceeding an order of magnitude.

The patterns we observe in patent behavior are closely tracked by the average R&D expenditures over the five years studied where the Pharmaceutical and Biotechnology industry is the most research-intensive (on average $24 million in R&D expenditures in the period 1998 to 2002) in the serial innovator firm population, followed by the Electrical Equipment industry and with the Semiconductor and Navigation & Detection industries trailing in third and fourth place (see Table 4). R&D expenditures for all industries have increased over the five-year period examined, except in the Communications Equipment industry that went into a deep crisis after the bursting of the Internet bubble in late 2000 and 2001 and the subsequent negative impact on the telecommunications industry. An interesting finding from Table 4 is that R&D expenditures in the Computer & Electronic Product manufacturing, the Communications Equipment, the Semiconductor, the Navigation & Detection, and the Surgical & Medical devices industry do not differ significantly between serial and non-serial innovator firms, suggesting higher efficiencies or at least propensities among serial innovator firms in those industries to patent relative to their non-serial innovator firm peers. This raises an interesting question that warrants closer examination in future research.

Table4. Differences of means of patents and R&D expenditures

Variable	Mean (SI)	Mean (Non SI)	Industry	Sign (2-tailed test)
Patents9802	31.07	4.87	Computer & Electronic	***
	34.66	7.50	Communications Equip	***
	38.80	5.95	Semiconductor	***
	54.60	5.66	Navigation detection	**
	28.26	4.42	Surgical and Medical	***
	58.80	4.50	Electrical Equipm	***
	43.74	4.62	Pharmaceutical	***
	39.58	2.08	Software & Services	***
R&DExp9802	13.02	10.23	Computer & Electronic	n.s.
	12.00	15.29	Communications Equip	n.s.
	15.16	14.21	Semiconductor	n.s.
	15.04	10.41	Navigation detection	n.s.
	7.97	6.40	Surgical and Medical	n.s.
	22.61	4.09	Electrical Equipm	***
	24.03	14.03	Pharmaceutical	***
	12.03	5.31	Software & Services	***

** significant at 5%; *** significant at 1%; n.s. not significant

Table 5 depicts a means test of the Cluster Location Quotient in order to see how different the population of serial innovator firms is from the sample of non-serial innovator firms along that dimension. From this simple statistical test, one can observe that overall, serial innovator firms are located in MSA areas with significantly higher values for the location quotient ($p<0.05$) than non-serial innovator firms. The average serial innovator firm is located in an MSA with a cluster location quotient of 4.79 whereas the non-serial innovator firm is located in an MSA with a cluster location quotient of 3.54, substantially lower. It is fair to conclude that serial innovator firms are located in agglomerations with *stronger regional specialization* than their non-serial innovator firm counterparts.

Table5. Means-Test-Cluster Location Quotient differences by Innov_Prowess

Variable	Mean (SI)	Mean (Non SI)	Industry	Sign (2-tailed)
Cluster Location Quotient				
	4.79	3.54	All	**
	13.66	8.99	Semiconductor	*
	2.87	2.05	Pharmaceutical	**
	2.79	0.79	Navigation	**
	4.08	4.65	Computer Mfg	ns
	3.64	3.87	Communications Equipment	ns
	2.89	3.75	Surgical and Medical Dev	ns
	6.58	3.74	Electrical Equipment	ns
	6.23	4.71	Software Services	ns

* significant at 1%, ** significant at 5%, n.s. not significant

The pattern of agglomeration is particularly strong in the Semiconductor, Pharmaceutical and Biotechnology, and Navigation and Detection industries. For instance, the average serial innovator firm in the Semiconductor industry is located in an

MSA with a cluster location quotient of 13.66 in that industry versus the average non-serial innovator firm which is located in an MSA with a cluster location quotient of 8.99. Again, both types of firms appear to be located in areas with strong regional specialization in semiconductor technology but the serial innovator firms happen to be located in the ‘stronger’ cluster. Only in the case of serial innovator firms in the Navigation, Detection & Instrumentation sector, one can confidently state that the average serial innovator firm is located in a technology cluster whereas an average non-serial innovator firm in that industry is located outside a technology cluster (using the conceptual cut-off value of 1 used to define a location quotient).

In the other industries no statistically significant differences in MSA cluster location quotients can be observed between serial and non-serial innovator firms. However, Table 5 indicates that firms in these industries are all located in MSAs with certain levels of regional specialization and that average firms in the Electrical Equipment and Software Services industries appear to be located in rather strong technology clusters.

The bivariate correlation matrix is depicted in Table 6 and the largest correlation coefficient that is statistically significant is .42 ($p<0.05$) between R&Dexpend9802 and Employees9802, and hence there is no cause for concern for multi-collinearity problems. This is further confirmed by an analysis of the variance inflation factors (VIF), where no individual variance inflation factor is larger than 10 and the mean of the VIF factors is not considerably larger than 1, two rules of thumb used for evaluating multi-collinearity problems (Chatterjee et al, 2006).

Table 6. Bivariate Correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12
1. Innov_Prowess												
2. Employees9802	-0.00											
3. Age	-0.14*	0.22*										
4. R&Dexpend9802	0.20*	0.42*	-0.17*									
5. Computermfg	0.08	0.03	0.03	-0.03								
6. Communicatequip	0.01	0.08	0.07	-0.01	-0.07							
7. Semiconductor	0.02	0.06	-0.06	0.01	-0.10	-0.11*						
8. Navigationinstrum	-0.03	0.13*	0.17*	-0.02	-0.04	-0.05	-0.07					
9. Surgicalandmedical	-0.04	-0.06	-0.06	-0.18*	-0.10*	-0.11*	-0.15*	-0.07				
10. Electricalequip	-0.01	0.05	0.01	-0.03	-0.04	-0.05	-0.06	-0.03	-0.06			
11. Pharmaceutical	0.02	-0.19*	-0.18*	0.27*	-0.20*	-0.22*	-0.30*	-0.14*	-0.31*	-0.13*		
12. Software	-0.00	0.02	-0.01	-0.09	-0.06	-0.07	-0.10	-0.04	-0.10*	-0.04	-0.20*	
13. Miscellaneous	-0.02	0.16*	0.24*	-0.12*	-0.05	-0.06	-0.08	-0.04	-0.08	-0.04	-0.17*	0.05

* significant at 5%

Analysis and Results

Hypothesis test for firm location

To verify whether small technology-based with high levels of innovative prowess are located in MSA with higher levels of industrial agglomeration three distinct regression models are tested. The first model (OLS) in Table 7 is the fully specified model and includes all the industry fixed effects. The focal dummy variable (Innov_Prowess) is insignificant suggesting that there is no statistically significant relationship between the level of innovative prowess and industry clustering, disconfirming Hypothesis 1a.

The key explanatory variable 'Innov_Prowess' however, may be endogenous and both this variable and the dependent variable may be determined simultaneously by other variables that are now incorporated in the regression error term[13]. To address the endogeneity problem, two instrumental variables were identified and tested and a two-stage least squares regression procedure was applied to verify the correct impact of the explanatory variable of interest[14].

A side-by-side comparison of the original OLS regression analysis with the full two-stage least squares (2SLS[#]) regression results using the original matched sample is

[13] A residual analysis revealed that there is a discernible pattern between our key explanatory variable and the residuals (and by extension the error term), an indication that the relationship between Innov_Prowess and the dependent variable may be endogenous

[14] two instrumental variables used to address the potential endogenous nature of the key explanatory variable are: (1) Managers, professionals and technicians in the MSA as a share of the total workforce in 2002, and (2) the proportion of university degrees in Science and Engineering in the MSA as a share of the total number of degrees awarded in the MSA in 2002.

Table7. Determinants of serial innovator firm location using OLS and 2SLS (stage 2)

DV = Cluster Location Quotient	OLS	2SLS#	2SLS+
Innov_Prowess	0.631	0.321	0.148
	(1.15)	(0.25)	(0.18)
Employees 2002	0.003	0.003	0.001
	(1.52)	(1.39)	(0.37)
Age	-0.049	-0.042	-0.039
	(1.79)†	(1.81)†	(0.97)
R&D Expend 9802	0.011	0.013	0.057
	(0.23)	(0.52)	(1.24)
Computer and Electronic Product Manuf	1.421	1.472	0.873
	(1.29)	(0.53)	(0.57)
Communications Equipment Manufacturing	0.893	0.813	0.281
	(0.98)	(0.81)	(0.19)
Semiconductor and related Electronics	8.330	8.291	6.140
	(3.71)**	(3.27)**	(3.42)**
Navigational, detection, measuring, control	-1.050	-1.112	-0.740
	(1.64)	(1.61)	(0.38)
Surgical and medical devices and equipment	0.692	0.612	0.724
	(0.93)	(0.78)	(0.53)
Electrical Equipment, Appliances, compon	2.231	2.112	0.741
	(0.83)	(1.34)	(0.37)
Pharmaceuticals and Biotechnology, Diagn	-0.281	-0.437	-0.524
	(0.63)	(0.94)	(0.54)
Software and Services	2.591	2.314	1.044
	(2.52)*	(2.83)*	(0.83)
CA	1.632	1.531	1.327
	(1.73)†	(1.79)†	(1.87)†
MA	1.293	1.104	1.394
	(1.04)	(1.26)	(1.35)
Constant	2.121	2.342	2.548
	(2.51)*	(2.38)*	(2.14)*
Observations	383	378	378
R^2	0.19	Cent R^2 0.197	0.142
F	5.26**	4.67**	4.32**

t statistics in parentheses.† sig.10%; * sig.5%; ** sign.1%; # sample 1, + sample 2 depicted in Table 7. The results of the two-stage least square regression analysis are consistent in terms of the sign and significance of parameter estimates with the OLS results. The coefficient on the parameter of interest Innov_Prowess is about half the size compared to the one in the OLS specification and is not significant, suggesting support for Hypothesis 1b. To further test the robustness of this result, another matched sample was created using the same procedure as was used to create the first matched sample. The results are depicted in the third model in Table 7, confirming the results found earlier.

Robustness Checks

To verify whether the results are not biased by the high amount of small firms located in three prominent technopoles in the US, another dataset was developed from which (serial and non-serial innovator) firms in the original dataset that are located in the San Francisco Bay area, the Boston are, and the Research Triangle Park region were removed. The regression model yields very similar results as those above, indicating that these three regions do not distort the outcome of the previous analysis.

Separate two-stage least squares regression models were developed for the Pharmaceutical & Biotechnology industry[15]. The results are depicted in Table 8 and show that the parameter estimate of interest, Innov_Prowess, is significant ($p<0.05$) providing support for Hypothesis 1a. The result is robust across the second matched sample as well. A similar analysis for the IT hardware industry (Computer and Electronic Manufacturing,

[15] Two instrumental variables were identified to address the potential endogenous nature of the locational preference of Pharmaceutical & Biotechnology firms. The first instrumental variable is the amount of academic R&D funding in the MSA in 2002 and the second instrument represents the proportion of degrees in the Sciences and Engineering in the MSA out of the total number of university degrees granted in the MSA in 2002

Communications Equipment, Semiconductor, and Navigational & Detection industries)[16] is depicted in Table 9. The results reveal that firms with higher levels of innovative prowess are located in MSAs with higher average levels of industrial specialization.

Table8. Determinants of locating in a biotechnology cluster (stage 2)

	Sample 1	Sample 2
Innov_Prowess	3.213	2.177
	(2.39)*	(1.93)†
Employees 9802	0.007	0.004
	(3.32)**	(1.82)
R&D Expend 9802	-0.034	-0.037
	(1.83)†	(1.37)
Age	-0.027	-0.005
	(0.82)	(0.19)
CA	2.345	2.187
	(1.98)*	(2.35)*
MA	1.637	1.751
	(2.24)*	(2.03)*
Constant	0.651	1.748
	(1.64)	(2.13)*
$F(4, 145)$	5.31**	4.34**
Uncentered R^2	0.487	0.448
Observations	147	149

Absolute value of t statistics in parentheses, Hansen J Statistic (over-identification test of all instruments): 0.012 Chi-sq (1) P-val = 0.91116; Hansen J statistic: 0.003 Chi-sq(1) P-val = 0.9539; † significant at 10%; * significant at 5%; ** significant at 1%

[16] The two instruments used for this analysis are the number of patents per 1000 inhabitants and the level of support for academic R&D

Table9. Determinants of locating in IT hardware clusters

	Sample 1	Sample 2
Innov_Prowess	8.467	6.239
	(1.84)†	(2.31)*
Employees 9802	0.007	-0.001
	(0.79)	(0.32)
R&D Expend 9802	0.052	0.142
	(0.52)	(0.82)
Age	-0.37	-0.088
	(1.45)	(1.74)†
CA	2.872	3.428
	(2.51)*	(2.43)*
MA	1.482	2.327
	(2.33)*	(2.04)*
Constant	2.831	2.314
	(0.74)	(0.93)
F(4, 145)	3.94**	3.14**
Centered R^2	0.110	0.127
Uncentered R^2	0.243	0.356
Observations	104	107

Absolute value of t statistics in parentheses, Hansen J Statistic (over-identification test of all instruments): 0.012 Chi-sq (1) P-val = 0.91116; Hansen J statistic: 0.081 Chi-sq(1) P-val = 0.7755; † significant at 10%; * significant at 5%; ** significant at 1%

Hypothesis Test for # of Research Universities

To test the second proposition of this essay – that firms with high levels of innovative prowess are more likely to be located in MSAs with a higher number of research universities, a number of count regression models were developed . The parameter coefficients are reported as incidence rate ratios (IRR) for ease of interpretation[17].

Table10. Determinants of spatial proximity to a research university

	# R-1 Univ	# R-1 Univ ^
Innov_Prowess	1.121	1.104
	(2.14)**	(1.84)*
Employ	0.957	0.984
	(1.47)	(1.95)*
Age	0.997	1.002
	(0.79)	(1.64)
R&D9802	1.009	1.006
	(2.44)**	(3.03)**
Computer Mfg	1.121	1.433
	(0.63)	(1.61)
Communication Equip	1.162	1.314
	(0.79)	(1.58)
Semiconductor	1.321	1.302
	(1.52)	(1.53)
Navigation	0.924	1.313
	(0.20)	(1.15)
Surgical Dev	1.251	1.370
	(1.72)*	(1.69)*
Electrical Equip	1.214	1.523
	(0.98)	(1.74)*
Pharmaceutical	1.141	1.362
	(1.93)*	(1.74)*
Software and Services	1.043	1.170
	(0.12)	(0.74)
CA	1.173	1.232
	(2.33)**	(1.99)**
MA	1.423	1.581
	(2.08)**	(2.13)**
Pseudo R squared	0.025	0.034
Obs	368	367

t statistics in parentheses * p<0.10, ** p<0.05, *** p<0.01; the two models report incidence rate ratios (IRR); ^ second sample of non-serial innovators

[17] A zero-truncated negative binomial was selected under the assumption that the data is truncated at zero and that over-dispersion will be observed in the dataset.

The first model in Table 10 shows that the variable of interest, Innov_Prowess is positive and significant ($p<0.05$) confirming Hypothesis 2. Firms with a high level of innovative prowess (serial innovators) are located in MSAs with 12.1 % more research-intensive universities than for firms with much lower levels of innovative prowess (non-serial innovators). Firms in the pharmaceutical and surgical device sectors in particular are located in MSA's with significantly more research universities vis-à-vis firms in the miscellaneous sector (the reference category), 14.1 % and 25.1 % respectively. Using a second matched sample we observe a weaker relationship ($p<0.10$) as indicated by the second model in Table 10. The explanatory power of both models is weak although the models overall are statistically significant ($p<0.01$).

Robustness Checks

Two additional analyses have been performed for the life sciences and the IT hardware industries as illustrated in Tables 11 and 12, respectively. The first model in Table 11 using the original matched sample suggests that the level of innovative prowess of life science firms is indeed related to the number of research-intensive universities in the focal firm's MSA ($p<0.10$). Life science firms with high levels of innovative prowess – serial innovator firms – are located in MSA areas with on average 6.4 % more research universities than less innovative biotech firms. The same analysis using the second sample reveals no such relationship between the level of innovative prowess and the number of research universities in the MSA, as shown by the second model in Table 11. A similar analysis was performed for firms operating in the IT hardware sector (semiconductor, communications equipment, computer & electronic product mfg, and the navigational, detection & instrumentation industries). The results reveal strong support

Table11. Determinants of spatial proximity to research universities for life science firms

	# R-1 Univ	# R-1 Univ ^
Innov_Prowess	1.064	1.039
	(1.71)*	(1.60)
Employ	.9984	.9999
	(2.23)**	(1.73)*
Age	.9920	.9923
	(0.52)	(0.58)
R&D9802	1.005	1.006
	(2.31)**	(1.97)**
CA	1.323	1.287
	(1.84)*	(1.92)*
MA	1.442	1.394
	(2.11)**	(2.34)**
Pseudo R squared	0.016	0.011
Obs	147	147

t statistics in parentheses * p<0.10, ** p<0.05, *** p<0.01; ^ second sample of non-serial innovators; both models report incidence rate ratios (IRR)

for Hypothesis 2 (see Table 12). The first model using the first matched sample indicates that IT hardware firms with high levels of innovative prowess reside in MSAs with on average 23.1 % (p<0.05) more research universities than their IT hardware peers with much lower levels of innovative prowess.

The second model that used the second matched sample yields a similar though statistically weaker result (p<0.10). Using a negative binomial regression model specification that does not make the assumption that each MSA should have at least one research university, yielded very similar results.

Table12. Determinants of spatial proximity to research universities for IT hardware firms

	# R-1 Univ	# R-1 Univ ^
Innov_Prowess	1.231	1.184
	(2.10)**	(1.74)*
Employ	1.003	.9985
	(0.25)	(0.69)
Age	.9932	1.006
	(1.37)	(1.72)*
R&D9802	1.004	1.005
	(0.65)	(0.89)
CA	1.173	1.148
	(1.84)*	(2.11)**
MA	1.203	1.188
	(2.13)**	(2.32)**
Pseudo R squared	0.043	0.026
Obs	104	107

t statistics in parentheses * p<0.10, ** p<0.05, *** p<0.01; ^ second sample of non-serial innovators; both models report incidence rate ratios (IRR)

Discussion of the results

The first part of this essay sought to examine whether a statistically significant relationship can be observed between the level of a firm's innovative prowess and the degree of industrial clustering in the focal firm's MSA. The results appear to indicate that as a whole, firms with high levels of innovative prowess do not seem to be located in MSAs with higher levels of industrial clustering than firms with much lower levels of innovative prowess. This seems to suggest that innovative prowess is not a discriminating factor in the way firms decide to locate in industrial agglomerations to benefit from both pecuniary and spillover advantages offering support for Hypothesis 1b. Firms operating in the Semiconductor and Software & Services industries also appear to be located in

MSAs with significantly higher levels of industrial agglomeration as do firms located in the state of California (see Table 7).

However, distinct differences can be observed when one looks at individual industries or a group of related industries. Focusing on the pharmaceutical and biotechnology sector alone, one can observe that biotechnology firms with higher levels of innovative prowess are indeed located in MSAs with higher average levels of specialization in biotechnology across two matched samples. Pharmaceutical and biotechnology firms in CA and MA are also located in MSAs with significantly higher levels of industrial agglomeration than those in the rest of the country. There is weaker evidence that the same is true for firms in the IT hardware sector. These two industry-level analyses appear to support Hypothesis 1a. Heterogeneity in terms of innovative prowess is associated with different needs for both knowledge spillovers and pecuniary advantages and the need to locate in a strong industrial cluster at least in these two important high tech industries. Firms with higher levels of innovative prowess are knowledge spillover-seeking entities that need to keep in very close contact with and remain attuned to the needs of customers who are often co-located in industrial clusters. In doing so, these firms will significantly reduce technological and market uncertainties and will improve their chances for competitive survival.

The second part of this essay sought to elucidate the proximity of firms with differential levels of innovative prowess to the scientific establishment in their locale. The hypothesis that firms with higher levels of innovative prowess - a capability built in part through the reliance on scientific knowledge - are located in closer spatial proximity to research universities than firms with much lower levels of innovative prowess was confirmed across two matched samples. The results indicate that firms with high levels of innovative prowess are consistently located in MSAs with a higher number of research universities than firms with much lower levels of innovative prowess. Innovative prowess - a key feature of serial innovator firms – is in part developed through cross boundary learning with entities doing mostly exploratory research i.e. universities. Since a lot of scientific knowledge is incipient and tacit, locating in areas with a larger number of research universities facilitates the transfer and cross-boundary learning by the innovative firm. Noteworthy is the fact that firms in the states of CA and MA are located in MSAs with a significantly higher number of research universities than those in the rest of the country. This can possibly be ascribed to the Silicon Valley (treated here as a Combined Metropolitan Statistical area) and Boston areas that house a disproportionate number of serial innovator firms and are home to a significant number of research universities.

Further analysis at the industry level confirms this principal finding. In the life sciences industry (Pharmaceutical & biotechnology, and surgical & medical device sector) a weak relationship between innovative prowess of life science firms and the number of research universities in the MSAs could be observed. However, such a relationship did not hold up in the second matched sample. One explanation for that is that more than 60 matches in the sample were 'flawed' in the sense that the non-serial innovator firm was an indirect competitor with a very different technology and market focus than the focal serial innovator. This may have distorted the results. Across both samples one observes that firms in CA and MA are located in MSAs with significantly more research universities than firms located in the rest of the country.

A second industry-level analysis, in this case the IT hardware sector (a collection of four 3-digit SIC level industries) confirmed the main finding that IT hardware firms with higher levels of innovative prowess are more likely to be located in MSAs with more research universities than IT firms with much lower levels of innovative prowess. Using a negative binomial regression specification instead of a zero-truncated model yielded very similar results across the board.

Conclusion

This essay empirically demonstrated that the concept of innovative prowess – firm-specific technological capabilities that enables small firms to sustain their innovative edge – is useful in delineating the spatial preferences of small, technology-based firms across a range of industrial sectors. Firms in two important industries, the pharmaceutical & biotechnology and the IT hardware industries behave differently in their location preferences vis-à-vis their location in MSA with higher levels of specialization. More specifically, firms with high levels of innovative prowess are on average located in MSAs with stronger technical specializations than firms with much lower levels of innovative prowess.

The innovative prowess of serial innovator firms has been built and maintained in part by locating in areas with high levels of industrial clustering. The empirical results suggest that beyond benefiting from pecuniary advantages, firms with higher levels of innovative prowess appear to seek knowledge spillovers from their immediate environment. Firms with high levels of innovative prowess also appear to be located in MSAs with more research universities suggesting that firms with very advanced technological capabilities that sustain cutting-edge innovative activities enhance their organizational and technological learning by locating in areas with a larger number of research-intensive universities. In other words, firms with higher levels of innovative prowess built and maintain this capability by locating near research universities to both benefit from pecuniary and knowledge spillover advantages.

The theoretical framework presented in this essay revolves around the central concept of knowledge spillovers and heterogeneities in both the sources of spillovers and abilities of small firms to take advantage of knowledge spillovers. The framework was empirically validated in full for small, highly innovative firms with high levels of innovative prowess in the pharmaceutical & biotechnology and IT hardware industries. The framework explains an asymmetric need and use for spillovers that originate from heterogeneous institutional sources by firms with differing levels of innovative prowess. However, for firms in other industries the framework was only partially validated in the sense that firms with high levels of innovative prowess operating in those industries appear to have a higher need for knowledge spilling over from research universities than firms with low levels of innovative prowess. The explanatory power of the theoretical framework is robust at least so for firms in the pharmaceutical and IT hardware sectors but empirical results indicate that the framework may not be universal across all industrial sectors, and that other contingent factors may apply.

Future research efforts should examine other aspects of the innovative prowess construct and tie it to e.g. firm performance variables other than the ones discussed in this dissertation, such as survival or profitability. In terms of limitations one can argue that the dichotomization between firms with high and low levels of innovative prowess will lead to a loss of information in the data.

REFERENCES

Adams, J., and Jaffe, AB 1996. 'Bounding the effects of R&D: An investigation using matched establishment-firm data'. *Rand Journal of Economics*, 27(4), pp. 700-721

Alcacer, J., and Chung, W. 2007. 'Location strategies and knowledge spillovers' *Management Science,* 53(5), pp. 760-776

Aldrich, H.E. and Auster, E.R. 1986. 'Even dwarfs started small: Liabilities of size and age and their strategic implications.' In B.M. Staw and L.L. Cummings (eds.), *Research in Organizational Behavior* 8: 165-198. Greenwich, CT: JAI Press.

Anselin, L., Varga, A., and Acs, Z. 1997. 'Local geographical spillovers between university research and high technology innovations' *Journal of Urban Economics,* 42, pp. 422-448

Arora A., Fosfuri A. 2003 'Licensing the Markets for Technology' *Journal of Economic Behaviour and Organization*, 52, pp. 277-295.

Arora A., Fosfuri A., Gambardella A. 2001 *Markets for Technology: The Economics of Innovation and Corporate Strategy*, The MIT Press, Cambridge MA

Arora A., Merges, R. 2004. 'Specialized supply firms, property rights, and firm boundaries' *Industrial and Corporate Change*, 13(3), pp. 451-475

Arthur, W. 1990. 'Silicon Valley locational clusters: when do increasing returns imply monopoly' *Mathematical Social Sciences*, 19, pp. 235-273

Asheim, B., Isaksen, A., Nauwelaers, C. and F. Tötdling 2003. *Regional Innovation Policy for Small and Medium Enterprises*, Cheltenham, UK and Lyme, US: Edward Elgar

Audretsch, D.B., and Feldman, M.P. 1996. 'R&D spillovers and the geography of innovation and production' *American Economic Review*, 86(3), pp. 630-640

Audretsch, D.B., Keilbach, M. 2004. 'Does entrepreneurship matter?' *Entrepreneurship Theory & Practice*, 28, pp. 419-430

Audretsch D, Lehmann E, Warning S. 2005. 'University spillovers and new firm location' *Research Policy* 34 (7), pp. 1113-1122

Baum, J.A.C., Li, S.X., and Usher, J.M. 2000. 'Making the next move: How experiential and vicarious learning shape the locations of chains' acquisitions' *Administrative Science Quarterly* 45, pp. 766-801.

Bergman, E.M., and Feser, E.J. 2002. *Industrial and regional clusters: Concepts and comparative applications.* The Web book of Regional Science, Regional Research Institute, West Virginia University.

Beaudry, C., and Breschi, S. 2003. 'Are firms in clusters really more innovative' *Economics of Innovation and New Technology*, 12(4), pp. 325-342

Beaudry, C., and Swann, P. 2001. 'Growth in Industrial clusters: A Bird's eye view of the United Kingdom' *Working Paper*, Stanford Institute for Economic Policy Research, Stanford, CA

Bercovitz, JL., and Feldman, MP. 2007. 'Fishing upstream: Firm innovation strategy and university research alliances' *Research Policy*, 36, pp. 930-948

Blumenthal, D., Causino, N., Campbell, E. 1997. 'Academic-industry research relationships in genetics: a field apart' *Nature Genetics* 16, pp. 104–108.

Blumenthal, D.E., Causino, Campbell N., Louis, K., 1996. 'Participation of life science faculty in research relationships with industry' *New England Journal of Medicine* 335, pp. 1735–1739.

Brown, J.S., P. Duguid. 2000. Mysteries of the region: Knowledge dynamics in Silicon Valley. In C. Lee, W.G. Miller, M.G. Hancock and H.S. Rowen (Eds.), *The Silicon Valley Edge: A Habitat for Innovation and Entrepreneurship,* pgs. 16-39. Stanford, CA: Stanford University Press.

Campi, M., Blasco, A., and Marsal, E. 2004. ‘The location of new firms and the life cycle of industries’ *Small Business Economics*, 22(3-4), pp. 265-281

Carod, J.M. 2005. ‘Determinants of industrial location: An application for Catalan municipalities’ *Papers in Regional Science*, 84(1), pp. 105-119

Chatterjee, S., and Hadi, A.S. 2006. *Regression Analysis by Example* (Fourth Edition). New York: Wiley

Chen, M.J. and Hambrick, D. 1995. ‘Speed, stealth and selective attack: How small firms differ from large firms in competitive behavior.’ *Academy of Management Journal* 38, pp. 453-482.

Cohen, W., and Levinthal, D. 1990. ‘Absorptive capacity: A new perspective on learning and innovation’ *Administrative Science Quarterly*, 35(1), pp. 128-153

Cohen, W., Nelson, R., and Walsh, J. 2002. ‘Links and impacts: The influence of public research on industrial R&D’ *Management Science*, 48(1), pp. 1-23

Cooke, P. 1992. ‘Regional innovation systems: Competitive regulation in New Europe’ *Geoforum*, 23(3), pp.365-382

Cooke, P. 2001 ‘Regional innovation systems, clusters, and the knowledge economy’*Industrial and Corporate Change*, 10 (4), pp. 945-974.

Cyert, R.M., March, J.G., 1963. *A Behavioral Theory of the Firm*, 2nd ed. Blackwell Publishers, Malden, MA.

Davis, G. F. and Greve, H. R. 1997. ‘Corporate elite networks and governance changes in the 1980s’ *American Journal of Sociology* 103, pp. 1-37.

Dierckx, I and Cool, K. 1989. ‘Asset stock accumulation and sustainability of competitive advantage’ *Management Science*, 35, pp. 1504-1513

Dussauge, P., Garrette, B., Mitchell,W., 2000. ‘Learning from competing partners: outcomes and durations of scale and link alliances in Europe, North America and Asia' *Strategic Management Journal*, 21 (2), pp. 99–126.

Evenson, R. 1993. 'Patents, R&D, and Invention potential: International Evidence' *American Economic Review*, 83(2), pp. 463-468

Feser, E.J. 1998. Old and new theories of industry clusters, in Steiner, M. (ed) *Clusters and Regional Specialization*, pp. 18-40. Pion, London

Feser, E.J., and Bergman, E.M. 2000. 'National industry cluster templates: A framework for regional applied cluster analysis' *Regional Studies*, 34(1), pp. 1-19

Fingleton, B., Igliori, D. and Moore, B. 2002. 'Employment growth of small computing service firms and the role of horizontal clusters: evidence from Great Britain 1991-2000' *Paper presented at the Regional Science Association*, Brighton, UK

Flyer, F., and Shaver, J.M. 2003. 'Location choices under agglomeration economies and strategic interaction' in Baum, J., and Greve, H. (eds) *Geography and Strategy: Advances in Strategic Management*, 20, pp. 175-195

Furman J. 2003. 'Location and organizing strategy: Exploring the influence of location on the organization of pharmaceutical research' *Advances in Strategic Management: A Research Annual*. 20, pp. 49-87

Geuna, A., 1999. *The economics of knowledge production: funding and the structure of university research*. Edward Elgar, Northampton, MA.

Gittelman M. 2007. 'Does geography matter for science-based firms? Epistemic communities and the geography of research and patenting in biotechnology' *Organization Science,* 18 (4), pp. 724-741

Goldfarb, B. 2005. 'Diffusion of general-purpose technologies: understanding patterns of electrification of US manufacturing 1880-1930'*Industrial and Corporate Change*, 14(5), pp. 745-773

Hall B.H., Ziedonis R.H. 2001 'The patent paradox revisited: an empirical study of patenting in the U.S. semiconductor industry, 1979-1995', *RAND Journal of Economics*, 32, pp. 101-128.

Hannan, M.T. and Freeman, J. 1977. 'The population ecology of organizations' *American Journal of Sociology*, 82, pp. 929-964.

Harhoff, D. 2000. 'R&D spillovers, technological proximity, and productivity growth – evidence from German panel data' *Schmalensee Business Review*, 52, pp. 238-259

Harrison, B. 2007. 'Industrial districts: old wine in new bottles' *Regional Studies*, 41, pp. 107-121.

Haveman, H.A. 1993. 'Organizational size and change: Diversification in the savings and loan industry after deregulation' *Administrative Science Quarterly*, 38, pp. 20-50

Hicks, D. 2002. *Serial Innovators: The Small Firm Contribution to Technical Change*. Report prepared for the US Small Business Administration under contract number SBAHQ-01-C-0149

Hicks, D., and Hegde, D. 2005. 'Highly innovative small firms in the markets for technology' *Research Policy*, 34, pp. 703-716

Isaksen, A. 1996. 'Towards increased regional specialization? The quantitative importance of new industrial spaces in Norway 1970-1990' *Norsk Geografisk Tidskrift*, 50, pp. 113-123

Isaksen, A. 2004. 'Knowledge-based clusters and urban location: the clustering of software consultancy in Oslo' *Urban Studies*, 41(5-6), pp. 1157-1174

Jaffe, A.B. 1989. 'Real effects of academic research' *American Economic Review*, 79(5), pp. 957-970

Jaffe, A.B., M. Trajtenberg, M., R. Henderson. 1993. ‘Geographic localization of knowledge spillovers as evidenced by patent citations’ *Quarterly Journal of Economics*, 63, pp. 577-598.

Jaffe, AB and Trajtenberg, M. 2002. *Patents, Citations, and Innovations: A Window on the Knowledge Economy*. MIT Press, Cambridge, MA

Kogut, B., 1988. ‘Joint ventures: theoretical and empirical perspectives’ *Strategic Management Journal,* 10, pp. 319–332.

Lane, P.J., Lubatkin, M., 1998. ‘Relative absorptive capacity and interorganizational learning’ *Strategic Management Journal* 19 (5), pp. 461–477.

Leahy, D., and Neary, J. 2007. ‘Absorptive capacity, R&D spillovers, and public policy’ *International Journal of Industrial Organization*, 25(5), pp. 1089-1118

Leonard-Barton, D., 1995. *Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation.* Harvard Business School Press, Boston, MA.

Levinthal, D., March, J., 1993. ‘The myopia of learning’ *Strategic Management Journal* 14, pp. 95–112.

Libaers, D., Hicks, D. and Porter, A.L. 2007. ‘A taxonomy of small firm technology commercialization’ *Working Paper*, School of Public Policy, Georgia Tech

Lundvall, BA., 1992 *National Systems of Innovation – Towards a Theory of Innovation and Interactive Learning*. Pinter Publishers, London

Malmberg, A., and Maskell, P. 2002. ‘The elusive concept of localization economies: towards a knowledge-based theory of spatial clustering’ *Environment and Planning A*, 34(3), pp. 429 – 449

Mansfield, E. 1986. ‘Patents and innovation – An empirical study’ *Management Science*, 32 (2), pp.173-181

Mansfield, E. 1986. 'Academic research and industrial innovation: An update of empirical findings' *Research Policy*, 26, pp. 773-776

March, J., 1991. Exploration and exploitation in organizational learning. *Organization Science* 2 (1), pp. 71–87.

Marshall, A. 1920. *The Principles of Economics*. London: McMillan

Martin, R., and Sunly, P. 2003. 'Deconstructing clusters: chaotic concept or policy panacea' *Journal of Economic Geography*, 3, pp. 5-35

Maskell, P. and A. Malmberg 1999. 'Localized Learning and industrial Competitiveness' *Cambridge Journal of Economics*, 23(2), pp 167-185.

McKendrick D. 2001. 'Global strategy and population-level learning: The case of hard disk drives' *Strategic Management Journal*, 22 (4), pp. 307-334

Moreno, R., Paci, R., Usai, S. 2005. 'Spatial spillovers and innovation activity in European regions' *Environment and Planning A*, 37(10), pp. 1793-1812

Mowery, D., Rosenberg, N., 1989. *Technology and the Pursuit of Economic Growth*. Cambridge University Press, Cambridge, UK.

Mowery, D.C., Oxley, J.E., Silverman, B.S., 1996. 'Strategic alliances and inter-firm knowledge transfer' *Strategic Management Journal* 17 (1), pp. 77–91.

Mowery, D., Nelson, R., Sampat, B., Ziedonis, A., 2001. 'The growth of patenting and licensing by U.S. universities: an assessment of the effects of the Bayh-Dole Act of 1980' *Research Policy* 30, pp. 99–119.

Nagle, M. 2007. 'Canonical analysis of university presence and industrial comparative advantage' *Economic Development Quarterly*, 21(4), pp. 325-338

Nelson, R., and Winter, S. 1982. *An Evolutionary Theory of Economic Change*. Harvard University Press. Cambridge, MA

Newlands, D. 2003. 'Competition and Cooperation in Industrial Clusters: The implications for Public Policy' *European Planning Studies*, 11(5), pp. 521-532

O'Donaghue, D., and Gleave, B. 2004. 'A Note on Methods for Measuring Industrial Agglomeration' *Regional Studies*, 38(4), pp. 419-427

Pfeffer, J. and Salancik, G.R. 1978. *The External Control of Organizations*. New York: Harper and Row.

Porter, M.E. 1990. *The Competitive Advantage of Nations*. New York: Free Press

Porter, M.E. 1998. 'Clusters and the New Economics of Competition' *Harvard Business Review,* 76(6), pp. 77-85

Porter, M.E. 2000. 'Location, competition, and economic development: Local clusters in a global economy' *Economic Development Quarterly*, 14(1), pp. 15-34

Pouder, R., and St John, C. 1996. 'Hot spots and blind spots: geographical clusters of firms and innovation' *Academy of Management Review*, 21(4), pp. 1192-1225

Prevezer, M. 1997. 'The dynamics of industrial clustering in biotechnology' *Small Business Economics*, 9, pp. 255-271

Rosenberg, N. 1994. 'Scientific Instrumentation and University Research' in Rosenberg, N (ed) *Exploring the Black Box: Technology, Economics, and History*. Cambridge University Press, Cambridge, UK, pp. 250-263

Rosenberg N. 2002. *America's University-Industry Interfaces*, Stanford University.

Rosenbloom, J. 2007. 'The Geography of Innovation Commercialization in the United States in the 1990s' *Economic Development Quarterly*, 21(1), pp. 3-16

Rosenkopf, A., Nerkar, 2001. ‘Beyond local search: boundary-spanning exploration, and impact in the optical disk industry’ *Strategic Management Journal*, 22, pp. 287–306.

Rosenthal, S., and Strange, W. 2003. ‘Geography, industrial organization and agglomeration’ *Review of Economics and Statistics*, 85(2), pp. 377-393

Saxenian, A.1994. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.

Schendel, D. 1994. ‘Introduction to competitive organization behavior: Toward an organizationally-based theory of competitive advantage’ *Strategic Management Journal*, 15, pp. 1-4.

Shaver J., and Flyer F. 2000 ‘Agglomeration economies, firm heterogeneity, and foreign direct investment in the United States’ *Strategic Management Journal*, 21 (12), pp. 1175-1193

Flyer F., and Shaver J. 2003. ‘Location choices under agglomeration externalities and strategic interaction’ *Advances in Strategic Management: A Research Annual*, 20, pp. 193-213

Sorenson, O., and Audia, P. 2000. ‘The Social Structure of entrepreneurial Activity: Geographic concentration of footwear production in the US, 1940- 1989’ *American Journal of Sociology*, 107 (2), pp. 424 –459

Stinchcombe, A.L. 1965. Social structure and organization. In J.G. March (ed.) *Handbook of Organizations*: 142-193. Chicago: Rand McNally.

Storper, M. 1997. *The Regional World: Territorial Development in the Global Economy*. Guilford Press.

Stuart, T., and Sorenson, O. 2003. ‘The geography of opportunity: spatial heterogeneity in founding rates and the performance of biotechnology firms’ *Research Policy*, 32(2), pp. 229-253

Teece, D., 1985. ‘Multinational enterprise, internal governance and industrial organization’ *American Economic Review,* 75, pp. 233–238.

Teece, D. 1986. ‘Profiting from technological innovation – implications for integration, collaboration, licensing and public policy’ *Research Policy*, 15(6), pp. 285-305

Thompson, P., and Fox-Kean, M. 2005. ‘Patent citations and the geography of knowledge spillovers: A Reassessment” *American Economic Review*, 95(1), pp. 450-460

Trajtenberg, M, Henderson, R., and Jaffe, A. 2002. University versus corporate patents: A window on the basicness of invention. In Jaffe, A., and Trajtenberg, M. (eds). *Patents, Citations & Innovations: A window on the knowledge economy*. MIT Press, Cambridge, MA

Von Hippel, E., 1988. *The Sources of Innovation*. Oxford University Press, New York.

Von Hippel, E. 1994. ‘Sticky information and the locus of learning’ *Management Science*, 40(4), pp. 429-439

Wernerfelt, B. 1984. ‘A Resource-Based View of the firm’ *Strategic Management Journal* 5 (2): pp.171-180

Wolfe, D., 2003. *Clusters Old and New: The Transition to a Knowledge Economy in Canada's Regions*. Kingston: Queen's School of Policy Studies

Wooldridge, J. 2006. *Introductory Econometrics: A Modern Approach.* 3rd Edition. Boston, MA: Thomson-Southwestern

Zucker, LG., and Darby, M. 1997. ‘Individual action and the demand for institutions: star scientists and institutional transformation’ *The American Behavioral Scientist*, 40(4), pp 502-514

Zucker, LG., Darby, MR., and Brewer, MB. 1999. ‘Intellectual human capital and the birth of US biotechnology enterprises’ *American Economic Review*, 88, pp. 290-306

ESSAY 2: PERFORMANCE DIFFERENTIALS AND INDUSTRIAL CLUSTERING

Introduction

This essay examines whether geographic clustering affects firm performance, more specifically upstream innovation performance operationalized here as the pace of technology development and the number of new product announcements. That is, do serial innovator firms located in MSA areas with high levels of industrial agglomeration perform differently than serial innovator firms that are located in MSA areas with lower levels of industrial clustering? Or does their status as proven (serial) innovators make their innovative performance invariant to industrial clustering? This question will be explored and two distinct dimensions of the upstream innovation process will be assessed in this respect.

That industrial clustering has beneficial effects on firm performance in general, and innovation performance in particular has been established and reported in the extant literature (Baptista and Swann, 1998; Beaudry and Breschi, 2003; Folta et al, 2006) but no one has examined firm performance differentials due to industrial clustering in an unusual population of serial innovator firms. Two dimensions of upstream innovative performance will be assessed of which one is unique and serves as a measure of the pace of technological progress of the technology the firm is commercializing.

Why are these measures of upstream innovation so important to the long-term competitiveness and survival of small firms? Firm innovative performance is of paramount importance in today's high velocity market environments in which most if not all of these serial innovator firms are operating. New product development is a critical component of corporate strategy because it can be used to leapfrog competition, create entry barriers, establish a leadership position in a product segment, open up new distribution channels, or attract new customers to improve the firm's market position (Clark and Fujimoto, 1991; Wheelwright and Clark, 1992). Due to shortening product life cycles, the strategic importance of new product innovation is growing to address competitive, technological, and customer challenges (Stalk and Hout, 1990; Wheelwright and Clark, 1992). At the same time contraction in the life span of products implies that the speed by which new technologies are developed is likely to be a key determinant of firm competitiveness as well.

This essay is structured as follows. The next section will briefly review the literature on the relationship between industrial clustering and firm performance. In addition it will elaborate on a proposed theoretical model that explains the role of location in the technological learning process of firms and two principal hypotheses will be developed that posit how industrial clustering may impact upstream innovation processes. The data set, variables, and the operationalization of the variables will be discussed in the third section. The fourth section of the essay highlights the results of the empirical analysis along with a discussion of the results. Finally, the last section provides some concluding remarks.

Theory and Hypothesis Development

This essay will examine whether industry clustering influences the innovation processes and the outcomes of the upstream part of the innovation process of small firms that we know excel at technological learning. The upstream part of the innovation process encompasses the activities ranging from idea generation, research and development, new product development, and culminates in the initial announcement of a new product. The downstream part of the innovation process comprises marketing, distribution, and the actual sales of the product (Tidd, Bessant, and Pavitt, 2001).

Regions with high levels of industry clustering have been found to influence the operations, behavior and performance of the firms located within them as will be discussed below. Firm performance is a multidimensional construct and includes financial, economic impact, social, and innovative metrics. This paper specifically focuses on the innovative performance of the firm and the outcomes of the technological learning process expressed as the *rate of new product announcements* and *the pace by which the technology developed by the serial innovator* progresses.

The finding that increased innovative firm performance is associated with their location in areas with high levels of industrial clustering has held empirically across several performance measures including new product introductions (Deeds et al, 1997), sales growth (Canina, Enz and Harrison, 2005) and firm survival (Folta et al, 2006; Sorenson and Audia, 2000; Sorenson and Stuart, 2003). A range of benefits have been identified that accrue to firms located in technology clusters compared to those in isolated areas, although there are contingencies that apply.

Porter (1998) argues that with increased levels of industry clustering firm performance is affected by the intensity of local competition which in turn serves as a strong impetus for cluster-based firms to innovate in order to compete and survive in the local environment. In a sense, he argues that industrial clusters require firms located in a cluster to be more innovative than those located in isolated areas. Porter offers no strong (statistical) empirical evidence and restricts himself to case studies however.

Other scholars found that the presence of similar firms in a particular geographic location generates demand externalities that lead to increased financial performance (Chung and Kalnins, 2001). The same authors found that *small* firms located in clusters were benefiting the most in terms of increased revenue. These firms appear to leverage the influx of customers that are drawn to cluster locations by the reputations of the larger firms in the cluster in that it enables the small firm to present their offerings to these customers. Cluster-based serial innovator firms would appear to be in a prominent position to benefit from new customers flocking to the cluster location.

Other contingencies are associated with receiving benefits from areas with high levels of clustering. For example and not surprisingly, firm survival rates decline with cluster size which suggests that firms, and especially small firms, may be at a disadvantage by locating in a large cluster where competition is likely to be more intense than in a smaller cluster (Folta et al., 2006). Similarly, Shaver and Flyer (2000) found that firms in areas with high levels of industry clustering face higher risks for failure but noted that 'weaker' firms were able to receive more benefits from cluster locations than 'stronger' firms. This and other research suggest that new or younger may be more likely to benefit from a cluster location than more established firms precisely because of the lack of path dependency, established routines, and larger size (Shaver and Flyer, 2000; Chung and Kalnins, 2001).

Another contingency that influences the extent and quality of benefits from a firm cluster location is corporate strategy (Canina et al, 2005). Specifically, established firms pursuing a diversification strategy and located in an area with high industry clustering achieved better performance than firms in similar locations pursuing a low-cost strategy. Likewise, Baum and Haveman (1997) found that firms that successfully differentiated themselves from others in the cluster location had a better chance of survival than those that did not.

Given their innovation intensity, serial innovator firms are likely pursuing diversification or niche strategies and are therefore distinct in their strategies from their peer firms in a cluster. As successful product differentiators they have better chances to withstand competition within a cluster and therefore have better survival chances in line with the findings of Baum and Haveman (1997). The section above provided a brief overview of the impact of industry agglomeration on firm-level performance outcomes along with the contingencies that may moderate this impact. The next section will start highlighting the theoretical underpinnings how firms may benefit from their geographical location.

Clusters, knowledge spillovers, and innovation processes

The arguments in the previous section shed some light on what conditions higher levels of firm performance are being observed for cluster-located firms relative to firms in isolated areas. Some scholars attribute the superior performance of cluster-based firms to the fact that they have easier access to knowledge spillovers, and specifically the tacit-related component of knowledge spillovers (Deeds et al, 1997; Bell, 2005). One may, however, not overlook the pecuniary advantages or traded interdependencies that are in principal available to all firms located in an industrial cluster (Storper, 1997). These traded interdependencies typically lead to all sorts of economies (scope, scale, transaction, functional such as R&D etc.) and allow cluster-based firms to operate more efficiently.

Knowledge spillovers are the direct or indirect voluntary transfer of various forms of knowledge from one entity to another at no cost to the recipient(s). These spillovers are the byproduct of research activities by other entities such as other private firms in the same (Audretsch, 1998) or another industry (Feser, 2002; Jacobs, 1969), universities or other institutions that perform research relevant to the recipient(s) of the spillovers. Knowledge spillovers are important since it informs the recipient(s) of the knowledge spillover about the technological direction and level of progress of the spillover originator (Brown and Duguid, 2000). Furthermore, knowledge spillovers provide a vantage point from which new market opportunities can be observed and entrepreneurs are argued to be the primary beneficiaries (Audretsch and Keilbach, 2004).

It is possible that serial innovator firms might have unique abilities to absorb knowledge spillovers and to ‘read’ them better than their peer non-serial innovator firms as has been verified in the first essay. This ability can in part be explained by the high levels of innovative prowess they built up through significant investments in formal R&D activities and easy access to external knowledge sources. Serial innovators, being at the forefront of the technology in their respective sectors, are also likely to be major sources of knowledge spillovers.

Technological spillovers do contribute significantly to the development and exploitation of a firm's innovative capabilities and that's one reason why foreign firms often locate subsidiaries in a cluster location to serve as a listening post and to learn about the innovation activities taking place in that region (Almeida, 1996; Frost, 2001). Almeida found that even highly innovative subsidiaries find it valuable to locate in areas with high industry clustering because they are able to assimilate locally produced knowledge. This is important because knowledge, and especially the tacit component, does not travel easily (at least not at high speed) and might be highly contextualized (Jaffe et al., 1993). The value and content of knowledge spillovers also tend to decay across space during the diffusion process (Anselin et al, 1997, 2000; Fisher and Varga, 2003).

The principal informal mechanism[18] through which knowledge spillovers is transmitted are employees, and the mobility of employees (Almeida and Kogut, 1999). A mobile workforce facilitates and enhances 'collective learning, as tacit knowledge is conveyed and shared when professional employees move from one company to another (Lee et al, 2000). It is furthermore argued that the entire region benefits when knowledge is being spread around (Appleyard, 1996; Saxenian, 1990). Local knowledge spillovers not only encompass technical knowledge but also knowledge about new products, new markets and market opportunities of new modes of doing business (diffused by e.g. marketing and sales professionals, or sales engineers who change jobs in technology clusters) that may aid a firm's innovation activities and may increase their absorptive

[18] More formal mechanisms for knowledge spillover transmission are strategic alliances, partnerships, acquisitions and licensing of technology

capacity (Cohen and Levinthal, 1990). The next section introduces two theoretical frameworks on which a theoretical model will be build that explains how firms learn and benefit from their spatial context and how this may affect firm performance outcomes.

A model of the effect of clustering on technological learning outcomes of firms

The mechanism whereby industrial clustering contributes to technological learning (innovation), and its outcomes (a range of firm performance measures), can be modeled by integrating two specific theoretical perspectives that represent views on industrial agglomeration and the theory of the firm, respectively. The first one is the New Economic Geography, a theory that was initially formalized by Paul Krugman's version of regional agglomeration, which mathematically theorized economic geography in terms of the 'increasing returns' paradigm and draws extensively on the early work of Alfred Marshall (1920). The second theoretical perspective is the evolutionary theory of technological change that introduces the important concept of organizational routines.

The two perspectives are quite distinct and yield partial insights into the performance of small innovative firms in spatial agglomerations. The synthesized framework offers an explicit account of what forces impinge upon firms located in agglomerations and the relationships that explain firm performance and intra-firm technological learning. The first perspective devised by Paul Krugman and further developed by others (Audretsch and Feldman, 1996; Baptista and Swann, 1998; Jaffe et al, 1993 and others) on industrial agglomeration and its determinants explains the favorable impact of geographical proximity on industrial dynamism and performance at the meso-level. By contrast, the second evolutionary perspective on organizational and technological change uses a microeconomic lens to study firm performance at the micro level. I will discuss them in turn and proceed with a synthesis of the two perspectives.

The first theoretical approach was popularized by Paul Krugman's contribution to regional agglomeration economics but has other influences as well. Krugman follows Marshall (1920) in identifying three types of factors that promote external scale economies (that operate at the cluster level): first, specialized labor market pooling; the creation of specialized supplier and related industries, and third, the development of technological knowledge spillovers. Krugman argues that knowledge spillovers are limited to high technology agglomerations and are national or international in scope (especially the explicit component), rather than regional and are hard to model (Krugman, 1986) in the same way Breschi and Lissoni (2001a, 2001b) think the local knowledge spillover school of thought is given too much importance. Recent research even called into question the existence of localized knowledge spillovers (Thompson and Fox-Kean, 2005).

Nevertheless, going back to Marshall one can identify two broad categories of external economies that operate at the cluster level. The *first category* comprises economies of scale, scope and transaction that yield all sorts of cost advantages for those firms located in an agglomeration in proximity to other firms in the same or related industry, and are known as pecuniary externalities (Marshall, 1920; Richardson and Gordon, 1978). The *second category* consists of knowledge or technology spillovers, intellectual gains made through voluntary exchange for which a direct compensation to the producer of the knowledge is not given (Marshall, 1920; Feldman and Florida, 1994).

The role of these two types of external economies has been hotly debated with known skeptics of knowledge spillovers like Breschi and Lissoni (2001a, 2001b), who believe Marshall's economies of specialization and labor market economies are important, pitted against the adherents of local knowledge spillover theory like Malmberg and Maskell (2002), Audretsch and Feldman (1996) and Jaffe et al. (1993). The debate is still raging. These external economies are likely to increase with higher levels of firm agglomeration.

The second theoretical perspective based on Nelson and Winter's book, *An Evolutionary Theory of Economic Change* develops an evolutionary account of organizational and technological change that is Darwinian in nature (Nelson and Winter, 1982). Their work is firmly rooted in the writings of economists like Schumpeter (1934) and Alchian (1950) and is a successful attempt to develop a unique model of the evolution of organizational action. The model proposed in their book also underpins the theoretical foundations of the various innovation system concepts including the regional innovation systems variant.

Central to the evolutionary theory of technological change at the system, sectoral, and more importantly for this study, the geographic cluster- and firm-level are *organizational routines* that Winter earlier defined as a pattern of behavior that is followed repeatedly, but is subject to change if circumstances change (Winter, 1964). Organizational routines are important concepts that enable us to explain economic, organizational and technological change. Several attributes that are characteristic of routines are noteworthy:

- Routines are collective phenomena and involve multiple actors (Nelson and Winter, 1982; Feldman and Pentland, 2003)
- Recurrence is a key characteristic of routines as the term itself implies (Winter, 1986)
- Routines are procedural in nature and hold the promise of explaining technological and organizational change, which is by definition a process.
- Routines are embedded in organizations and its structures and are specific to the context (Teece and Pisano, 1994; Cohen et al, 1996 and others). Several types of specificity have been suggested

The effects of organizational routines on organizational operational processes and performance are powerful and multifaceted. Routines coordinate activities within organizations and tie them together, well known in the corporate world as business processes (Nelson and Winter, 1982; March and Olsen, 1989; Dosi et al, 2000). As coordinating devices – and under certain conditions- they can be more efficient than contracts. Furthermore, Nelson and Winter posit that actors in their theory are assumed to be boundedly rational and possess incomplete information and have imperfect information processing capabilities. Routines also have the desirable property of reducing uncertainty in the face of decision-making in fluid and unpredictable market environments in that decision makers use rule of thumbs, or gather more information to reduce the probability of making the 'wrong' decision (Dosi and Egidi, 1991 and others). Moreover, routines provide stability in organizational settings although the stability-providing impact of routines can become pathological in some cases, leading to deteriorating organizational or system performance (Leonard Barton, 1995; Rumelt, 1995). Finally, routines store knowledge and serve as an ‘organizational memory’. Nelson and Winter argue that ‘the routinisation’of activity in an organization constitutes the most important form of storage of the organization’s specific operational knowledge’ (Nelson and Winter, 1982: p. 99). Routines are a key repository of knowledge in the firm, including tacit knowledge (Winter, 1995).

Firms also continuously evaluate routines through search processes that may lead to modification or even replacement of routines and this process is commonly referred to as *learning* (Nelson and Winter, 1982: p. 400). Nelson and Winter argue that this is how firms accumulate capabilities, bundles of related routines that govern the exploitation of resources. Capabilities that are cross-functionally integrated and coordinated are referred to as *competences* and express what a firm particularly excels at (Prahalad and Hamel, 1990). The next section will merge these two theoretical frameworks to yield insights into how small firms learn and benefit from their spatial context.

Theoretical Framework

Attempts have been made to integrate the two perspectives discussed above to examine the firm-level underpinnings of innovative regions, which was hitherto treated as a black box (Caniels and Romijn, 2005). The key question is how individual firms can acquire capabilities and develop competences by co- locating in space, and how this will affect the pace and magnitude of technological learning and firm innovative performance in general. When firms settle in clusters we might expect them to derive benefits from three Marshallian factors: 1. presence of a specialized labor pool; 2. an industrial center with specialized support and supplier firms, and 3. technology spillovers. For reasons of convenience we divide these three factors in two broad categories, namely pecuniary (cost) advantages and pure knowledge spillovers.

The pecuniary advantages of being located in an agglomeration imply scale, scope, and transaction economies (and are therefore market-based) that are not commonly believed to be contributing to learning and capability development by many scholars (Malmberg and Maskell, 2002). However, there are dissenting views on this issue most prominently by Breschi and Lissoni (2001a) who argue that pecuniary effects may impact learning (innovation) activities because of the 'availability of common sets of resources…like a pool of specialized and skilled labor, whose main effect is that of reducing the costs and uncertainties associated with firm's innovative activities' (p. 820).

Furthermore it is plausible that pecuniary advantages are positively correlated with the level of industry clustering in a given area. That is, higher levels of pecuniary advantages are associated with higher levels of industry clustering. In addition to pecuniary advantages, it is plausible to expect that the level and intensity of knowledge spillovers is also likely to increase with higher levels of industrial clustering.

Two distinct firm-level *learning mechanisms* can be identified that operate at the firm-level of cluster-based companies (Caniels and Romijn, 2005): 1. *trial and error*, which is an unintentional and ad-hoc process, and which does not require systematic investments in organizational improvement (no costs involved), and 2. purposefully and directed *organizational search* to improve performance is a systematic process and obviously involves investments in fixed and intangible assets and human resources. For our purpose we will focus on the second learning mechanism, the directed organizational search for improvement through investments.

One can for instance examine the effects of spontaneous pecuniary advantages on knowledge investments. These advantages occur spontaneously in the sense that no collaborative activities among actors in a cluster are required to bring about these advantages. Clusters can generate a minimum level of demand for new, specialized products and services that cannot be produced outside of clusters profitably (Stewart and Ghani, 1991). This will stimulate organizational search processes that lead to new routines and organizational capabilities required to develop these products and services.

A second important mechanism that engenders a pecuniary advantage is the presence of specialized suppliers and human capital that are attracted by large local demand for their services and inputs. The presence of these two factors lowers transaction costs associated with input procurement and costs of finding specialized workers. Interaction between actors in terms of collaborations may lead to the capture of additional externalities. In addition, firms regardless of size may embark on larger, more capital-intensive projects because pooling of resources from several firms is possible in cluster arrangements (Caniels and Romijn, 2005). At the same time individual firms will drastically reduce their investments outlays and the risk they are exposed to. This again lowers the costs of organizational search while expanding the scale and scope benefits accruing to firms.

Various mechanisms by which a firm's learning processes can be enhanced by pure knowledge spillovers from other firms, and hence increasing the efficiencies of intra-firm search processes have been described in the literature. Deliberate investments in innovation and learning are expected to yield a higher pay off in clusters than outside (Caniels and Romijn, 2005). Investing in innovative activities raises the absorptive capacity of the firm that facilitates recognition, valuation, acquisition and assimilation of external knowledge inputs and will enhance the innovative prowess of the firm (Cohen and Levinthal, 1990). Moreover, the geographical proximity eases the observance and absorption of 'free' knowledge inputs in the local environment, and this is expected to enhance the new product development process as well as the speed of technological development. The ideas underlying this type of externality of firm learning can be traced directly to evolutionary theory, namely bounded rationality and selective perception of the environment (Simon, 1986).

The hypotheses developed in this essay will focus on activities where purposeful knowledge investments are made and where knowledge spillovers and pecuniary advantages both contribute to the enhancement of the technological capabilities of serial innovator firms and where efficiencies (e.g. lower transaction costs) can be achieved by locating in a cluster. The theoretical framework also implies that higher levels of pecuniary advantages and knowledge spillovers lead to enhanced firm level-learning outcomes such as the rate of new product development or the speed of technology development. The way the *level* of pecuniary benefits and knowledge spillovers will be modeled is by using one single index, the *cluster location quotient*. This metric provides a measure of the degree of clustering in a particular geographical area in a specific period t in an industry i.

Extant research has used different proxies for firm innovation. Beaudry and Breschi (2003) on one hand used patent counts as a measure of innovative performance and concluded that clustering alone is not conducive to higher innovation performance, rather the presence of other innovative firms in the cluster positively affects the likelihood of innovating. Non- innovative firms in the same industrial sector and located in the cluster appear to have a strong negative effect on the focal firm's innovative performance. Beaudry and Breschi furthermore found that a strong presence of firms in related industries spurs innovative performance. Baptista and Swann (1998) on the other hand found that innovation performance, measured as the number of new innovations per firm, is positively influenced by industrial clustering in a small sample of UK firms. That sample includes many firms (75.8 %) that do not introduce new products at all even during the extended period (eight years) they examined i.e. the dataset contained predominantly non-innovative firms both small and large in size. The distribution is extremely skewed in that in 92.8% of cases the number of innovations per observation reports a zero count.

Furthermore, one may expect decreasing returns to be associated with the number of new product announcements due to congestion effects and scarcities in essential innovation inputs with increasing levels of industry clustering (Pouder and St. John, 1996; Prevezer, 1997). Moreover, for high-technology firms such as serial innovators competition for scientists and engineers (Zucker et al., 1999) will increase when levels of industrial clustering keep rising as does the risk for knowledge expropriation by rival cluster-based firms (Shaver and flyer, 2000). Such congestions costs raise the possibility that serial innovator firms may experience diseconomies of agglomeration. Prior research also indicated that diseconomies of agglomeration play a role when the size of the cluster increases and exceeds about 65 firms in a given locale (Folta et al, 2006).

Given what was said above I posit that:

Hypothesis 1a: A serial innovator firm located in an area with higher levels of industry clustering is likely to announce more new products than a serial innovator firm located in an area with lower levels of industry clustering.

Hypothesis 1b: The relationship between the level of industry clustering and the rate of new product announcements is characterized by decreasing returns to increasing levels of industrial clustering.

The pace of technological progress defined as the speed by which new technologies created by (serial innovator) firms develop is one of the least studied factors in innovation processes and is often assumed and not empirically verified. As such very little hard evidence on speed of technological advance and its implications has been provided as noted by other authors (Clark and Fujimoto, 1991; McDonough and Barczak, 1991; Kessler and Bierly, 2002; Carbonell and Rodriguez, 2006). Recently, learning from customers has been found to be a strong predictor of innovation speed (Bierly and Daly, 2007) while others have found an inverted U-shape effect of innovation speed on new product quality, indicating that speed has a beneficial effect on new product quality at first, levels off at higher innovation speeds, and becomes detrimental to new product quality at very high levels of innovation speed (Lukas and Menon, 2004). No study, however, has empirically examined the speed of technological advance in a geographical cluster context, as the relationship has always been assumed.

The second hypothesis uses a new construct to measure technological progress, the TCT (Technology Cycle Time) variable, defined as the median age of the patents cited on the front page of a patent (Kayal and Waters, 1999). This patent-based technology indicator was originally developed by CHI, a private consulting company with support from the National Science Foundation. The assumption is that the lower the median age – the technology is more recent – the more quickly one generation of inventions is being replaced by another. One study has been published that validated the use of this new indicator to measure technological progress in one specific technological field, that of superconductor technology (Kayal and Waters, 1999). It confirmed the superiority of this metric over that of traditional patent counts, R&D expenditures or number of R&D personnel in gauging and assessing the pace of technological innovation. The notion of technological progress conceived as a sequence of substitutions of successively better technological combinations provides a far better measure of innovation speed (Ayres, 1994). The faster this sequence of substitutions takes place, the more rapidly the technology progresses over time.

According to the model developed above, both pecuniary and knowledge spillover effects should contribute positively to the speed of technological advance of the artifacts developed by serial innovator firms since coordination and transaction costs with co-located innovation partners will be reduced and efficiency levels enhanced. The geographical proximity to other firms with similar knowledge bases will speed up coordination and communication (pecuniary and spillover advantages) with local partners involved in innovation and commercialization (Bierly and Daly, 2007), and will likely result in the acceleration of technological development activities in which these firms are engaged. The higher the level of industry clustering the more efficient coordination and communication between innovation partners and the faster new technologies may be developed.

Hence, one may therefore expect that:

Hypothesis 2: Serial innovators located in areas with higher levels of industry clustering have on average lower values for TCT (higher levels of technological progression) than a serial innovator firm in the same industry located in areas with lower levels of industry clustering

Schematically, the hypothesized relationships can be represented by:

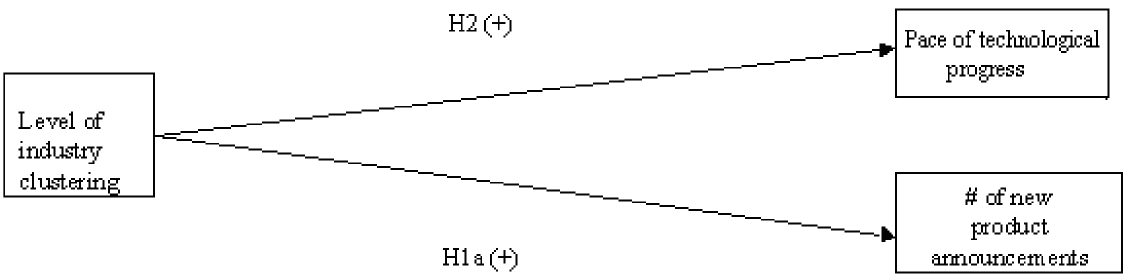


Fig 3. Relationship between industrial clustering and two innovation measures.

Dataset

The dataset employed in this essay comprises a defined population of serial innovators[19] – firms with 500 or fewer employees with a portfolio of a minimum of 15 utility patents granted in the 5-year period preceding 2002, who are independently owned, not bankrupt at the time of this study (2006), and are long-lived – a unique set of

[19] The initial dataset on serial innovators was collected under SBA contract SBAHQ-01-C-0149 by Dr. Diana Hicks

strong technology-based firms that have built a competitive advantage around a strong proprietary technology and have sustained or strengthened its competitive position while remaining small in size (Hicks and Hegde, 2005). This is a population since we include all US firms that meet the criteria indicated above to specify what a serial innovator firm is.

According to Buchanan[20] these small firms invest substantial time and money in technological innovation. They furthermore adopt or at least mimic best R&D management practices used in large firms and most of them have a formal R&D department or group with formal structures, committees for assessing new ideas and approving funds. Compensation of senior management personnel is often tied to the granting of patents or completion of prototypes, in the form of bonuses. She found that these firms tend to set a measurable goal that a certain percentage of their revenue should come from new products or be allocated to R&D activities. Again, these are organizational routines often encountered in much larger firms and this may well be another feature that sets these serial innovator firms apart from the much larger population of small technology-based firms.

The procedure used to define the population can be summarized as follows: firms are labeled serial innovators if they meet the following criteria.

1. have 500 or fewer employees, in line with the Small Business Administration definition of a small firm
2. have been granted 15 or more US utility patents in the period 1998-2002

[20] Buchanan profiled a number of serial innovator firms in the August 2002 issue of Inc. Magazine

3. are independent, i.e. not majority owned by a large firm, not a joint venture, and not a subsidiary of a large US or foreign firm
4. are a going concern, not bankrupt in 2006
5. are long-lived, i.e. have survived at least one full economic cycle

Such firms tend to be long lived. It is important to note that this population has been restricted to *public* firms because of the greater availability of non-patent firm-level data critical to test the propositions put forth earlier. After cleaning for firms that are defunct, have merged, or have changed names, the total number of serial innovators in the population dataset numbers 401, that is, 203 are privately owned and 198 firms are public.

The author added to the original serial innovator data information derived from COMPUSTAT, the firms' websites, Hoover Database, the Lexis Nexis database and SEC 10-K annual reports. Cluster data is gleaned from the Cluster Mapping Project at Harvard Business School and cross-checked with location quotient data available from the Bureau of Labor Statistics (BLS). The section on measures and their operationalization contains specific data on the data sources used per variable.

Measures

Dependent variables:

To test Hypotheses 1a and 1b we use the number of new product announcements in 2002 (New Product Announcements2002 as the dependent variable, a non-negative integer count measure). Data for this measure is gleaned from three sources that are cross-checked with one another: the Lexis Nexis database for product announcements, the firm’s SEC 10 K filing, and the firm’s website press release and archive section. Reconciliation of these three figures yields a final new product count result.

To test Hypothesis 2 we use the Technology Cycle Time indicator as dependent variable, a continuous measure (TCT). The Technology Cycle Time (TCT) parameter is a new measure of technological progress, or more specifically of innovation speed. Technology cycle time (TCT) indicates how fast the given technology is turning over, and is calculated as the median age in years of the U.S. patent references on the front page of the company's patents (Kayal and Waters, 1999; Kessler and Bierly, 2002; Narin, 1994). Hence patents with relatively shorter cycle times represent technologies that are advancing more quickly from a prior technology to the current.

Data on the TCT variable was sourced from a prior research project conducted for the Small Business Administration (SBA) by Professor Diana Hicks.

Independent variables:

For hypotheses 1a, 1b and 2, the independent variable of interest is the cluster location quotient (**CLQ**), discussed earlier. This is a continuous variable.

However, a suitable instrumental variable for this endogenous variable needs to be identified.

Control variables:

1. Employ - continuous variable, average number of employees of firm in the period from 1998 to 2002. The assumption is that larger organizations with more employees, have more bureaucratic procedures and routines, a more complex management hierarchy which results in inertia of business processes, slowing down both new product

announcements and progress of technology development (innovation speed), two key metrics of the upstream innovation process (Aldrich, 2007; Memon et al, 2002).

2. Age - continuous variable of firm age in 2002

Age of the serial innovator firm in years since inception. Firm age is a differentiating factor in many industries. Younger companies are more nimble, more responsive but may have routines that are not fully institutionalized, including those for innovation, which may result in a slower rate of new product announcements and pace of technology development (Nelson and Winter, 1982; Gopalakrishnan and Bierly, 2006). Older firms, like serial innovators have created, optimized, and institutionalized organizational routines – including new product development processes – that have evolved and been refined over time (Nelson and Winter, 1982) and positively affect new product performance including the rate of new product announcements and the product development cycle (Montoya-Weiss and Calantone, 1994). There is also evidence that organizational learning (including learning how to develop new products) is more efficient and faster in older firms than younger ones (MacPherson and Holt, 2007).

3. R&D 9802 - expenditures on R&D in firm over the five year period studied. The influence of R&D levels on the pace of technological progress has led to contradictory findings and needs more empirical research (Kessler and Bierly, 2002). On the one hand, more resources available for R&D would speed up technology development (Menon et al, 2002), but on the other hand incumbent small firms may invest most of their R&D resources in incremental technology development projects that would meet the needs of existing customers and that often is not patented (Christensen and Bower, 1996; Hartmann et al., 2002).

4. # Patent references to science - the average number of references on a patent referring to the science literature. The impact of this variable is unclear because new technologies are being developed to speed up drug development processes but it is recognized that pre-clinical research still is much slower in terms of development speed and product development than other types of research (Thomke et al, 1998).

5. # Expected patent references to science - This variable controls for the technology specific component of the importance of science. It is calculated as the average number of backward science citations by technology class and year, and then matched such average to each patent of each firm by technology class and year. Subsequently the expected values are averaged across firms, to obtain what would be expected by a firm with a similar patent portfolio.

6. Industry dummies **–** One can expect differences in the rate of new product announcements across industries. Eleven 3-digit SIC industries will be included in the regression models and the codes are obtained from the firms' SEC-10K reports.

The econometric models for H1a and H1b and H2 with the endogenous explanatory variable are:

P [New Product Announcements2002|$X_{i, s}$] = f (CLQ, CLQ^2, Employ, Age, R&D9802, Patent ref to science, Industry fixed effects) a negative binomial regression model.

E [TCT |$X_{i, s}$] =f (CLQ, Employees, Age, R&D9802, Pat Ref to science, Industry fixed effects) an OLS regression model

Analysis and Results

Descriptive Statistics

The bivariate correlation matrix provided in Table 13 indicates that one correlation coefficient, notably the one between the dummy variable pharmaceutical & biotechnology industry and the average number of expected science references on a patent suggests that multi-collinearity might be a problem. The variance inflation factors will be calculated later on to test this possibility.

Significant industry differences in the rate of new product announcements in 2002 can be observed (Table 14). A difference of means test between the various industries and the Pharmaceutical industry (used as a reference category) indicates that the Information Technology sector (encompassing the Semiconductor, the Communications Equipment, the Software, and the Computer & Electronic industries) introduces significantly more new products than the Pharmaceutical industry. Since this dataset is a population - in the sense that it comprises all US-based firms that can be labeled serial innovators - one concludes that even within the IT industry there are significant differences in new product announcements. As could be expected, the life sciences industry, more specifically the Pharmaceuticals & Biotechnology industry and to a lesser extent the Surgical & Medical devices industry have very low rates of new product announcements, a testament to the long product development cycles of these type of products, exacerbated by the regulatory procedures with which these firms have to comply.

Table 13. Bivariate Correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13
1.Cluster Locat	1.00												
2.Employees	0.11	1.00											
3.R&Dexp9802	0.02	0.38*	1.00										
4.Age	-0.08	0.06	-0.15*	1.00									
5.#science ref	-0.14*	-0.02	0.32*	-0.15*	1.00								
6.#exp science	-0.26*	-0.16*	0.41*	-0.24*	0.61*	1.00							
7.Computer&	-0.03	0.04	-0.08	0.08	-0.17*	-0.25*	1.00						
8.Communicat	0.04	0.05	-0.10	0.11	-0.15*	-0.25*	-0.08	1.00					
9.Semiconduct	0.46*	0.05	-0.05	-0.08	-0.21*	-0.32*	-0.12	-0.11	1.00				
10.Electricaleq	0.03	0.02	-0.05	0.02	-0.08	-0.15*	-0.05	-0.04	-0.06	1.00			
11.Navigation	-0.04	0.09	-0.02	0.08	-0.03	-0.05*	-0.05	-0.04	-0.06	-0.02	1.00		
12.Surgical&	-0.09	-0.08	-0.24*	-0.03	-0.16*	-0.18*	-0.11	-0.10	-0.14*	-0.06	-0.06	1.00	
13.Pharmaceut	-0.21*	-0.12	0.40*	-0.15*	0.55*	0.85*	-0.25*	-0.23	-0.32*	-0.13	-0.13	-0.30*	1.00
14.Software&	0.04	0.10	-0.08*	0.02	-0.03	-0.20*	-0.08	-0.07	-0.10	-0.04	-0.04	-0.09	0.21*

* significant at 5 %

Table 14. Means test of product announcements vis-à-vis the pharmaceutical industry

Sector	Mean/Obs	Mean/Obs (Pharma)	Sign
Computer & Electronic	2.53/17	.60/80	***
Communications Equip	5/15	.60/80	***
Semiconductor	8.30/26	.60/80	***
Navigation & detection	1.2/5	.60/80	n.s
Surgical & medical dev	2.70/24	.60/80	**
Electrical Equipment	1.8/5	.60/80	*
Software & Services	3.08/12	.60/80	***

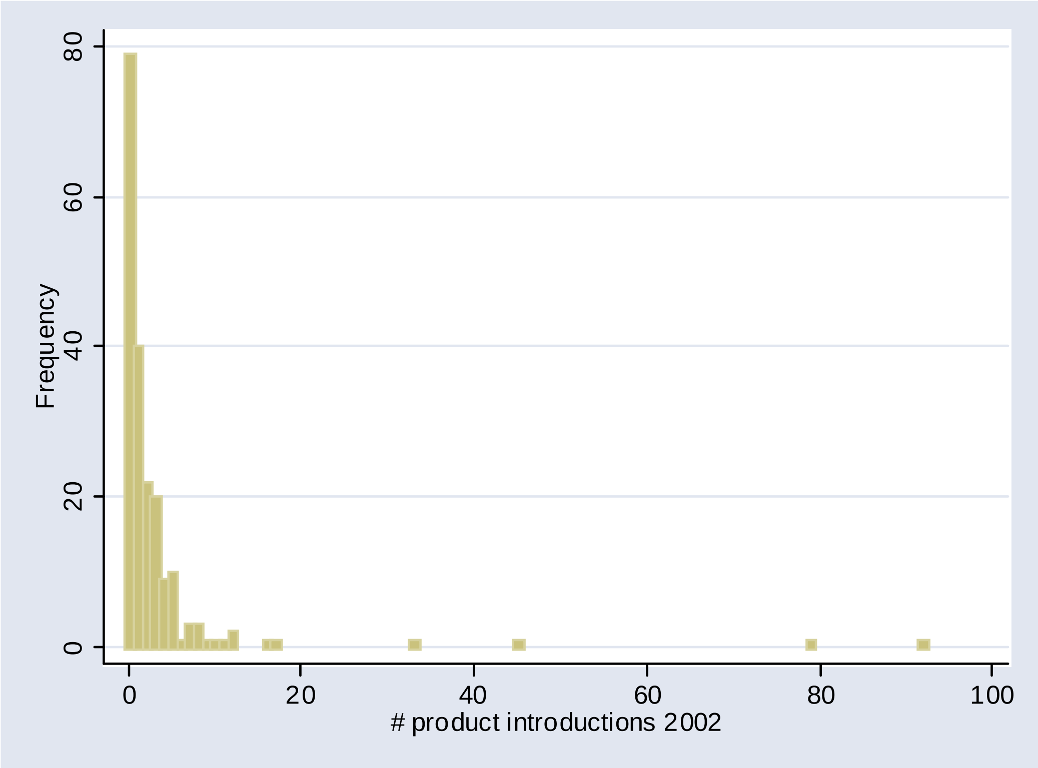
* significant at 10 % ** significant at 5 %, ***significant at 1%, n.s. not significant

Hypothesis Test for New Product Announcements

Hypothesis 1a posits that serial innovator firms located in MSA areas with higher levels of industry agglomeration are likely to perform better in terms of new product introductions than their peers who are located in areas with lower levels of industry clustering. The dependent variable for Hypotheses 1a and 1b is the number of new product announcements made in the year 2002 by serial innovator firms. The frequency histogram of the number of new product announcements in 2002 is presented in Fig.4 and is clearly highly skewed and far from normally distributed. Table 15 depicts seven regression models used to test Hypotheses 1a, b[21].

[21] An exploratory approach will be used whereby successively more control variables are added to the key explanatory variable of interest. The Wald-Chi square statistic will be used to judge when further additions would represent a significant improvement over the base model (Rabe –Hesketh and Everitt, 2007).

Fig 4. Histogram of the number of product announcements in 2002



Across all models one can conclude that the coefficient on the key independent variable of interest (Cluster Location Quotient) is positive and significant ($p<0.01$), a robust finding indeed and providing strong support for Hypothesis 1a. Social scientists include a squared term in regression models to verify whether increasing or decreasing marginal returns can be observed (Wooldridge, 2003; p. 189), a technique applied in a industrial clustering context by other researchers (Fernhaber et al, 2008). The results in Table 15 indicate that the parameter estimate for the squared term is consistently negative and significant across all models ($p<0.01$) confirming Hypothesis 1b. The inclusion of a squared term (Cluster Location Quot. Sq) increases the explanatory power of the model markedly and consequently indicates a better fit with the observed data as can be seen in

Table 15. Predicted number of expected product announcements in 2002

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Cluster Location quotient	0.099	0.174	0.169	0.153	0.163	0.137	0.123
	(4.47)**	(5.49)**	(5.28)**	(4.70)**	(5.55)**	(4.63)**	(4.04)**
Cluster Location quot sq		-0.003	-0.003	-0.002	-0.002	-0.002	-0.002
		(4.31)**	(4.18)**	(3.53)**	(3.96)**	(3.64)**	(3.60)**
Employees			0.001	0.003	0.0031	0.002	0.002
			(0.99)	(2.83)**	(2.75)**	(1.68)†	(2.05)*
R&D Expend 9802				-0.051	-0.048	-0.029	-0.026
				(4.36)**	(4.46)**	(2.54)*	(2.22)*
Age					0.047	0.033	0.033
					(4.05)**	(2.84)**	(2.40)*
Number of science references						-0.011	-0.009
						(1.30)	(1.15)
Expected number of Science references						-0.064	0.036
						(2.19)*	(0.82)
Computer and Electronic Product Manufacturing							-0.475
							(0.94)
Communications Equipment Manufacturing, optics							-0.144
							(0.31)
Semiconductor and related Electronics							0.108
							(0.23)
Navigational, detection, measuring, control							-1.17
							(1.91)†
Surgical and medical devices and equipment							-0.355
							(0.76)
Electrical Equipment, Appliances, components							-1.185
							(1.40)
Pharmaceuticals and Biotechnology, Diagnostics							-1.857
							(3.51)**

Software and Services							-0.581
							(1.07)
Constant	0.495	0.288	0.089	0.393	-0.433	0.295	0.333
	(3.06)**	(1.76)†	(0.35)	(1.48)	(1.37)	(0.78)	(0.58)
Pseudo R2	0.029	0.042	0.043	0.068	0.090	0.109	0.132
Observations	198	198	198	187	187	187	187

Absolute value of z statistics in parentheses
† significant at 10%; * significant at 5%; ** significant at 1%

a residual analysis where the predicted values appear closer to the observed values (not shown here). The number of new product announcements appears to increase at a decreasing rate and reaches a maximum at the point where the cluster location quotient takes a value of 30.75 (0.123/2*0.002), after which the number of new product announcements declines at an increasing rate. The magnitude of the clustering effect on the rate of new product introductions is significant as shown in Table 15. For every unit increase in the value of the cluster location quotient the average number of new product announcements will increase by 13.2 per cent (see Table 16).

Table 16. Change in expected number of product announcements in 2002 in per cent

Productannouncements2002	b	z	P>z	%	% Std X	SD of X
Clusterlocation	0.123	4.03	0.000	13.2	157.1	7.68
Cluster location sq	-0.002	-3.59	0.001	-0.2	-52.6	377.78
Employees9802	0.002	2.05	0.031	0.2	35.0	125.67
R&D9802	-0.026	-2.21	0.027	-2.6	-31.5	14.38
Age	0.033	2.39	0.017	3.4	29.7	7.66
Navigation &	-1.178	-1.65	0.050	-69.2	-17.4	0.16
Pharmaceutical	-1.857	-3.50	0.000	-84.4	-59.9	0.49

b = raw coefficient
z = z-score for test of b=0
P>z = p-value for z-test
% = percent change in expected count for unit increase in X
% St dX = percent change in expected count for SD increase in X
SD of X = standard deviation of X

The explanatory power of the fully specified model is satisfactory and has improved significantly over the base model. The Pseudo R2 or McFadden R2, a widely used measure to assess the explanatory power of a non-linear model is 13.2 per cent (see Table 17). A likelihood ratio test of the alpha variable indicates that the equi-dispersion assumption is violated and that it was correct to use a negative binomial regression specification instead of a simple Poisson regression specification[22].

Table 17. Measures of Fit

Measures of Fit	
Log-Lik Intercept Only: -396.85	Log-Lik Full Model:-344.32
D (170): 688.6	LR(16): 105.06
	Prob > LR: 0.000
McFadden's R2: 0.132	McFadden's Adj R2: 0.094
Maximum Likelihood R2: 0.430	Cragg & Uhler's R2: 0.436
AIC: 3.86	AIC*n: 722.65
BIC: -200.63	BIC': -26.59

Control variables and robustness checks

The results for the control variables are also noteworthy. The size of the firm (Employees) appears to have a positive impact on the rate of new product introductions ($p<0.05$) in the fully specified model. The amount of expenditures on R&D (R&D Expend9802) has a negative impact on the dependent variable and is significant ($p<0.05$). The extent to which the technologies rely on findings reported by the scientific literature, represented by the Number of Science references variable is not significant. For each firm another variable was included – Expected number of Science References – and represents what would be expected in terms of science references by a firm with a similar age/technology mix of patents (Expected number of Science references), to control for the age profile of the patents and for the technology-specific component of the importance of science[23].

[22] Likelihood-ratio test of alpha=0: chibar 2 (01) = 572.15 Prob>=chibar 2 = 0.000
[23] This constructed variable can be obtained as follows: first compute the average number of backward science citations by technology class and year, and then match such average to each patent of each firm by technology class and year. Compute the average of the

The fully specified model on the far right also includes the industry fixed effects. The industry effects indicate that the rate of new product announcements is lower in the Pharmaceutical & Biotechnology industry ($p<0.01$) than for the 'Miscellaneous' industry (84.4 % lower rate of new product announcements than firms in the Miscellaneous industry), which serves as the reference industry, but not so for the Medical Devices and Software industries. Firms operating in the Navigation & Detection Instrumentation sector ($p<0.10$) also seem to have lower rates of new product announcements than those in the Miscellaneous sector, a 69.2 per cent lower rate of new product announcements than firms in the Miscellaneous industry to be precise.

Separate regression models for the rate of new product announcements were developed for the Pharmaceutical & Biotechnology and IT hardware sectors (the merger of the semiconductor, communications equipment, navigation & instrumentation, and electrical equipment industries). The results in Table 18 indicate that the level of industrial clustering (Cluster Location Quotient) in the pharmaceutical and biotechnology industry does not have a bearing on the number of announcements for new products thereby *disconfirming Hypothesis 1a* but does in the IT hardware sector *confirming Hypothesis 1a*. We observe that the number of product announcements in the IT hardware sector increase at a decreasing rate as the level of industrial clustering increases *confirming Hypothesis 1b*.

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expected values across firms, to obtain what would be expected by a firm with a similar patent portfolio. This variable controls for the technology specific component of the importance of science.

Table 18. Determinants of new product announcements for two industries

	Pharmaceutical	IT hardware
Cluster Location quotient	-0.034	0.179
	(0.73)	(2.07)**
Cluster Location Quot Sq.	-0.001	-0.002
	(1.24)	(1.98)*
Employees	0.002	0.008
	(2.38)**	(2.93)*
R&D exp 9802	-0.029	-0.001
	(1.77)†	(1.78)†
Age	0.042	0.242
	(1.97)**	(1.88)
Number of science references	-0.045	-0.007
	(1.78)*	(1.17)
Expected number of Science references	-0.001	-0.000
	(0.34)	(0.83)
Constant	0.520	0.921
	(0.67)	(2.04)**
Observations	76	107
Pseudo R2	0.021	0.034

Absolute value of z statistics in parentheses, corrected for spatial autocorrelation
† significant at 10%; ** significant at 5%; * significant at 1%

An additional model was developed (Table 19) for the dataset that does not include firms in the San Francisco Bay area, the Boston metropolitan area, and the Research Triangle Park. The results are consistent with those for the entire dataset discussed above.

Table 19. Determinants of new product announcements for firms not located in Silicon Valley, the Boston Area or Research Triangle Park

Cluster Location Quotient	0.242
	(1.99)**
Cluster Location Quot. Sq	-0.002
	(2.04)**
Employees	0.012
	(0.86)
R&D Expend 9802	-0.002
	(0.53)
Age	0.191
	(2.31)**
Number of science references	-0.002
	(0.65)
Expected number of Science ref	-0.340
	(0.91)
Computer and Electronic Mfg	-.518
	(2.41)**
Communications Equipment Mfg	-0.79
	(4.39)*
Semiconductor &	-0.35
	(4.32)*
Navigational, &	-0.83
	(2.25)**
Surgical & Medical dev.	-0.25
	(3.47)*
Electrical Equipment & Components	-0.29
	(3.81)*
Pharmaceuticals & Biotechnology	-1.63
	(2.58)**
Software & Services	-1.42
	(2.59)**
Constant	0.22
	(2.45)**
Observations	106
Pseudo R2	0.022

Absolute value of z statistics in parentheses, corrected for spatial autocorrelation
** significant at 5%; * significant at 1%

To further check the robustness of our results, a knowledge production function was introduced and tested which hypothesized that a firm's patent output is determined by the following non-linear function:

Patents9802 = *f* (G, F, I)

Table 20. Determinants of patent production

Cluster Location quotient	0.026
	(2.13)*
Cluster Location Quotient Sq.	-0.001
	(2.91)**
Employees	0.000
	(0.26)
R&D Expend 9802	0.025
	(7.20)**
Age	0.006
	(1.07)
Number of science references	0.000
	(0.18)
Expected number of Science references	-0.006
	(0.42)
Computer and Electronic Product Manufacturing	-0.314
	(1.45)
Communications Equipment Manufacturing, optics	-0.253
	(1.16)
Semiconductor and related Electronics	-0.157
	(0.76)
Navigational, detection, measuring, control	0.104
	(0.37)
Surgical and medical devices and equipment	-0.199
	(1.00)
Electrical Equipment, Appliances, components	0.191
	(0.61)
Pharmaceuticals and Biotechnology, Diagnostics	-0.282
	(1.40)
Software and Services	-0.053
	(0.23)
Constant	3.237
	(13.83)**
Observations	184

Absolute value of z statistics in parentheses
* significant at 5%; ** significant at 1%

where # Patents9802 is a measure of innovative output, G is a measure for the level of geographical industry clustering, F is a vector of firm-level control variables, and I are the industry fixed effects. The results are depicted in Table 20 and indicate that spatial clustering (Cluster Location Quotient) does have a positive effect on the number of patents produced although diminishing returns can be observed in patent production as a result of increasing levels of industrial clustering.

Hypothesis Testing for Technology Cycle Time

To test Hypothesis 2 that posits a positive relationship between the level of industrial clustering and the pace of technological progress (the inverse of Technology Cycle Time) within the firm, an OLS model was specified and the regression results are presented in Table 21 in the form of six distinct econometric models. Across the six models presented in Table 21, the coefficient on the variable of interest (Cluster Location Quotient) is negative and not significant (except in the first model) suggesting that Hypothesis 2 can not be supported. Furthermore no decreasing returns can be observed across all models as the coefficient on the squared term is not significant. The fully specified model on the far right includes the industry fixed effects. Again, and confirming the finding in model five it appears that the more the firm's technology is based on knowledge originating from the science base the slower the pace of technological progress in the firm's core technology proceeds ($p<0.05$). The explanatory power of the fully specified model is relatively good at 29 per cent.

Table 21. Determinants of the Technology Cycle Time, with potentially endogenous variable

OLS	(1)	(2)	(3)	(4)	(5)	(6)
Cluster Location quotient	-0.080	-0.065	-0.068	-0.043	-0.064	-0.046
	(1.77)†	(1.43)	(1.45)	(0.93)	(1.36)	(1.00)
Clustersq	0.001	0.000	0.000	0.000	0.000	0.000
	(0.98)	(0.73)	(0.83)	(0.38)	(0.67)	(0.83)
Employees		-0.002	-0.000	-0.001	-0.002	-0.001
		(1.71)†	(0.01)	(0.65)	(1.18)	(1.08)
R&D 9802			-0.035	-0.026	-0.018	-0.018
			(2.88)*	(2.13)*	(1.29)	(1.34)
Age				0.070	0.064	0.054
				(3.30)**	(2.97)*	(2.61)**
Number of science references					0.019	0.018
					(2.11)*	(2.16)*
Expected number of Science references					-0.082	-0.244
					(2.26)*	(4.73)**
Computer and Electronic Product Manufacturing						-0.849
						(1.13)
Communications Equipment Manufacturing, optics						-2.056
						(2.71)*
Semiconductor and related Electronics						-2.201
						(3.07)**
Navigational, detection, measuring, control						-1.313
						(1.27)
Surgical and medical devices and equipment						-0.044
						(0.07)
Electrical Equipment, Appliances, components						0.002
						(0.00)
Pharmaceuticals and Biotechnology, Diagnostics						1.330
						(1.80)†

Software and Services						-1.479 (1.69)†
Constant	7.202 (32.63)**	7.585 (24.16)**	7.728 (22.53)**	6.637 (14.12)**	7.165 (12.82)**	8.425 (10.91)**
Observations	198	198	187	187	187	187
R-squared	0.02	0.04	0.067	0.12	0.15	0.29

t statistics in parentheses, corrected for spatial autocorrelation
+ significant at 10%; * significant at 5%; ** significant at 1%

The cluster location quotient however might be endogenously related to the Technology Cycle Time variable[24]. The results of the second stage of the regression procedure[25] are displayed in Table 22 along with the results of the simple Ordinary Least Squares (OLS) regression. The coefficient on the variable of interest (Cluster Location Quotient) remains statistically insignificant confirming the results obtained by a simple OLS procedure and providing further empirical evidence that *Hypothesis 2 is not supported*. All other coefficients broadly conform to the results found in the OLS regression model.

Control variables and robustness checks

Two within-industry regression models were developed and tested to see what the determinants of the Technology Cycle Time are within specific industries. Table 23 illustrates two distinct models for the Pharmaceutical & Biotechnology sector and the Semiconductor industry. Each regression model uses a different set of instrumental variables[26]. From Table 23 we note that the cluster location quotient in both of the models is not significant, suggesting no relationship between the level of industry clustering and

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[24] A residual analysis indicates that there is evidence that this may be the case.

[25] Appropriate instrumental variables appear to be the average prevailing wage in the MSA in a particular industry in 2002 as reported by the 2002 Economic Census and the total invested amount of venture capital in the focal industry and in the MSA over the five-year period studied. Data for this variable originates from the quarterly Price Waterhouse Coopers MoneyTree report on Venture Capital.

[26] For the pharmaceutical industry we use the average wage in the MSA in the Pharmaceutical industry in 2002 and the total number of science & engineering degrees in the MSA in 2002; for the semiconductor industry average wage in the MSA in the semiconductor industry in the MSA in 2002 was chosen in addition to the amount of invested venture capital in the semiconductor industry over the five year period from 1998 to 2002

Table 22. Determinants of the Technology Cycle Time (2SLS)

	OLS	2SLS#
Cluster Location quotient	-0.046	-0.021
	(1.00)	(0.80)
Cluster Location quotient square	0.000	
	(0.83)	
Employees	-0.001	-0.001
	(1.08)	(1.26)
R&D 9802	-0.018	-0.017
	(1.34)	(1.31)
Age	0.054	0.056
	(2.61)*	(2.87)*
Number of science references	0.018	0.018
	(2.16)*	(2.24)*
Expected number of Science references	-0.244	-0.240
	(4.73)**	(4.89)**
Computer and Electronic Manufacturing	-0.849	-0.849
	(1.13)	(1.18)
Communications Equipment Manufacturing	-2.056	-2.055
	(2.71)*	(2.82)*
Semiconductor and related Electronics	-2.201	-2.152
	(3.07)**	(3.07)**
Navigational, detection, measuring, control	-1.313	-1.312
	(1.27)	(1.32)
Surgical and medical devices and equipment	-0.044	-0.036
	(0.07)	(0.06)
Electrical Equipment, Appliances, comp.	0.002	-0.016
	(0.00)	(0.01)
Pharmaceuticals and Biotechnology	1.330	1.290
	(1.80)†	(1.83)†
Software and Services	-1.479	-1.519
	(1.81)†	(1.94)†
Constant	8.425	8.328
	(10.91)***	(11.46)***
Observations	187	187
R-squared	0.29	
Centered R-squared		0.286
Uncentered R-squared		0.930
Sargan statistic		1.265ns

Absolute value of t statistics in parentheses, corrected for spatial autocorrelation
† significant at 10%; * significant at 5%; ** significant at 1%

Table 23. Determinants of Technology Cycle Time by sector (2SLS)

	(1)	(2)
DV = TCT	Pharmaceut.	Semicond
Cluster Location quotient	-0.088	-0.01
	(0.65)	(0.73)
Employees	-0.002	0.002
	(0.86)	(2.22)*
R&D Expend9802	-0.017	0.011
	(1.04)	(0.45)
Age	0.128	0.065
	(2.51)**	(2.03)*
# of science references	0.017	0.486
	(2.04)*	(5.50)**
Expect # of Science ref	-0.22	-0.82
	(2.98)**	(1.68)†
Constant	8.68	4.87
	(5.05)**	(5.68)**
Observations	76	25
F-statistic	5.98***	22.75***
Centered R-square	0.33	0.49
Uncentered R-square	0.93	0.97
Sargan statistic	0.068ns	0.277ns

t statistics in parentheses, corrected for spatial autocorrelation
* significant at 5%; ** significant at 1%

the pace of technological progress. As a robustness check, an additional regression model was run on data that did not include firms in the three large technology clusters (Silicon Valley, the Boston MSA, and Research Triangle Park) and Table 24 illustrates that the results are consistent with those for the entire dataset discussed above.

One- way ANOVA analyses using TCT as the dependent variable and a dichotomous variable In Tech Cluster as independent variable and defined as taking the value 1 if the cluster location quotient is equal or greater than 1.2 (a commonly used cutoff value in other studies) and the value 0 otherwise, were conducted to further test the robustness of our results.

Table 24. Determinants of Technology Cycle Time in for firms outside Silicon Valley, Boston and Research Triangle Park using 2SLS

DV = TCT	
Cluster Location quotient	0.086
	(1.44)
Employees	-0.004
	(2.16)**
R&D 9802	-0.008
	(0.86)
Age	0.034
	(1.09)
Number of science references	0.013
	(1.48)
Expected number of Science references	-0.155
	(2.91)***
Computer and Electronic Manufacturing	-0.126
	(0.11)
Communications Equipment Manufacturing	-1.08
	(1.46)
Semiconductor and related Electronics	-0.414
	(0.54)
Navigational, detection, measuring, control	-0.117
	(0.19)
Surgical and medical devices and equipment	0.743
	(0.93)
Electrical Equipment, Appliances, comp.	-0.140
	(0.14)
Pharmaceuticals and Biotechnology	1.290
	(2.11)**
Software and Services	-0.064
	(0.11)
Constant	7.885
	(8.18)***
Observations	106
Centered R-squared	0.202
Hansen J statistic	0.327[ns]

Absolute value of t statistics in parentheses, corrected for spatial autocorrelation
† significant at 5%; ** significant at 5%; *** significant at 10%

The results in Table 25 reveal that in none of the industries one can observe statistically significant differences in the average value of the Technology Cycle Time as a result of being located in a technology cluster or not, disconfirming Hypothesis 2.

Table 25. ANOVA analyses of differences in Technology Cycle Time by sector.

ANOVA (cutoff for Cluster Location Quotient: 1.2)

Dependent Var.	Independent Var.	Industry	# Obs	F value	Prob>F
TCT	In Tech Cluster	Pharmaceutical	78	1.90	0.172^{ns}
		Surgical & Medical	24	0.00	0.980^{ns}
		Electrical Equipm	6	2.87	0.189^{ns}
		Computer Manuf	18	0.20	0.660^{ns}
		Software & Serv	12	0.58	0.465^{ns}
		Semiconductor	26	0.51	0.482^{ns}
		Communicat Equip	16	1.70	0.215^{ns}
		Navigation & Detect	5	0.10	0.771^{ns}

* significant at 5%   n.s. not significant

Discussion of results

The analysis above sought to examine performance differentials between serial innovator firms located in MSA areas with high levels of industrial clustering and those that are located in MSA's with lower levels of industry agglomeration. The two dimensions of upstream innovation performance assessed in this essay are the number of product announcements made in the year 2002 and the pace by which the inventive process progresses. These performance measures are the outcomes of technological learning processes that take place within and among firms and with the aid of external knowledge spillovers that enhances the learning process.

Across a range of regression models and after correcting for spatial autocorrelation it was established that firms located in MSA areas with increased levels of agglomeration are indeed more productive in terms of new product announcements than firms located in MSA areas with lower levels of agglomeration. The empirical analysis also provided evidence indicating that the rate of new product announcements increases at a decreasing rate with higher levels of industrial clustering confirming Hypothesis 1b. This indicates that both pecuniary advantages and knowledge spillovers contribute to technological learning within serial innovator firms and has a positive impact on this dimension of innovation performance but at very high levels of industrial clustering diseconomies of agglomeration set in.

Furthermore significant industry differences could be observed among serial innovator firms in terms of the rate of new product announcements. More specifically, serial innovator firms in the Pharmaceutical & Biotechnology and the Navigation & Detection industries announce significantly fewer new products than firms that operate in the Miscellaneous industry, the reference. Probing deeper, a within-industry analysis of the Pharmaceutical & Biotechnology industry where very low rates of product introduction can be observed suggests that industrial clustering does not appear to affect innovation productivity in terms of new products. The inherent risky nature of the drug development process and the cumbersome and often unpredictable regulatory approval procedures (Orsenigo, 1989; Orsenigo et al, 2001) may trump any benefits that may be received from agglomeration economies. A second explanation is that proportionately more firms outside the three large technopoles (San Francisco Bay area, Boston, Research Triangle Park) are developing and marketing diagnostics and assays whereas firms in the three areas mentioned above are proportionately more engaged in drug discovery and development. Therefore any benefits from agglomeration economies to firms that develop drugs might be offset due to the fact that firms developing diagnostics and medical tests – arguably less 'risky' products in terms of technological and regulatory uncertainty – churn out products at a higher rate. In contrast, serial innovator firms in the IT industry that are located in strong industrial IT agglomerations have significantly more new product announcements in 2002 than their peers located in weaker IT clusters.

Hypothesis 2 examines whether the pace of technology development is different between those serial innovator firms located in MSA areas with elevated levels of industrial agglomeration and those that are located in technology clusters with much lower industry concentration levels. Across a range of econometric specifications and after conducting two rigorous robustness checks, no evidence could be noted to support Hypothesis 2.

One explanation for this non-finding is that serial innovator firms mostly develop general purpose technologies in the sense that references made by a serial innovator patent are more broadly spread across patent technology classes than those of large firm patents (Hicks and Hegde, 2005) increasing the likelihood that the cited patents are owned by firms that are geographically dispersed. In addition, Hicks and Hegde found that serial innovator firm patents were significantly more general[27] in chemicals, pharmaceuticals, electrical appliances, industrial machinery, and office equipment[28].

The Technology Cycle Time is a function (the median value of the referenced patents grant dates) of references made by a serial innovator firm patent over time from a whole range of patent technology classes. Another feature of serial innovator patents is their high originality, and therefore the less derivative nature of these technologies, in that these patents reference other patents across a broad technological spectrum (Hicks and Hegde, 2005). A patent with high originality has fewer immediate precedents in its own technology class and therefore draws and synthesizes knowledge from a wide range of technologies outside the firm, even after controlling for self-citations. Given what we know about the patent referencing behavior of serial innovator firms and that these patents refer to previous art in many different technology classes (likely owned by firms that are geographically dispersed) that each move at different speeds and the fact that serial innovator firms self-cite their own patents significantly less than larger firms, it is reasonable to assume that indeed the level of industrial clustering might not impact the level of the Technology Cycle Time, and conversely the pace of technology development. Tacit knowledge not reported or partially encoded in patents cited by the serial innovator firm but required to develop the patented technologies does not travel easily, is sticky and

[27] Trajtenberg et al. (2002, p.60) use the generality index as a measure to gauge how broad-based the technologies described in patents are, in terms of applicability across industries.

[28] Including a variable that measures the generality of the technology was included in the models but was not found to be significant. Upon closer inspection it was found that the variability in this variable is small and hence did not appear statistically significant.

is location-specific. This may be another reason why industrial clustering does not have any impact on the Technology Cycle Time.

In future studies, it would be advisable to break down the references by geographical origin e.g. those that originate from near the focal firm's location, and those that refer to entities far away from the focal firm. In a sense one can create a 'local' TCT and a 'remote' TCT measure and see whether this dis-aggregation of the innovation speed measure makes a difference. To further elucidate the factors and processes that impinge on technology cycle times, survey research of this set of serial innovator firms will be required to identify additional and perhaps better predictors of the pace of technological progress.

The pace of technological progress also varies across industries with firms in the Pharmaceutical & Biotechnology industry innovating at the slowest speed relative to those in the 'Miscellaneous' industry, while firms in the Semiconductor and Communications Equipment industries, and to a lesser extent the Software industry innovating at a significantly higher pace than firms in the Miscellaneous industry, the reference category.

An interesting finding is that the average number of references reported by a firm's patent portfolio to the science literature is negatively related to the pace at which the firm innovates, suggesting that science-based technologies develop much slower than technologies that rely less on (life) science, a point that has been made repeatedly before.

Conclusion

This essay examined innovation performance differentials in a unique set of small, innovative firms. The two measures of upstream innovation performance considered are the number of new product announcements made by serial innovator firms and the innovation speed by which technology development processes proceed.

What this essay contributes to the literature is the fact that innovation performance should be disaggregated into its constituent dimensions. The results of this essay suggest that agglomeration economies do play a role even in a population of some of the most innovative, small firms in America. However, there are important differences across industries that need further examination.

The first performance dimension assessed indicates that industrial clustering positively affects the number of new product announcements in a given year even in an unusual population of small, highly innovative firms. However, one can observe that as the level of industrial clustering exceeds some point, the marginal benefits to being in a cluster will decline in line with several extant studies on the effects of firm agglomeration.

Another dimension of innovative performance – the pace of technological progress - is invariant to industrial agglomeration plausibly because the technologies developed by serial innovators which are generic in nature draw on technological developments from a variety of patent technology classes whose contributors are spatially scattered. That's why industrial clustering might not have the effect hypothesized in this study.

The theoretical framework employed in this essay was partially validated by the empirical results. In line with extant theories of industrial agglomeration and findings in the literature, the empirical results reported in this essay cogently illustrate the beneficial impact of increasing levels of industrial clustering on firm productivity. Overcrowding inside industrial clusters however has a tempering effect on productivity gains. In this specific case firm productivity was proxied by a measure of innovation productivity – the number of new product announcements over one year. The explanatory power of the framework is modest and the validity of the theoretical framework could not be confirmed for firms in the pharmaceutical & biotechnology sectors. The theoretical framework however is not valid to explain how differing levels of industrial agglomeration might affect the pace of technology development. One possible explanation is that this might indicate that the measure for the pace of technological development is not an appropriate indicator for innovation speed at the firm-level. An alternative explanation for this non-finding is that the TCT construct comprises a component that is geography-specific and one that is not and that the combination leads to a conflation of unique impacts. In a sense, it might be that the TCT construct in the theoretical framework lacks validity and hence is unable to validate the model.

Future initiatives that can be further explored are the development of larger datasets and making the analysis longitudinal, performing large-sample within-industry analyses to assess upstream innovation performance of serial innovator firms, and the relative position of serial innovator firms in the knowledge network of technology clusters. In a sense, one can examine whether serial innovator firms benefit more or less from increased industry agglomeration than non-serial innovators along a much wider range of innovation and other performance indicators than presented here. One may also want to make a distinction between new-to-the-world products and mere product improvements.

REFERENCES

Alchian, A. 1950. ‘Uncertainty, evolution and economic theory’ *Journal of Political Economy*, 58, pp. 211-221

Aldrich, H. 2007. *Organizations and Environments*. Stanford, CA: Stanford University Press

Almeida, P. 1996. ‘Knowledge sourcing by foreign multinationals: Patent citations analysis in the U.S. semiconductor industry’ *Strategic Management Journal*, 17, pp. 155-165.

Almeida, P., B. Kogut. 1999. ‘Localization of Knowledge and the Mobility of Engineers in Regional Networks’ *Management Science*, 45, pp. 905-917.

Anselin, L., Varga, A., and Acs, Z. 1997. ‘Local geographical spillovers between university research and high technology innovations’ *Journal of Urban Economics*, 42, pp. 422-448

Appleyard, M.M. 1996. ‘How does knowledge flow? Interfirm patterns in the semiconductor industry’ *Strategic Management Journal* 17, pp. 137-154.

Appold, S.J. 1995. ‘Agglomeration, interorganizational networks, and competitive performance in the U.S. metalworking sector’ *Economic Geography*, 71, pp. 27-54.

Audretsch, D., and Feldman, M.P, 1996 ‘R&D spillovers and the Geography of innovation and production’ *American Economic Review*, 86, pp. 630-640

Audretsch, D.B. 1998. ‘Agglomeration and the location of innovative activity’ *Oxford Review of Economic Policy* vol. 14 (2), pp. 18-29.

Audretsch, D.B., Keilbach, M. 2004. ‘Does entrepreneurship matter?’ *Entrepreneurship Theory & Practice*, 28, pp. 419-430.

Ayres, R. 1994. ‘Toward a nonlinear dynamics of technological progress’ *Journal of Economic Behavior & Organization*, 24, pp. 35 -69

Baptista, R. and Swann, P. 1998. ‘Do firms in clusters innovate more?’ *Research Policy*, 27, pp. 525-540

Barney, J. 1991. ‘Firm resources and sustained competitive advantage’ *Journal of Management*, 17, pp. 99-120

Baum, J.A.C., H.A. Haveman. 1997. ‘Love Thy Neighbor? Differentiation and Agglomeration in the Manhattan Hotel Industry, 1898-1990’ *Administrative Science Quarterly*, 42, pp. 304-338.

Bell, G.G. 2005. ‘Clusters, networks, and firm innovativeness’ *Strategic Management Journal*, 26, pp. 287-295.

Bierly, P., and Daly, P. 2007. ‘Sources of external organizational learning in small manufacturing firms’ *International Journal of Technology Management*, 38(1-2), pp. 45 -68

Breschi, S., and Lissoni, F. 2001a. ‘Localized knowledge spillovers vs. innovative milieux: Knowledge ‘tacitness’ reconsidered. *Papers in Regional Science*, 80, pp. 255-73

Breschi, S., and Lissoni, F. 2001b. ‘Knowledge spillovers and local innovation systems: a critical survey’. *Industrial and Corporate Change*, 10, pp. 975-1005

Caniels, M. and Romijn, H. 2005. ‘What drives innovativeness in industrial clusters? Transcending the debate’ *Cambridge Journal of Economics*, 29, pp. 497-515

Canina, L., Enz, C.A., Harrison, J.S. 2005. ‘Agglomeration effects and strategic orientations: Evidence from the U.S. lodging industry’ *Academy of Management Journal*, 48, pp. 565-581.

Carbonell, P., & Rodriguez, I. 2006. ‘The impact of market characteristics and innovation speed on perceptions of positional advantage and new product performance’ *International Journal of Research in Marketing*, 23(1), pp. 1-12.

Christensen, C., and Bower J. 1996. ‘Customer power, strategic investment, and the failure of leading firms’ *Strategic Management Journal*, 17(3), pp. 197-218

Chung, W. & Kanins, A. 2001. ‘Agglomeration effects and performance: A test of the Texas lodging industry. *Strategic Management Journal*, 22, pp. 969-988.

Clark, K.B. and Fujimoto, T. 1991. *Product Development Performance*. Boston, MA: Harvard Business School Press.

Cohen, M.D., Burkhart, R., Dosi, G, Egidi, M., Marengo, L., Warglien, M., and Winter, S. 1996. ‘Routines and other recurring action patterns of organizations: contemporary research issues’ *Industrial and Corporate Change*, 5, pp. 653-698

Cohen, W.M. & Levinthal, D.A.. 1990. ‘Absorptive capacity: A new perspective on learning and innovation’ *Administrative Science Quarterly*, 35, pp. 128-152.

Cohen, W.M., and Klepper, S. 1991. ‘The tradeoff between firm size and diversity in the pursuit of technological progress’ *Small Business Economics*, 4, pp. 1-14

Cohen, W.M., and Klepper, S. 1996. ‘Firm size and the nature of innovation within industries: the case of process and product R&D’ *Review of Economics and Statistics*, 78(2), pp. 232-243

Cyert, R., and March, J. 1963. *A Behavioral Theory of the Firm*. Englewood Cliffs, NJ: Prentice Hall

Deeds, D.L., D. Decarolis, J.E. Coombs. 1997. ‘The impact of firm-specific capabilities on the amount of capital raised in an initial public offering: Evidence from the biotechnology industry’ *Journal of Business Venturing*, 12, pp. 31-46.

Dosi, G. and Egidi, M. 1991. 'Substantive and procedural uncertainty- and exploration of economic behaviors in changing environments' *Journal of Evolutionary Economics*, 1, pp. 145-168

Dosi, G., Nelson, R., and Winter, S. 2000. 'Introduction: the nature and dynamics of organizational capabilities' in G. Dosi, R.R. Nelson, and S.G. Winter (eds) *The Nature and Dynamics of Organizational Capabilities*, pp. 1-22, Oxford. Oxford University Press.

Egidi, M. 1992. 'Organizational Learning , problem solving and the division of labor', in H.A. Simon, M. Egidi, R. Marris and R. Viale (eds). *Economics, Bounded Rationality and the Cognitive Revolution*, pp. 148-173, Aldershot, Edward Elgar.

Elam, M. 1993. 'Innovation as the Craft of Combination- Perspective on Technology and Economy in the spirit of Schumpeter' Linkoeping. Department of Technology and Social Change.

Enriquez, J., and Goldberg, R. 2000. 'Transforming life, transforming business: the life science revolution' *Harvard Business Review*, 78(2), pp. 94-100

Feldman, M.P. and Florida, R. 1994. 'The geographic sources of innovation: Technological infrastructure and product innovation in the United States' *Annals of the Association of American Geographers*, 8, pp. 210-229

Feldman, M.S. and Pentland, B.T. 2003. 'Reconceptualizing organizational routines as a source of flexibility and change' *Administrative Science Quarterly*, 48, pp. 94-118.

Fernhaber, S., Gilbert BA, and P. McDougall. 2008. 'International entrepreneurship and geographical location: an empirical examination of new venture internationalization' *Journal of International Business Studies*, 39(2), pp. 926-950

Feser, E.J. 2002. 'Tracing the sources of local external economies.' *Urban Studies*, 39, pp. 2485-2506.

Folta, T.B., Cooper, A.C., Baik, Y. 2006. 'Geographic cluster size and firm performance' *Journal of Business Venturing*, 21, pp. 217-242.

Frost, T.S. 2001. 'The geographic sources of foreign subsidiaries' innovations' *Strategic Management Journal*, 22, pp. 101-123.

Gopalakrishnan, S., and Bierly, P. 2006. 'The impact of size and firm age on knowledge strategies during product development: A study of the drug delivery industry' *IEEE Transaction on Engineering Management*, 53(1), pp. 3-16

Hartmann, GC., Myers MB, RS Rosenbloom. 2002. 'Planning your firm's R&D investment' *Research Technology Management*, 49(2), pp. 25-36

Hicks, D., and Hegde, D. 2005. 'Highly innovative small firms in the markets for technology' *Research Policy*, 34, pp. 703-716

Hodgson, G.M. 2001. *How Economics Forgot History: The Problem of Historical Specificity in Social Science*. Routledge: London.

Jacobs, J. 1969. *The Economy of Cities*. London: Penguin.

Jaffe, A.B., M. Trajtenberg, M., R. Henderson. 1993. 'Geographic localization of knowledge spillovers as evidenced by patent citations' *Quarterly Journal of Economics*, 63, pp. 577-598.

Kayal, A., and Waters, R. 1999. 'An empirical evaluation of the Technology Cycle Time indicator as a measure of the pace of technological progress in superconductor technology' *IEEE Transactions on Engineering Management*, 46 (2), pp. 127-131

Kessler, E., and Bierly, P. 2002. 'Is faster really better? An empirical test of the implications of innovation speed' *IEEE Transactions on Engineering Management*, 49(1), pp. 2-12

Krugman, P. 1991. *Economic Geography and Trade*. MIT Press. Cambridge

Leonard-Barton, D. 1995. *Wellsprings of Knowledge-Building and Sustaining the Sources of Innovation*. Harvard Business School: Boston, MA

Levitt, B., and March, J. 1988. ‘Organizational Learning’ *Annual Review of Sociology*, 14, pp. 319-340

Long, S. 1997. *Regression Models for Categorical and Limited Dependent Variables* SAGE Publications, Thousand Oaks, CA

Long, S., and Freese, J. 2001. *Regression Models for Categorical Dependent Variables using Stata*, Stata Press, College Station, TX

Lukas, B., and Menon, A.2004. ‘New Product Quality: intended and unintended consequences of new product development speed’ *Journal of Business Research*, 57(11), pp. 1258-1268

MacPherson, A., and Holt, R. 2007. ‘Knowledge, learning and small firm growth: A systematic review of the evidence’ *Research Policy*, 36, pp. 172-192

Malerba, F., and Orsenigo, L. 1996. ‘Technological regimes and firm behavior’, in G. Dosi and F. Malerba (eds), *Organization and Strategy in the Evolution of the Enterprise*, pp. 42-71, Macmillan: Houndmills.

March, J. Sproull, L., and Tamuz, M. 1991. ‘Learning from samples of one or fewer’ *Organization Science*, 2, pp. 1-13

Marshall, A. 1920. *Principles of Economics*. Macmillan. London

Malmberg, P., and Maskell, P. 2002. ‘The elusive concept of localization economies: towards a knowledge based theory of spatial clustering’ *Environment and Planning a*, 34(3), pp. 429- 449

McDonough, E.F. and Barczak, G. 'Speeding up new product development: The effects of leadership style and source of technology' *International Journal of Product Innovation Management*, 10, pp. 203-211

Menon, A., Chowdhury, J. and Lukas, B. 2002. 'Antecedents and outcomes of new product development speed' *Industrial Marketing Management*, 31(4), pp. 317- 328

Montoya-Weiss, M., and Calantone, R. 1994. 'Determinants of new product performance –A review and meta-analysis' *Journal of Product Innovation Management*, 11(5), 397-418

Narin, F. 1994. 'Patent Bibliometrics' *Scientometrics*, 30(1), pp. 147-155.

Nelson, R. and Winter, S. 1973. 'Toward an Evolutionary theory of economic capabilities' *American Economic Review* (Papers and Proceedings), 68, pp. 440-449

Nelson, R. and Winter, S. 1982. *An Evolutionary Theory of Economic Change*. Cambridge, MA. Harvard University Press.

Orsenigo, L. 1989. *The Emergence of Biotechnology. Institutions and Markets in the Industrial Innovation*. London: Pinter Publishers.

Orsenigo, L., Pammoli, F., and Riccaboni, M. 2001. 'Technological Change and Network Dynamics: Lessons from the Pharmaceutical Industry' *Research Policy*, 30(3), pp. 485-508

Porter, M.E. 1998. *On Competition*. Boston: Harvard Business School Publishing.

Pouder, R., and St John, C. 1996. 'Hot spots and blind spots: geographical clusters of firms and innovation' *Academy of Management Review*, 21(4), pp. 1192-1225

Prahalad, C. and Hamel, G 1990. 'The core competence of the corporation' *Harvard Business Review*, May-June, pp. 79-91

Prevezer, M., 1997. ‘The dynamics of industrial clustering in biotechnology’ *Small Business Economics* 9, pp. 255–271.

Rabe –Hesketh, S., and Everitt, B. 2007. *A Handbook of Statistical Analyses Using Stata*. Boca Raton, FL. Chapman & Hall/CRC

Richardson, H., and Gordon, P 1978. ‘Note on spatial multipliers’ *Economic Geography*, 54(4), pp. 309-313

Rumelt, R. 1995. ‘Inertia and Transformation’ in C. Montgomery (ed.), *Resource-based and Evolutionary Theories of the Firm- Towards a Synthesis*, pp. 101-132. Dordrecht, Kluwer.

Sandstrom, A., Pettersson, I., and Nilsson, A. 2000. ‘Knowledge production and knowledge flows in the Swedisch Biotechnology innovation system’ *Scientometrics*, 48(2), pp. 179-201

Saxenian, A.1990. ‘Regional networks and the resurgence of Silicon Valley’ *California Management Review*, 33, pp. 89-111.

Schumpeter, J. 1934. *The Theory of Economic Development*. Cambridge, MA. Harvard University Press

Shaver, J.M., F. Flyer. 2000. ‘Agglomeration economies, firm heterogeneity, and foreign direct investment in the United States’ *Strategic Management Journal*, 21, pp. 1175-1193.

Simon, H. 1947. *Administrative Behavior*. New York: The Free Press.

Simon, H. 1986. On the behavioral and rational foundations of economic dynamics, pp. 21-44 in Day, R. and Eliasson, G. (eds) *The Dynamics of Market Economics*, Amsterdam, North Holland

Sorenson, O., P.G. Audia. 2000. ‘The social structure of entrepreneurial activity: Geographic concentration of footwear production in the United States, 1940-1989’ *American Journal of Sociology*, 106, pp. 424-462.

Stalk, G, and Hout, T. 1990. *Competing Against Time: How Time-Based Competition is Reshaping Global Markets*. New York: Free Press.

Stewart, F., and Ghani, E. 1991. ‘How significant are externalities for development?’ *World Development*, 19, pp. 569-94

Storper, M. 1997. *The Regional World: Territorial Development in the Global Economy*. Guilford Press.

Teece, D., and Pisano, G. 1994. ‘Dynamic capabilities and strategic management’ *Strategic Management Journal*, 18, pp. 509-534

Thomke, S., Von Hippel, E., and Franke, R. 1998 ‘Modes of experimentation: an innovation process – and competitive – variable’ *Research Policy*, 27(3), pp. 315-332

Thompson, P., and Fox-Kean, M. 2005. ‘Patent citations and the geography of knowledge spillovers: A Reassessment’ *American Economic Review*, 95(1), pp. 450-460

Tidd, J., Bessant, J., and Pavitt, K. 2001. *Managing Innovation: Integrating Technological, Market and Organizational Change*. West Sussex: John Wiley & Sons

Trajtenberg, M., Henderson, R., and Jaffe, A. 2002. University vs. corporate patents: a window to the basicness of their inventions. In Trajtenberg, M., Jaffe, A.B. (eds), *Patents, Citations and Innovations.* Cambridge, MA: MIT Press.

Wheelwright, S.C. and Clark, K.B. 1992. *Revolutionizing Product Development*. New York: Free Press.

Winter, S.G. 1964. ‘Economic natural selection and the theory of the firm’ *Yale Economic Essays*, 14, pp. 225-272

Winter, S.G. 1984. ‘Schumpeterian competition in alternative technological regimes’ *Journal of Economic Behavior and Organization*, 5, pp. 137-158

Winter, S.G. 1986. ‘The research program of the behavioral theory of the firm: orthodox critique and evolutionary perspective’, in B. Gilad and S. Kaish (eds), *Handbook of Behavioral Economics*, Vol. A., pp. 151-188. Greenwich, CT. JAI Press.

Wooldridge, J.M. 2003. *Introductory Econometrics: A Modern Approach*. 2nd Edition. Ohio: Thomson South Western Publishers.

Zucker, L.G., Darby, M.R., Brewer, M.B., 1999. ‘Intellectual human capital and the birth of U.S. biotechnology enterprises’ *American Economic Review* 88, pp. 290– 306.

ESSAY 3: CLUSTERING AND FIRM INTERNATIONALIZATION

Introduction

This final essay assesses serial innovator firm performance in the downstream section of the innovation process, namely commercialization, and more specifically, the sale of this technology to customers outside of the home market (the United States). Is location or more precisely the level of industrial agglomeration associated with systematic differences in the internationalization efforts of serial innovator firms? Are some small technology-based firms benefiting more from industrial clustering than others in their efforts to internationalize their operations? These are the research questions that will be addressed in this essay. This essay is structured as follows. In the second section a theoretical framework will be presented that frames the research question in terms of organizational ecology arguments and the implications of a firm's ecology on its performance, including firm growth and commercialization. The third section of the essay presents the model along with the operationalization of the hypothesized relationships. The fourth section includes the results of the analysis, and the fifth and final section proceeds with a discussion of the results.

Theory and Hypotheses Development

The third and final essay intends to make a contribution to the new discipline of International Entrepreneurship (IE), a field that emerged in the early to mid-nineties and is still in its infancy (Oviatt and McDougall, 1994). The essay will examine whether industrial agglomeration has any impact on the internationalization of small, long-lived technology-based firms such as serial innovators. It is likely that the pioneering technologies developed by these firms might serve the needs and requirements of customers in markets other than the United States, especially sophisticated ones. The General Purpose Technology character of the technologies developed by serial innovator firms (Hicks and Hegde, 2005), technologies that are applicable in a wide range of industries, is noteworthy since these technologies play a key role in fueling economic growth (David, 1991; Bresnahan and Trajtenberg, 1995).

General Purpose Technologies (GPTs) – often labeled enabling technologies - are characterized by their pervasiveness, as an input or facilitating technology that is used by a wide range of industrial sectors. As a GPT diffuses throughout an economy, it fosters investment in (specialized) complementary assets and technological change in the user industries, engendering efficiencies and productivity gains within industrial sectors and across the economy as a whole (Helpman and Trajtenberg, 1998). Hence these types of technologies are seen by many industrialists and policymakers as key enablers of economic growth, and are therefore prime technologies with great export potential.

The discussion of the relationship between industrial agglomeration and the internationalization of serial innovator ventures will be grounded in organizational ecology arguments. Organizational Ecology (OE) uses a biological metaphor and analytical techniques to try and explain the conditions under which organizations emerge, grow, and die (Hannan and Freeman, 1977). Organizational Ecology analyzes an environment in which organizations engage and compete and where the emergence and disappearance of organizations occurs through an evolutionary process (natural selection). This theory provides an evolutionary account that examines the founding of new ventures, organizational growth and death of organizations (Hannan and Freeman, 1989).

This essay will focus on the organizational growth phase. Organizational ecology predicts that ventures may experience growth because of the number of similar organizations in its close vicinity i.e. the venture is located in a geographical cluster that confers a range of benefits to the cluster-based firm. Like many other phenomena in the social sciences however there might be diminishing or increasing returns associated with organizational growth as a consequence of its spatial context. More specifically, as the level of industrial agglomeration increases, the number of firms in that area will increase and by definition the supply of local resources but competition for these resources will intensify, which may limit growth at some point when firm growth catches up with and exceeds local resource availability.

The internationalization of small technology-based firms may sometimes be spurred by demand for firm products and services that spans national boundaries (Oviatt and McDougall, 1994) or might be motivated by the need to recover steep development costs (Qian and Li, 2003). Another motivation to venture abroad is provided by Vernon (1966) who argues that products that have reached the ‘decline’ stage in their product life cycle can extend their life by catering to less sophisticated (foreign) markets where these products are perceived as new and sophisticated. Besides contributing to the expansion of their customer base, internationalization of small firms is argued to positively impact venture survival and growth (D’Souza and McDougall, 1989). Many small firms decide to conduct international business, especially in their output markets, by virtue of a pull from attractive international markets (O’Farrell et al, 1996).

The initial location of a small firm (both new and established) seems to play a role in its ability to capture the benefits from internationalization. This has been cogently argued by Dunning (1998) and Porter (1990) who identified the resources within close vicinity of a firm's location to be critical to the level of internationalization pursued by the firm. These resources range from the availability of managers with expertise in foreign markets, distribution channel capacity overseas, expert knowledge of foreign markets to other firms with international operations and/or exposure. Both authors focus primarily on large or medium-sized firms and in the case of Dunning only on multinational corporations (MNCs). In addition, they provide no empirical evidence beyond anecdotal or case study evidence.

Whether a firm is able to extract what it requires from the local environment depends on specific features of both the local environment and the firm (Delacroix, Swaminathan and Solt, 1989). Small firms in particular are heavily dependent on their immediate vicinity for critical resources to sustain a competitive advantage, and even to operate (Glasmeier, 1988; Romanelli and Schoonhoven, 2001). Critical resources include skilled labor, access to external knowledge sources such as universities, other private firms, government laboratories, and a whole range of supporting business services and suppliers. In a sense, the theoretical argument outlined above indicates that industrial clustering might influence a firm's ability, including a serial innovator firm, to internationalize its commercialization activities.

Industry clustering, resources and small firm internationalization

Industrial clusters comprise many resources that small firms may leverage to initiate and accelerate their internationalization activities, including international commercialization. Porter (2000) lists a range of resources available to cluster-based firms: 1. specialized input suppliers, 2. distribution channels and logistical services; 3. universities, think tanks, vocational training providers, trade associations, and standard setting bodies; 4. an experienced labor pool and 5. firms, both domestic and foreign that compete directly or indirectly with each other. Increasing levels of industry clustering obviously will lead to an increase in both the diversity and volume of local resources available for (small) firms to tap into, provided they have appropriate access to these resources (Bresnahan et al, 2001).

Beneficial effects of industrial clustering on firm internationalization

Foreign firms in particular are often attracted to industrial clusters (Birkinshaw and Hood, 2000; Shaver and Flyer, 2000) and increase the awareness of and responsiveness to opportunities in foreign markets (Vernon, 1966) in these clusters. In addition, they signal to other firms in the cluster, including small ones, what standards are expected when competing in international markets (O'Farell, Wood and Zheng, 1996). A high number of foreign firms or domestic firms with international operations would raise awareness and knowledge among entrepreneurs in the cluster to internationalize their firm's activities. It thus appears that the presence of foreign firms or domestic firms with international operations in technology clusters might positively influence other actors within the cluster and may make it more conceivable for entrepreneurs to consider targeting international markets.

Furthermore, the presence of domestic and foreign firms in an area with high levels of industry clustering may be beneficial to small firms wanting to internationalize because of the (specialized) complementary assets to which the latter may get access (Teece, 1986). The terms and conditions of the commercial agreements between large and small firms however may prove a bone of contention since they may be viewed as unfair or unreasonable by the small firm because of power asymmetries (Christopherson and Clark, 2007). The situation might be different for serial innovator firms precisely because they do not negotiate from a position of weakness, primarily because of their possession of valuable technology assets (patents) and expertise.

Coviello and Munro (1995) argue that technology agglomerations can be conceived as networks of firms embedded in a geographical area and serve as a critical source of expertise and knowledge about opportunities in international markets. Firms operating in areas with strong industry clustering tend to be better connected to other firms and hence learn faster about opportunities available to them in foreign markets. Cluster- based firms after all have access to knowledge spillovers that not only contain a technological component, but market related information as well (Audretsch and Keilbach, 2004).

Networks of firms imply networks of entrepreneurs. A large presence of networks of ethnic entrepreneurs might enhance the international dimension of a technology agglomeration, both directly and indirectly as can be observed in such well-known technology clusters as Silicon Valley and Route 128 near Boston (Saxenian, 1996; 2005). These individuals develop and maintain global linkages with technology agglomerations in their home countries and in effect contribute to the economic development of these countries while at the same time technology clusters in the US benefit from access to these new industrial clusters (Saxenian and Li, 2003).

Furthermore, areas with high levels of industry clustering often have a strong presence of venture capitalists or other financial services providers that may fund the internationalization process of small firms in the cluster. Venture capitalists often posses the social capital to bring entrepreneurs in contact with firms that have the expertise and (specialized) complementary assets that can be leveraged by the entrepreneur to initiate international activities (Davila et al, 2003). As noted above, the literature suggests several mechanisms by which industrial clusters foster an international orientation in its inhabitants. Therefore I hypothesize that

Hypothesis 1a: Serial innovator firms located in agglomerations with high levels of industry clustering are expected to be more export-intensive than serial innovator firms located in agglomerations with low levels of industry clustering.

Negative effects of industrial clustering on firm internationalization and decreasing returns on agglomeration

Despite the benefits of being located in a dense industrial cluster, there are some disadvantages to increased levels of industrial clustering. Pouder and St John (1996) point to the fact that growing clusters may reach a point where congestion and saturation may begin to 'choke off' the benefits of agglomeration economies. This congestion effect starts to manifest itself when similar firms operating in the same area vie for the same local resources (labor, capital, knowledge inputs, etc) and this might lead to diminishing returns in the benefits of industrial clustering (Arthur, 1990). Other authors have shown that as clusters grow in size, firms residing in the cluster are exposed to increasing congestion costs to the point where individual firm performance starts leveling off or declining, including internationalization (export) activities (Folta et al, 2006).

Organizational ecologists argue that in regions with too much industrial clustering competition is so fierce that firms - especially small ones - may have a hard time gaining access to local resources at reasonable terms (Arthur, 1990). A disconnect from or weak access to key resources in the region, due to fierce competition, may make it difficult for small firms to attract the best employees or the cheapest form of finance (Stuart and Sorenson, 2003; Christopherson and Clark, 2007). Knowledge workers are known to be a key mechanism to channel knowledge spillovers from one firm to another and small firms that experience difficulty in recruiting skilled personnel may lose out in terms of spillover acquisition and absorption (Almeida and Kogut, 1999). If access to local resources is limited, small firms may choose to service other firms in the cluster or focus exclusively on the domestic market, which from a resource point of view is less demanding than pursuing international opportunities in other markets (Castrogiovanni, 1991).

Serial innovator firms develop pioneering, leading edge (general purpose) technologies like novel medical instruments or drugs, new types of digital displays or revolutionizing electronic or photonic devices that enjoy strong patent protection in the US and in many cases in selected overseas markets as well. These technologies furthermore exhibit a high degree of generality (Hicks and Hegde, 2005) a novel digital display, a revolutionary new sensor or novel microprocessor architecture are technologies that have wide applicability across industrial sectors, both in the domestic market and abroad.

Serial innovator firms are in a unique position to negotiate with large firms who do possess (specialized) complementary assets and provide access to product markets or who are operating in the markets for technology and in-license technologies from small, innovative firms (Arora et al, 2001). These are two distinct modes available to serial innovators to internationalize their technology commercialization process. Alternatively, some serial innovator firms may opt to go it alone and secure venture capital or more traditional funding to target international markets. These attributes or characteristics set serial innovator firms apart from the larger group of technology-based firms who may not have the leverage, negotiation power or 'star' power, to emulate what serial innovator firms may do.

Serial innovator firms, due to their pioneering novel technologies, solid position in the technology space, and long list of prominent customers may not be affected as much by increasing levels of industrial clustering as the average small, technology-based firm, and may even successfully compete with larger cluster-based firms for cluster-based resources and access to other institutional resources in their respective locations when levels of industrial clustering keep increasing. That is, these elite firms may not experience diminishing returns in their internationalization activities as a result of increased levels of industrial agglomeration in their MSA locations.

Hypothesis 1b: The relationship between serial innovator firms' location in MSA's with increasing levels of industry clustering and the firms' international intensity is not characterized by decreasing returns.

Firm heterogeneity, industrial clustering, and internationalization

Internal resources play a critical role in deciding to venture abroad and offer the firm's products in international markets. One of those resources obviously is technology, a unique advantage of serial innovator firms that may not only be exploited domestically but in international markets as well. Serial innovator firms are well-known technology pioneers with a stellar reputation in their respective product markets who are regularly profiled and appear in competitive rankings of small companies in widely circulated international business magazines like Business Week, Forbes 200 Best Small companies ranking[29] or Inc. (Hicks and Hegde, 2005), a form of advertising that might well introduce the firm and its technology to customers based in foreign markets.

Having strong technological capabilities and the ability to learn and innovate is a significant advantage for firm internationalization as they help absorb, assimilate, and reconfigure new knowledge into the firm's operations (Knight and Cavusgil, 2004). Serial innovator firms are in a stronger position, capability-wise, to benefit from cluster-based resources in particular, and increased levels of industrial agglomeration in general than the average technology-based firm. Hence I posit that:

Hypothesis 2: Serial innovator firms are expected to benefit more from industrial clustering than non-serial innovator firms, i.e. firm type moderates the relationship between the level of industry clustering and international intensity.

The simple model in Fig. 5 below clarifies the posited relationship

[29] http://www.forbes.com/lists/2007/23/biz_07200best_The-200-Best-Small-Companies_Company.html

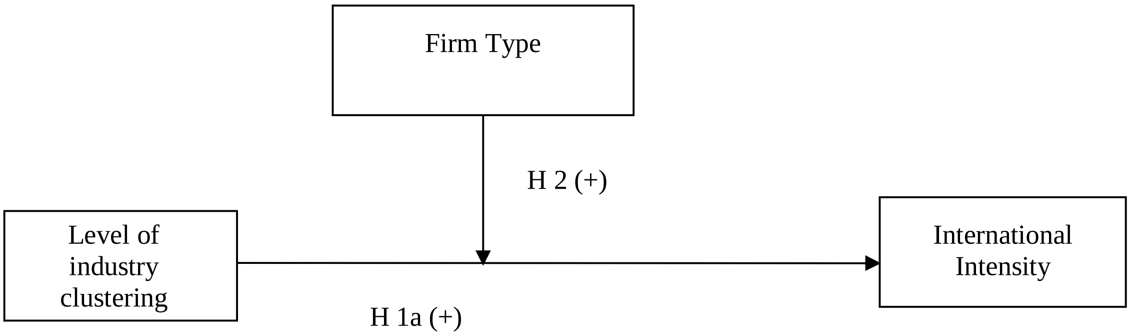

Fig 5. Research model

Dataset

The dataset employed in this essay to address Hypothesis 1a and 1b comprises a defined population of serial innovators[30] – firms with 500 or fewer employees with a portfolio of a minimum of 15 utility patents granted in the 5-year period preceding 2002, who are independently owned, not bankrupt at the time of this study (2006), and are long-lived – a unique set of strong technology-based firms that have built a competitive advantage around a strong proprietary technology and have sustained or strengthened its competitive position while remaining small in size (Hicks and Hegde, 2005). This is a population since we include all US firms that meet the criteria indicated above to specify what a serial innovator firm is.

According to Buchanan[31] these small firms invest substantial time and money in technological innovation. They furthermore adopt or at least mimic best R&D management practices used in large firms and most of them have a formal R&D

[30] The initial dataset on serial innovators was collected under SBA contract SBAHQ-01-C-0149 by Dr. Diana Hicks
[31] Buchanan profiled a number of serial innovator firms in the August 2002 issue of Inc. Magazine

department or group with formal structures, committees for assessing new ideas and approving funds. Compensation of senior management personnel is often tied to the granting of patents or completion of prototypes, in the form of bonuses. She found that these firms tend to set a measurable goal that a certain percentage of their revenue should come from new products or be allocated to R&D activities. Again, these are organizational routines often encountered in much larger firms and this may well be another feature that sets these serial innovator firms apart from the much larger population of small technology-based firms.

The procedure used to define the population can be summarized as follows: firms are labeled serial innovators if they meet the following criteria.

1. have 500 or fewer employees, in line with the Small Business Administration definition of a small firm
2. have been granted 15 or more US utility patents in the period 1998-2002
3. are independent, i.e. not majority owned by a large firm, not a joint venture, and not a subsidiary of a large US or foreign firm
4. are a going concern, not bankrupt in 2006
5. are long-lived, i.e. have survived at least one full economic cycle

Such firms tend to be long lived. It is important to note that this population has been restricted to public firms because of the greater availability of non-patent firm-level data critical to test the propositions put forth earlier.

The author added to the original serial innovator data information derived from COMPUSTAT, the firms' websites, Hoover Database, the Lexis Nexis database and SEC 10-K annual reports. Cluster data is gleaned from the Cluster Mapping Project at Harvard

Business School and cross-checked with location quotient data available from the Bureau of Labor Statistics (BLS). The section on variables and their operationalization contains specific data on the data sources used per variable.

The dataset to address Hypothesis 2 comprises a matched data sample. To conduct a comparative analysis between serial and non-serial innovator firms a matched sample of 'serial innovator' and 'non-serial innovator' firms was created. The matched firms – who do not meet the criteria to be labeled a serial innovator firm - were identified using the following procedure:

1. For each highly innovative small firm I consulted the Hoover's Company & Capsules Database that provides brief information on 40,000 public and non-public companies (Capsules) and 225,000 key executives, to identify a matched non-serial innovator firm. The Profiles include an overview and history of company operations as well as: key officers, competitors, number of employees and selected historical financial data (seven years).

2. For each innovative firm, Hoover's yielded a list of direct competitors, along with their HQ location and work force size – potential non-serial innovator firms.

3. From the list of direct competitors operating in the relevant niche market, I selected one firm incorporated and headquartered in the US, and having a workforce of 500 employees or less. These firms operate in the same 'niche' market segment as the serial innovator firm but have a less stellar record of invention. This step therefore results in the selection of a non-serial innovator firm.

4. In case the list of competitors did not yield a non-serial innovator firm that met these two criteria, a list of competitors from a competing firm was checked; i.e. a competitor of a competitor, often termed “indirect competitor”. The same procedure was followed and care was taken that the firm that met the two criteria outlined above was active in the same sector as our focal firm. The problem with indirect competitors is that the strategic focus of these firms deviates significantly from the focal serial innovator firm. The danger exist that one starts to compare firms with distinctly different knowledge- and technology bases and product portfolios.

5. The procedure highlighted in points 2, 3, and 4 was repeated for each of the innovative firms, resulting in a sample of non-serial innovator firms.

Measures

Dependent variable: To test Hypothesis 1 a,b and 2 we use as dependent variable international intensity (INT_ INTENS) operationalized as the percentage of total sales derived from international markets (Autio et al, 2000; McDougall and Oviatt, 1996; Preece et al, 1999; Reuben and Fisher, 1997). To compute a firm’s international intensity, I divide the average sales derived from outside the US by the total average revenues of the firm in the 5 year period studied, both sourced from the SEC 10 K annual filing for each year.

Independent variable: For Hypothesis 1 a, b the independent variable of interest is the cluster location quotient (**CLQ**), discussed earlier. This is a continuous variable. For

Hypothesis 2, the independent variable is the interaction term between CLQ and Firm Type.

Control variables:

1. Employ - continuous variable, average number of employees of firm in the period between 1998 and 2002. Small firms are most likely to export from urban areas and in concentrated industrial sectors (Mittelstaedt et al, 2006). Until very late into the 20th century, scholars of international business believed that success in foreign markets required large size (Gomes-Casseres, 1997) but the knowledge revolution, technology and globalization have removed many barriers for small, highly innovative firms to venture abroad (Ghoshal and Bartlett, 1999)

2. Age - the age in years of the firm since its inception in 2002. Prior research indicated that older firms have a higher propensity to export than their younger peers (Manez et al, 2004).

3. R&D9802 - The average size of the budget expended on R&D in the period between 1998 and 2002. Prior research indicated that R&D has a major positive impact on export performance (Roper et al, 2006; Yang et al, 2004) but there has been evidence that R&D intensity is not significantly related to export performance (Rodriguez and Rodriguez, 2005)

4. # Patents 9802 - The total number of patents granted to a firm during the period from 1998 to 2002. Prior studies indicate that patents, and patent intensity are strong predictors of export performance (Amendola et al, 1993; Rodriguez and Rodriguez, 2005)

5. Presence of firms with global operations - dummy variable that indicates the presence of firms with global operations or foreign firms in the industry of the focal firm. Foreign firms are commonly attracted to regions with industry clustering (Birkinshaw and Hood, 2000; Shaver and Flyer, 2000) and increase the awareness of small firms to opportunities in international markets (Vernon, 1966). Data is obtained from the Bureau of Economic Analysis, a government agency that collects trade data by state, MSA, and in some instances even county.

6. Industry dummies **-** export performance differs across industries (e.g. Roper et al, 2006)

The model for H1a and b is an OLS model expressed formally as:

$E [INT\_ INTENS \mid X_{i,s}] = \alpha + \beta_1 CLQ + \beta_2 CLQ^2 + \beta_3 Age + \beta_4 Employees + \beta_5 Patents + \beta_6 R\&DExpend + \beta_7 Presence\ of\ global\ firms + \beta_8\ Industry\ fixed\ effects$

The model for H2 is an OLS model that comprises an interaction term:

$E [INT\_ INTENS \mid X_{i,s}] = \alpha + \beta_1 CLQ + \beta_2 CLQ^2 + \beta_3 Firm\ Type + \beta_4 TypeofFirm*CLQ + \beta_5 Age + \beta_6 Employees + \beta_7 R\&DExpend + \beta_8\ Industry\ fixed\ effects$

Analysis and Results

Descriptive Statistics

The bivariate correlation matrix provided in Table 26 indicates that the largest correlation coefficient, between the industry variable representing the semiconductor industry and the Cluster Location Quotient is 0.46 and statistically significant ($p<0.05$). Consequently, no problems with multi-collinearity will be expected although variance inflation factors will be calculated after the fully specified regression model.

Table. 26. Bivariate correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Internat Int	1.00													
2. CLQ	0.33*	1.00												
3. CLQsq	0.23*	0.88*	1.00											
4. Patents9802	-0.03	0.01	-0.03	1.00										
5. Employees	0.16*	0.12	0.04	0.25*	1.00									
6. R&D9802	-0.20*	0.03	0.04	0.44*	0.38*	1.00								
7. Global firms	0.11	0.17*	0.01	-0.11	0.07	-0.05	1.00							
8. Computer&	0.22*	-0.03	-0.02	-0.03	0.05	-0.08	0.06	1.00						
9. Communicat	0.13	-0.04	-0.04	-0.03	0.05	-0.09	0.00	-0.09	1.00					
10 Semiconduct	0.49*	0.46*	0.37*	-0.01	0.07	-0.04	0.10	-0.12	-0.11	1.00				
11. Navigation	0.05	-0.04	-0.02	0.06	0.09	-0.02	0.02	-0.05	-0.04	-0.06	1.00			
12. Surgical	-0.04	-0.08	-0.06	-0.10	-0.08	-0.23*	-0.05	-0.11	-0.11	-0.14*	-0.07	1.00		
13. Electrical Eq	-0.07	0.04	0.02	0.07	0.02	0.05	0.09	-0.05	-0.04	-0.06	-0.02	-0.07	1.00	
14. Pharmaceutical	-0.51*	-0.20*	-0.13	0.07	-0.12	0.40*	-0.18*	-0.24*	-0.23*	-0.31*	-0.13	-0.30*	-0.13	
15. Software	0.03	0.05	-0.02	-0.00	0.11	-0.08	0.15*	-0.07	-0.07	-0.10	-0.04	-0.09	-0.04	-0.20*

* significant at 5%

On average, serial innovator firms export about a quarter of their output to foreign countries (Table 27).

Table 27. Descriptive Statistics – International Intensity of serial innovator firms

Variable	# Obs	Mean	StDev	Min	Max
Exportshare1998	198	.221	.281	0	.94
Exportshare1999	198	.239	.281	0	.97
Exportshare2000	198	.251	.273	0	.98
Exportshare2001	198	.276	.289	0	.98
Exportshare2002	198	.278	.295	0	.99
International intensity	198	.253	.268	0	.93

Moreover, Table 27 shows that the share of exports as a proportion of total sales of the average serial innovator firm has increased rather significantly (5 %) over a short period of five years that coincided with a global downturn in technology markets. Table 28 shows that significant industry differences can be observed in international or export intensity. Some industries are more globalized than others and this is clearly reflected in Table 28, for instance the semiconductor, computer manufacturing, and telecommunications equipment industries are very export-oriented since both production and marketing activities in these industries are very much dispersed across the globe.

Small and medium-sized enterprises have become increasingly prominent international participants in the global market and even engage in foreign direct investments although this again varies by industry, with the computer and peripherals, software, and industrial electronics industries spearheading this pattern (Oviatt and McDougall, 1997; Knight and Cavusgil, 1997).

Table 28. Descriptive Statistics – International Intensity by industry

Industry	Obs	Mean	Stdev	Min	Max
Computer Manufacturing	17	.443	.296	0	.938
Communications Equipm	15	.378	.336	0	.922
Semiconductor	26	.595	.163	.378	.926
Medical devices	24	.218	.205	0	.713
Pharmaceutical	78	.082	.148	0	.794
Software	12	.293	.188	0	.704

Other industries such as the pharmaceutical & biotechnology and medical device industries face high regulatory hurdles both in the home market and overseas and engage in international commercialization activities only when they have received regulatory approval to market their products in the home market (Orsenigo, 1989). In some cases though, these firms first seek regulatory approval overseas (the EU has slightly less stringent regulatory requirements) and subsequently file an application with the Food and Drug Administration later on, but this depends on the corporate and commercialization strategy the firm is pursuing. A more plausible explanation is that small biotechnology firms license their drug compounds to large domestic pharmaceutical companies who subsequently bring these drugs to other foreign markets.

Another factor playing a role is the size, scale and scope of the US market for the technologies developed by serial innovator firms and might in some cases even serve as a disincentive to export. Finally, some serial innovator firms have extensive commercial activity in the US defense sector, another factor that can prevent them from exporting their technologies that are considered ‘sensitive’ by the Department of Defense or the National Security Agency.

Table 29. Means test for International Intensity by industry

Industry	Mean S I firm/Obs	Mean Non SI firm/Obs	Sign
Communicat. equipment	.378/15	.197/15	**
Semiconductor	.595/26	.365/26	***
Computer & Electron Mfg	.420/16	.385/16	n.s.
Navigationalinstrum	.347/7	.316/ 7	n.s.
Surgicalandmedical	.213/28	.188/28	n.s.
Electricalequipment	.124/6	.226/6	n.s.
Pharmaceutical &Biotech	.082/77	.060/77	n.s.
Software & Services	.293/12	.217/12	n.s.

** significant at 5%, *** significant at 1%

A difference of means test (see Table 29) furthermore reveals that the international intensity of serial innovator firms is significantly higher than for the non-serial innovator firms in only two industries, the communications equipment ($p<0.05$) and the semiconductor industries ($p<0.01$). In all other industries no notable statistically significant differences could be found between serial innovators and non -serial innovator firms. In a second matched sample (results are not shown in the interest of space) significant differences in international intensity can be noted in the Communications

Equipment ($p<0.05$), Semiconductor ($p<0.01$), and Computer & Electronic Manufacturing ($p<0.1$) industries.

Hypothesis test for Cluster Location Quotient

Hypotheses 1a & b posit that industrial clustering has a beneficial effect on the export performance of serial innovator firms and that this effect does not suffer from diminishing returns to agglomeration. Across all models[32] in Table 30 the coefficient of interest (Cluster Location Quotient) is positive and statistically significant (at least $p<0.05$) providing support for Hypothesis 1a. Model 8 suggests that a one unit increase in the value of the cluster location quotient leads to an expected increase in international intensity, which is a fraction, of 0.9 percentage points.

The fully specified in Table 30 also illustrates that the parameter estimate on the squared term is not significant indicating support for Hypothesis 1b[33]. The fully specified model includes dummy variables for eight industries and a reference industry, in our case the Miscellaneous industry. The model indicates that firms operating in the Pharmaceutical & Biotechnology industry have an expected level of international intensity that is 12.8 per cent ($p<0.05$) lower than that of the 'Miscellaneous' sector. Firms in the Computer and Electronic Product Manufacturing industry have an expected level of international intensity that is 19.6 per cent ($p<0.05$) higher than that of firms in the Miscellaneous industry. Firms in the Semiconductor industry have an expected level of international intensity that is 32.7 per cent higher than those of their peers in the

[32] All models have been corrected for spatial autocorrelation using the SPATWMT command to create a spatial weights and eigenvalues matrix, and the SPATREG command to subsequently correct for spatial autocorrelation.
[33] A robustness test on the non-serial innovator sample revealed that the coefficient on the squared term was significant ($p<.10$) providing further but weak support for H1b

Table 30. Determinants of International Intensity of serial innovator firms

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cluster Location Q	0.012	0.021	0.021	0.020	0.018	0.018	0.017	0.009
	(4.74)**	(4.65)**	(4.72)**	(4.31)**	(3.61)**	(3.59)**	(3.51)**	(2.13)*
Cluster Location Q^2		-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
		(2.84)**	(2.90)**	(2.60)*	(1.79)†	(1.79)†	(1.73)†	(1.63)
Patents 98-02			-0.000	-0.001	0.000	0.000	0.000	0.000
			(0.82)	(1.43)	(0.20)	(0.19)	(0.27)	(0.23)
Employees				0.000	0.000	0.000	0.000	0.000
				(1.86)†	(2.56)*	(2.52)*	(2.44)*	(0.27)
R&D 9802					-0.005	-0.005	-0.003	-0.000
					(4.69)**	(4.48)**	(4.83)**	(0.78)
Age						-0.000	0.000	-0.001
						(0.13)	(0.10)	(0.42)
Firms with global operations in MSA							0.020	-0.014
							(0.49)	(0.40)
Computer and Electronic Product Manufacturing								0.196
								(2.20)*
Communications Equipment Manufacturing, optics								0.175
								(1.67)†
Semiconductor and related Electronics								0.327
								(4.45)**
Navigational, detection, measuring, control								0.126
								(0.97)
Surgical and medical devices and equipment								-0.007
								(0.10)
Electrical Equipment, Appliances, components								-0.098
								(1.03)
Pharmaceuticals and Biotechnology, Diagnostics								-0.128
								(2.00)*

Software and Services								0.045
								(0.53)
Constant	0.197	0.170	0.181	0.142	0.192	0.187	0.175	0.218
	(9.04)**	(6.71)**	(6.15)**	(3.78)**	(4.76)**	(3.19)**	(2.88)**	(2.60)*
Observations	198	198	198	198	187	187	187	184
R-squared	0.11	0.13	0.13	0.15	0.19	0.19	0.20	0.48

Robust t statistics in parentheses
† significant at 10%; * significant at 5%; ** significant at 1%

Miscellaneous sector ($p<0.01$), and the corresponding figure for the Communications Equipment industry is 17.5 per cent ($p<0.10$). The fit of the model has improved significantly and explains just over 48 per cent of the variation in the dependent variable, an excellent result[34].

Table 31 depicts two within-industry regression analyses. The first model on the left pertains to serial innovator firms in the pharmaceutical & biotechnology sector and indicates that the level of industrial clustering does not affect the internationalization processes of biotechnology & pharmaceutical serial innovator firms (disconfirming Hypothesis 1a and 1b) again highlighting the regulatory issues these firms face or the fact that most of them license their products to large domestic biotechnology or pharmaceutical companies. The second model on the right of Table 31 refers to serial innovator firms in the IT hardware sector (an amalgamation of 4 SIC industries: semiconductor, navigation & instrumentation, Communications equipment, and Computer & Electronic Product manufacturing). Serial innovators in those sectors do benefit significantly from industrial clustering ($p<0.05$) and appear to experience no diminishing returns when the clustering effect becomes very strong confirming Hypothesis 1a and 1b, in line with was found for the entire population in Table 30.

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[34] Multicollinearity is no issue since the variance inflation factors have a mean of 2.56, substantially close to 1 and no individual variance inflation factor exceeding 10 (Rabe-Hesketh and Everitt, 2007).

Table 31. Determinants of International Intensity – by Industry

	Pharmaceutical	IT hardware
Cluster Location Q	0.002	0.034
	(0.94)	(2.07)*
Cluster Location Q^2	-0.000	-0.002
	(0.61)	(0.92)
Patents 98-02	0.072	0.045
	(1.92)†	(2.34)*
Employees	0.003	0.002
	(2.37)*	(4.14)**
R&D 9802	-0.001	0.003
	(1.77)†	(1.69)†
Age	-0.000	0.001
	(0.34)	(2.55)*
Firms with global operations in MSA	0.045	0.030
	(3.22)**	(2.49)*
Constant	0.017	1.164
	(2.58)*	(2.71)*
Observations	147	107
R-squared	0.39	0.44

† significant at 10%; * significant at 5%; ** significant at 1%

To test the robustness of the model, a different way of classifying firms in industries using the North American Industrial Classification System (NAICS) at the 3-digit level has been used to code the industry variable. Table 32 provides the regression results using this specific industry classification scheme and confirms support for our previous results above in that the coefficient on the cluster location quotient is positive and significant, albeit at the 10 per cent confidence level ($p<0.10$) suggesting that for each unit increase in the location quotient, the international intensity increases by 0.7 per cent on average, in line with the results in Table 30.

Table 32. Determinants of International Intensity using the NAICS classification

Cluster Location Quotient	0.007
	(1.67)†
Cluster Location Quotient^2	-0.000
	(0.79)
Patents 98-02	-0.000
	(0.24)
Employees	0.000
	(0.19)
R&D Expend9802	0.000
	(0.21)
Age	-0.002
	(1.13)
Firms with global operations in MSA	-0.045
	(1.28)
Chemical, Pharmaceutical, plastics	-0.498
	(7.49)**
Machinery Manufact	-0.207
	(2.33)*
Computer and Electronic Mfg	-0.121
	(1.88)†
Medical devices	-0.324
	(5.24)**
Constant	0.577
	(5.24)**
Observations	178
R-squared	0.49

Robust t statistics in parentheses
† significant at 10%; * significant at 5%; ** significant at 1%

No decreasing marginal effects in International Intensity can be observed in the fully specified model, again providing support for H1b. The industry effects in Table 32 deviate somewhat from those using the SIC industry classification, and indicate that the chemical, pharmaceutical, and plastics industry along with the medical devices industry exports much less than the electrical equipment and components industry, the reference industry for the industry variable. The computer and electronic manufacturing industry (which includes the semiconductor industry) appears the most export-intensive, after the electrical equipment & components industry in line with the findings made above.

Hypothesis Test for Firm Type

Additionally, another model has been developed to test Hypothesis 2. The hypothesized relationship seeks to examine to what extent Firm Type can moderate the relationship between the level of industry agglomeration (proxied by the cluster location quotient) and international intensity. The results are depicted in Table 33.

The regression results for the first model using the original matched sample reveal that serial innovator firms do benefit more from industrial clustering, by 0.6 percentage points for each additional unit increase in the value of the cluster location quotient, than non-serial innovator firms ($p<0.05$), *confirming Hypothesis 2*. This once more indicates the pre-eminent position that serial innovator firms assume, among both small and large firms, in a technology cluster although there are significant industry differences notably between IT hardware and life science firms. Redoing the analysis using the second matched sample reveals a similar pattern albeit the size of the effect is slightly smaller ($p<0.05$).

Table 33. Impact of Firm Type as a moderator between industry clustering and international intensity

	Matched sample #1	Matched sample #2
Cluster Location Q	0.001	0.002
	(0.33)	(1.77)†
Cluster Location Q^2	-0.000	-0.000
	(1.09)	(1.41)
Type of Firm	0.043	0.052
	(1.68)†	(1.85)†
Type of Firm x Cluster Location Q	0.006	0.004
	(2.53)*	(2.06)*
Employees 2002	0.000	0.001
	(3.42)**	(2.49)*
R&D Expend 9802	-0.002	-0.000
	(2.50)*	(1.77)†
Age	-0.002	-0.004
	(2.51)*	(2.02)*
Computer and Electronic Product Manufacturing	0.193	0.132
	(2.61)*	(2.89)*
Communications Equipment Manufacturing, optics	0.085	0.056
	(1.27)	(1.53)
Semiconductor and related Electronics	0.244	0.438
	(3.85)**	(2.93)*
Navigational, detection, measuring, control	0.137	0.173
	(1.77)	(1.01)
Surgical and medical devices and equipment	-0.008	0.000
	(0.14)	(0.47)
Electrical Equipment, Appliances, components	-0.039	0.012
	(0.51)	(1.12)
Pharmaceuticals and Biotechnology, Diagnostics	-0.117	-0.144
	(2.28)*	(2.71)*
Software and Services	0.014	0.239
	(0.23)	(0.79)
Constant	0.177	0.202
	(3.02)**	(2.24)*
Observations	368	373
R-squared	0.40	0.43

Robust t statistics in parentheses
† significant at 10%; * significant at 5%; ** significant at 1%

Discussion of results

The analysis in the previous section indicated that serial innovator firms located in MSA areas with high levels of industry clustering are significantly more export-intensive than their counterparts that are located in areas with much lower levels of industry clustering providing strong support for Hypothesis 1a. The magnitude of the impact of increased levels of firm agglomeration is decidedly small although at moderate to high levels of industry clustering the effect is amplified. The analysis furthermore revealed no diminishing marginal effects in export performance results providing support for Hypothesis 2b, a result that is interesting and intriguing at the same time. This suggests no negative effects of increased levels of industrial clustering on the export performance of serial innovator firms can be observed, and this might indicate that serial innovator firms are successful in competing for scarce resources in their respective locales, even when this competition becomes fiercer and fiercer and when large established firms or multinational companies vie for the same resources.

As expected, significant industry differences can be observed in export performance with the computer manufacturing industry and the semiconductor sector being the most export oriented industries while the pharmaceutical & biotechnology industry, facing strict regulatory hurdles both at home and overseas and long research and product development cycles, being the worst performer in export performance.

As predicted by the organizational ecology theory the size and diversity (local & traded cluster) of a focal firm's immediate environment does indeed impact organizational performance and validates the central arguments that underpin the theory.

That no diminishing returns could be observed is striking as well, and perhaps an indication that serial innovator firms are in a privileged position within the technology cluster (along with larger firms with international operations who have inherently more power, both market and political) and can successfully compete with other cluster-based firms of all sizes for resources in the MSA. These resources may range from qualified personnel, acquisition of knowledge from university or government laboratories, and access to publicly-funded laboratories, business services and specialized or generic complementary assets owned by other firms. Within-industry analyses reveal significant differences as serial innovator biotechnology firms do not seem to benefit at all from industrial clustering in their efforts to internationalize their commercialization process. Two explanations are advanced here. First strict regulations delay the approval process by many years and are country or region-specific. One has to go through another round of expensive clinical trials to obtain approval from foreign drug regulation agencies. Secondly, many biotechnology & pharmaceutical firms sell their products through the markets of technology to mostly US-based licensees that often possess the complementary assets, including distribution channels and sales forces in overseas markets (provided the products are cleared for marketing in those markets).

A regression analysis based on a matched sample of serial and non-serial innovator firms indicates that serial innovator firms do benefit proportionately more from industrial clustering than their non-serial innovator peers (confirming Hypothesis 2). The analysis provides additional evidence that serial innovator firms behave differently from the larger population of small technology-based firms. These firms appear to be actors in an industrial cluster with better, more privileged access to localized resources and skills than less innovative technology firms.

Conclusion

In this essay, a statistically significant empirical relationship was uncovered between the level of industrial agglomeration and one specific dimension of the downstream innovation process of small, highly innovative firms, their export performance. More specifically, the results of the analysis indicate that for serial innovator firms, industrial clustering has a positive influence on the commercialization performance in general, in the sense that higher values for the cluster location quotient lead to higher expected levels of international intensity. The size of the effect is small, but becomes relatively larger at higher levels of industrial clustering.

It confirms one of the central premises of organizational ecology, which holds that organizational performance can in part be explained by elements of the organizational ecology of the focal firm, and the extent to which this firm is surrounded by other firms with similar knowledge bases and resource requirements. In addition, the theory predicts that at very high levels of industrial agglomeration, when the ecology of like firms becomes very dense and compact, competition for local resources heats up and congestion effects may choke off the positive effects of external agglomeration economies. However, empirically no such attenuation in export performance could be found. Apparently, serial innovator firms behave only partly as explained by the theoretical framework. The explanatory power of the organizational ecology framework is strong and robust although the empirical finding that serial innovator firms are not affected by overcrowding is weak in the statistical sense.

These unique firms might well be able to successfully withstand competitive pressures that come with increasing levels of industry clustering because of internal assets such as expertise, technology, and privileged access to external assets and knowledge. This is certainly another avenue that needs to be explored in further detail. Diminishing returns might be experienced earlier and to a larger extent by non-serial innovator firms.

Interestingly enough, the presence of other, larger firms with global operations that do have the generic or specialized complementary assets which may assist serial innovator firms to commercialize their products in foreign markets does not influence the international intensity of serial innovator firms. This is another future research direction that warrants exploration and ties in with the fact that serial innovator firms often operate in the markets for technology and out-license their technology to larger firms, perhaps not necessarily located in the firm's vicinity, for further commercialization.

The fact that serial innovator firms are more export-intensive than their non-serial innovator counterparts in at least two important industries and that their location in MSA areas with higher levels of industry agglomeration facilitates the internationalization process of these firms has policy implications at different levels of administrative jurisdiction and in a diverse range of substantive policy areas. It is probably safe to state for now that these firms do contribute to the international stature of the technology cluster in which they are located and this identifies yet another research topic that can be examined in future research. These implications however will be discussed in a separate chapter after this essay.

Finally, it was established that serial innovator firms benefit more from industrial clustering than non-serial innovator firms, a finding that provides another avenue for future research into the differential firm behaviors between these two types of firms.

REFERENCES

Almeida, P., and Kogut, B (1999) 'Localization of Knowledge and the Mobility of Engineers in Regional Networks' *Management Science*, 45(7), pp. 905-917

Amendola, G., Dosi, G., and Papagni, E. 1993. 'The dynamics of international competitiveness' *Review of World Economics,* 129 (3), pp. 451-471

Arora, A., Fosfuri, A., and Gambardella, A. 2001. *Markets for Technology: The Economics of Innovation and Corporate Strategy*. Cambridge, MA. MIT Press.

Arthur, W. (1990) 'Silicon Valley Locational clusters: When do increasing returns imply monopoly?' *Mathematical Social Sciences*, 19, pp. 235-251

Audretsch, D.B., Keilbach, M. 2004. 'Does entrepreneurship matter?' *Entrepreneurship Theory & Practice*, 28, pp. 419-430.

Autio, E., Sapienza, H., and Almeida, J. 2000. 'Effects of age and entry, knowledge intensity, and imitability on international growth' *Academy of Management Journal*, 43(5), pp. 909-925

Bernard, A., and Jensen, B. 1999. 'Exceptional exporter performance: cause, effect, or both?' *Journal of International Economics*, 47, pp. 1-25

Birkinshaw, J., and Hood, N. (2000) 'Characteristics of Foreign Subsidiaries in Industry Clusters' *Journal of International Business Studies*, 31(1), pp. 141-154

Bresnahan, T., and Trajtenberg, M. 1995. 'General Purpose Technologies: Engines of Growth' *Journal of Econometrics*, 65 (1), pp. 83-108

Bresnahan, T., Gambardella, A, and Saxenian, A. (2001) 'Old Economy Inputs for New Economy Outcomes: Cluster Formation in the New Silicon Valleys' *Industrial and Corporate Change*, 10(4), pp. 835-860

Castrogiovanni, G. (1991) ‘Environmental munificence: A Theoretical assessment’ *Academy of Management Review*, 16(3), pp. 542-565

Christopherson, S., and Clark, J. (2007) ‘Power in Firm Networks: What it means for Regional Innovation Systems’ *Regional Studies*, 41(9), pp. 1223-1236

Christopherson, S., and Clark, J. (2007) *Remaking Regional Economies: Power, Labor and Firm Strategies in the Knowledge Economy*. Routledge: New York

Coviello, N. and Munro, H. (1995) ‘Growing the entrepreneurial Firm: Networking for International Market Development’ *European Journal of Marketing*, 29(7), pp. 49-61

David, P. A., 1991.General Purpose Engines, Investment, and Productivity Growth: From the Dynamo Revolution to the Computer Revolution, in *Technology and Investment - Crucial Issues for the 90s*, E. Deiaco, E. Hörner and G. Vickery, (eds.), London: Pinter Publishers.

Davila, A., Foster, G., & Gupta, M. 2003. ’Venture capital financing and the growth of startup firms’ *Journal of Business Venturing*, *18*, pp. 689–708

D’Souza, D. and McDougall, P. 1989. ‘Third World Joint Venturing: A Strategic Option for the smaller firm’ *Entrepreneurship, Theory & Practice*, 13(4), pp. 1-31

Delacroix, J., Swaminathan, A. and Solt, M.E. 1989. ‘Density Dependence versus Population dynamics: An Ecological study of failings in the California Wine Industry’ *American Sociological Review*, 54(2), pp. 245-262

Dunning, J.H. 1998. ‘Location and the Multinational Enterprise: A neglected factor’ *Journal of International Business Studies*, 29(1), pp. 45-66

Folta, T.B., Cooper, A.C., Baik, Y. 2006. ‘Geographic cluster size and firm performance’ *Journal of Business Venturing*, 21, pp. 217-242.

Ghoshal, S., and Bartlett, C. 1999. *Managing Across Borders: The Transnational Solution*. Cambridge, MA: Harvard Business School Press.

Glasmeier, A 1988. 'Factors governing the development of High Tech industry agglomerations: A tale of three cities' *Regional Studies*, 22, pp. 287-301

Gomes-Casseres, B. 1997. 'Alliance strategies of small firms' *Small Business Economics*, 9, pp. 33-44

Hannan, M. T. and J. H. Freeman 1989. *Organizational Ecology*, Cambridge, MA: Harvard University Press

Hannan, M., and Freeman, J 1977. 'The Population Ecology of Organizations' The *American Journal of Sociology*, 82(5), pp. 929-964

Helpman, E., and Trajtenberg, M. 1998. Diffusion of General Purpose Technologies, in Helpman, E., and Trajtenberg, M (eds) *General Purpose Technologies and Economic Growth* . Cambridge, MA: MIT Press.

Hicks, D., and Hegde, D. 2005. 'Highly innovative small firms in the markets for technology' *Research Policy*, 34, pp. 703-716

Knight, G.A. and Cavusgil, S.T. 2005. 'A Taxonomy of Born-Global Firms' *Management International Review*, 45(3), pp. 15-35

Knight, G. and Cavusgil, S. 2004. 'Innovation, Organizational Capabilities, and the Born-global Firm' *Journal of International Business Studies*, 35(2), pp. 124-141

Manez, J., Rochina, M., and Sanchis, J. 2004. 'The decision to export: a panel data analysis for Spanish manufacturing firms' *Applied Economics Letters*, 11(11), pp. 669-673

McDougall, P., and Oviatt, B. 1996. 'New Venture Internationalization, Strategic change, and Performance: A Follow up study' *Journal of Business Venturing*, 11(1), pp. 23-40

Mittelstaedt, J., Ward, W., and Nowlin, E 2006. 'Location, industrial concentration, and the propensity of small US firms to export- Entrepreneurship in the international marketplace' *International Marketing Review*, 23(5), pp. 486-503

O'Farrell, P.N., Wood, P., and Zheng, J 1996. 'Internationalization of Business Services: An interregional analysis' *Regional Studies*, 30(1), pp. 101-118

Orsenigo, L. 1989. *The Emergence of Biotechnology. Institutions and Markets in the Industrial Innovation*. London: Pinter Publishers.

Oviatt, B.M. and McDougall, P 1994. 'Toward a Theory of International New Ventures' *Journal of International Business Studies,* 25(1), pp. 45-65

Oviatt, B.M., and McDougall, P.P. 1997. 'Challenges for internationalization process theory: the case of international new ventures' *Management International Review*, 37(2), pp.85-99.

Porter, M.E. 1990. *The Competitive Advantage of Nations*. New York, Free Press.

Porter, M.E. 2000. 'Location, Competition, and Economic Development: Local Clusters in a Global Economy' *Economic Development Quarterly*, 14(1), pp. 15-34

Pouder, R., and St John, C. 1996. 'Hot Spots and Blind Spots: Geographical Clusters of Firms and Innovations' *Academy of Management Review*, 21(4), pp. 1192-1225

Preece, S., Miles, G., and Baetz, M. 1999. 'Explaining the International Intensity and Global Diversity of Early stage technology based firms' *Journal of Business Venturing*, 14(3), pp. 259-281

Qian, G., and Lee, L. 2003. 'Profitability of Small and Medium Sized Enterprises in High Tech Industries: The case of the Biotechnology industry' *Strategic Management Journal*, 24(9), pp. 881-887

Reuber, A.R. and Fisher, E. 1997. 'The influence of the Management Team's International Experience on the Internationalization Behaviors of SME's' *Journal of International Business Studies*, 28(4), pp. 807-825

Rodriguez, J., and Rodriguez, M 2005. 'Technology and export behavior: A resource based view' *International Business Review*, 14(5), pp. 539-557

Romanelli, E. and Schoonhoven, C.B. 2001. The Local Origins of New Firms, in C.B. Schoonhoven and E. Romanelli (eds) *The Entrepreneurship Dynamic*, Stanford: Stanford University Press, pp. 40-67

Roper, S., Love, J, Higon, D. 2006. 'The determinants of export performance: evidence for manufacturing plants in Ireland and Northern Ireland' *Scottish Journal of Political Economy*, 53(5), pp. 586-615

Saxenian, A.L. 1996. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press

Saxenian, A.L. 2005. 'From brain drain to brain circulation: Transnational communities and regional upgrading in India and China' *Studies in Comparative International Development*, 40(2), Summer 2005.

Saxenian, A.L, and Ly, C.Y 2003. 'Bay- to- bay strategic alliances: the network linkages between Taiwan and the US venture capital industry' *International Journal of Technology Management*, 25 (1-2), pp. 137-150

Shaver, J. and Flyer, F. 2000. 'Agglomeration Economies, Firm Heterogeneity, and Foreign Direct Investment in the US' *Strategic Management Journal*, 21(12), pp. 1175-1193

Stuart, T., and Sorenson, O. 2003. 'The Geography of Opportunity: Spatial Heterogeneity in Founding Rates and the Performance of Biotechnology Firms' *Research Policy,* 32(2), pp. 229-253

Teece, D. 1986. 'Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy' *Research Policy*, pp. 285-305

Vernon, R. 1966. 'International Investment and International Trade in the Product Cycle' *Quarterly Journal of Economics*, 80, pp. 190-207

Yang, C., Chen, J., and Chuang, W. 2004. 'Technology and export decision' *Small Business Economics*, 22(5), pp. 349-364

3. IMPLICATIONS FOR POLICY MAKING

Several implications for policymaking can be envisioned from the empirical results. The implications may be operative on one or more levels of jurisdiction and the policy maker may have varying degrees of power to influence the desired outcome. The empirical results derived in this research study likely impinge on more than one substantive policy area. Substantive policy areas that may be relevant for serial innovator firms include tax, R&D, human resources, trade, and innovation policy and the complex, dynamic interplay between these distinct policy areas. I will divide the implications in three separate sections that correspond to the empirical contributions of each of the three essays.

The empirical findings in this dissertation can be summarized as follows:

- Innovative prowess – a defining trait of serial innovator firms – does not correlate positively with the strength of the cluster in which these firms are located. However, there is evidence to the contrary for firms in the pharmaceutical and IT hardware industries.
- Firms with high levels of innovative prowess i.e. serial innovator firms are consistently located in MSAs with a higher number of research universities compared to non-serial innovator firms.
- Industrial cluster strength is positively related to one measure of innovation performance i.e. new product announcements, but has no impact on another measure of innovation performance i.e. the pace of technology progress of serial innovator firms. The pace of technological

progress is considered to be an upstream innovation measure whereas the announcement of a new product initiates the commercialization phase of this product.

- Industrial cluster strength is positively related to commercial performance i.e. measured as the export intensity of serial innovator firms.
- Industrial cluster strength benefits serial innovator's commercial performance (export intensity) more than that of non-serial innovator firm's.

Location of serial innovator firms

Throughout the discussion that follows, the normative assumption is made that firms with high levels of innovative prowess i.e. serial innovators located in a specific spatial jurisdiction are making a positive contribution to local economic development for a number of reasons:

- the presence of such a firm may initiate a new technological trajectory for this region or territory.
- the presence of such a firm may be used by policy makers as a recruitment tool to illustrate the innovative and dynamic potential of the region and lure other firms to the region.
- the presence of such a firm provides high quality jobs, although limited in number. These firms may generate jobs up and down the supply chain.

- the presence of such a firm may have a psychological effect on budding entrepreneurs in the region to start their own venture

The principal finding of the first essay is that firms with high levels of innovative prowess – serial innovators - are not necessarily located in MSA areas with significantly higher average levels of industrial clustering than non-serial innovator firms of similar size. However, industry-specific analyses reveal that such firms in the pharmaceutical & biotechnology and IT hardware sectors are indeed located in MSA areas with a significantly higher degree of regional specialization than their counterparts with much lower levels of innovative prowess. Further examination in the future is required to establish similar patterns in other industries although the population-level regression analysis (that comprises all industries) suggests that at least in some industries no differences in location behavior between firms with differing levels of innovative prowess can be expected.

A second finding was that firms with high levels of innovative prowess are consistently located in MSAs with a higher number of research universities compared to firms that are much less innovative. The former have a need to access and benefit from a pool of expertise in the basic and applied sciences (and newly trained scientists and engineers) that are often present in agglomerations with high levels of technical specialization. Cross-boundary organizational and technological learning through partnerships with universities is stimulated as the innovative prowess of serial innovator firms has been built in part by conducting a significant amount of exploratory research and since there is a (significant) overlap in organizational knowledge bases between these two entities.

With respect to the first finding, beyond the knowledge spillover-seeking behavior of serial innovator firms one can argue that these firms also have a strategic need for (specialized) complementary assets, a need that can be fulfilled by locating in a cluster where these assets are available (a pecuniary advantage). In sum, both pecuniary and knowledge spillovers are important for firms with high levels of innovative prowess. However, as noted above this phenomenon may be specific to certain industries. Pecuniary advantages and knowledge spillovers are certainly important in the pharmaceutical & biotechnology and IT hardware industries. However, the specific location behavior of serial innovator firms in other industries may be different in the sense that both these unique firms and their non-serial innovator peers could be located in industrial clusters of very similar strength.

The finding that pharmaceutical and IT hardware firms with high levels of innovative prowess are located in areas with significantly higher levels of industrial specialization than competing but less innovative firms is intriguing. Upon closer inspection it was found that a much higher proportion of serial innovator firms are engaged in actual drug discovery and development activities whereas non-serial innovator firms are proportionately more engaged in the development of diagnostic tests and assays. The nature of the R&D process in the first case requires arguably more systemic interaction with other geographically proximate actors than in the second case because of the complexity and uncertainty of the innovation process and the array of skills required.

To provide case-based evidence and to help elucidate the policy implications of the location behavior of serial innovator firms I will profile a representative sample of serial innovator firms in more detail. The serial innovator firms discussed here are based in disparate locations and regions around the US so as to provide a balanced picture of the spatial distribution of these firms.

Calipers Technology pioneered the ‘Lab on Chip’ concept and has since its founding in 1995 in Boston, MA revolutionized the way drug discovery is done and has created a whole new market of laboratory tools based on micro and nanofluidics that radically improve the speed by which new molecular compounds are being tested against known disease targets. Calipers generated $140 million in 2007, 70 % from pharmaceutical and biotechnology firms in the US and 30 % from academia and exports.

Evans & Sutherland Inc., a spinout firm from the University of Utah was founded by David Evans and Ivan Sutherland in 1968, two pioneering computer science professors who are widely considered to be the founding fathers of the field of Computer Graphics. Products developed include flight simulators, avionics displays, and virtual reality technology and the firm is not only known for its pioneering technologies but also for its former employees (Jim Clark who started Silicon Graphics, Ed Catmull who founded Pixar Inc, and John Warnock who co-founded Adobe Systems Inc.). Along with Novell Inc, a software and networking company founded in 1984, Evans & Sutherland Inc was responsible for putting the Utah Valley on the map as a center for high technology development, an area that also encompasses the University of Utah and Utah State University. Both firms have spun out numerous other small firms that focus on developing specialized niche technologies.

Ampex Inc.[35], a serial innovator firm, is another Silicon Valley pioneer that was founded just after WWII to commercialize electronic imaging technologies and data storage systems. Today, the Data Systems division of AMPEX continues to shape breakthrough technologies for the acquisition, storage and processing of visual information. It was the first to develop a digital component post-production system using digital image compression technology to produce images of unsurpassed quality. Zymogenetics Inc.[36] (° 1981), based in Seattle, Washington is one of the first firms spun out from the University of Washington's famed life sciences laboratories and was founded by Professors Earl W. Davie and Benjamin D. Hall of the University of Washington and the late 1993 Nobel Laureate in Chemistry Michael Smith of the University of British Columbia to commercialize therapeutic proteins. It was one of the first biotechnology firms in the Seattle area, a locale now known as a vibrant and rapidly growing cluster of biopharmaceutical and other life sciences firms.

Finally, Quidel Inc, a rapid diagnostic test bioscience company commenced operations in 1979 and was one of the first life science firms to be based in the San Diego MSA. The firm develops medical diagnostics kits for a range of disease areas including pregnancy complications, infectious diseases, oncology, autoimmune diseases and osteoporosis, both for professional and research use[37]. The firm was founded by Dr. David H. Katz, an immunologist who was previously employed by the Scripps Research Institute in La Jolla and invented the Suppressive Factor of Allergy (SFA) technology, patented it and commercialized the technology by setting up Quidel Corp. The first

[35] For a more complete profile see http://en.wikipedia.org/wiki/Ampex
[36] For a more complete profile see http://en.wikipedia.org/wiki/ZymoGenetics
[37] For a more complete profile see http://www.quidel.com/about/

biotechnology firm in the San Diego MSA, which was also a diagnostics firm, Hybritech Inc was founded in 1978 and was acquired by Lilly Inc in 1986[38]. Numerous other serial innovator firms have similar histories and development patterns as the one discussed above.

Many of the IT hardware firms that can be labeled as serial innovators are pioneers in their respective product markets and emerged in the eighties and nineties in the well-known technology poles such as Silicon Valley, the Boston area, and the Austin/Dallas, TX corridors and were the early instigators of these technology agglomerations. When these industries (semiconductor, navigation & instrumentation, communications equipment, and computer manufacturing) matured, a dispersion of followers/late entrants – disproportionately made up of non-serial innovator firms with lower levels of innovative prowess and even imitators - could be observed. Examples of non-serial innovators in this respect are Authentidate (°1992 in Albany, NY); Brillian (°1990 in Phoenix, AZ), Neomedia Technologies Inc (°1996 in Fort Myers, FL), Solitron Devices Inc (° 1987 in Miami, FL), Ultradata Systems (° 1995 in St. Louis, MO) and many others. Similarly, some segments of the biotechnology industry such as assay and diagnostics development have matured to such an extent that non-serial innovator firms operating in those product segments can be found in places such as Lansing, MI (Neogen Inc.° 1982), Chattanooga, TN (Chattem Inc. °1886), Atlanta, GA (Theragenics Inc.°1981, Corautus Genetics Inc.° 1992), Portland, OR (AVI Biopharma Inc.°1985) and Houston, TX (Lexicon Genetics Inc °1995), Gainesville, FL (Exactech Inc °1985, Ixion

[38] http://www.sandiegometro.com/1999/apr/biotech.html

Biotechnology Inc.° 1995) among others, locations not known as strong biotechnology or pharmaceutical agglomerations.

From the foregoing exposition it seems clear that economic development policies with regard to small, high technology firms should not be necessarily generic, broad-based and agnostic about the type of firms one wants to attract, grow and retain. Policymakers in charge of economic development should be cognizant about the needs of the region in question, the current inventory of assets and resources resident, the type and development stage of industries and subsectors they seek to target and of course the strategic objectives they aim to realize. Small, high tech firms too consider their needs when selecting a location for their operations, a decision they often deem strategic.

In a fundamental sense, one of the roles of policymakers responsible for economic development is to serve as matchmakers between 'their' region and small, technology intensive firms with the objective to achieve mutually beneficial outcomes for both actors. These individuals therefore need to have a keen understanding of both the needs and objectives of the jurisdiction over which they preside and the entrepreneurs that contemplate locating in the jurisdiction. What the results in the first essay indicate is that economic development policy ought to take into account the industry, degree of reliance on the science base, specific subsectors and their lifecycle aspects and the different levels of innovative prowess that small firms may posses. Indeed, innovative prowess at least in the pharmaceutical & biotechnology and IT hardware sector has proven to be one of the drivers of firm location. However, founders of serial innovator firms make other considerations on where to locate i.e. resistance to relocation for social or family reasons; in IT hardware and the pharmaceutical & biotechnology industry, the most innovative research universities where a large number of the serial innovator firms originate from are located in areas with an already strong presence of firms in these two industries.

In other industries such as e.g. the software or medical devices industries innovative prowess plays no significant role, as indicated by preliminary results in the first essay. For instance, for the software industry we have seven serial innovators located in Silicon Valley (Echelon, Intertrust, Macrovision, Roxio, Secure computing, Immersion), two in the Los Angeles MSA (3 D Systems; Universal Electronics), two in the Boston area (Media 100; Scansoft) with others scattered around the nation in locations like Portland, OR, Las Vegas, NV, St. Louis, MO, Los Angeles, CA etc. The spatial distribution of non-serial innovators the pattern is similar: five firms in Silicon Valley (Intervideo, Communication Intelligence, Teknowledge, Magma Design Automation, Websense), two in the Los Angeles MSA (Smith Micro, Moldflow), and two in the Austin MSA (DTM, Multimedia Games) and other firms in places such as Boston, MA; Portland, OR, Albany, NY etc. In the medical devices industry we have four serial innovator firms in Boston, MA versus six in the non-serial innovator firm group; four serial innovator firms in Silicon Valley versus seven in the matched group; three serial innovator in the Minneapolis, MN area versus three in the control group; four serial innovators in the Los Angeles MSA versus three in the matched group; plus a host of both single serial innovators and non-serial innovator firms in other locations. In both industries, a cursory view at the locations of both groups of firms appears to support the statistical results obtained in the analysis in the first essay. More studies on these and other industries are required to firmly establish that innovative prowess does not play a role in the location of small, innovative firms like serial innovators.

From the statistical analysis in the first essay and the case study evidence presented above it is fair to argue that serial innovator firms are important for *regional economic development* in several respects. First, as an initiator of an entirely new technological trajectory in a particular location that create new market(s) and jobs up and down the supply chain of these firms. Second, as incubators for sustained innovation and novel technologies that may be spun off, basically serving as a vehicle of corporate entrepreneurship in much the same way that large technology companies spin off technologies or have former employees set up their own ventures with ideas gained from the parent company. These spinout firms are likely to be located in the same area as the parent organization, thereby further contributing to economic development objectives set by policymakers in that area. Third, because they work at the technological frontier serial innovator firms are great training places for scientists and engineers who learn valuable skills that can be transferable to other firms in the region, if and when they seek to leave the serial innovator firm.

Policymakers can indirectly influence the workings of the regional innovation system in which serial biotechnology and IT hardware innovators are embedded through a set of policy initiatives aimed at fostering a supportive local environment that nurtures and increases the chances of survival of highly innovative firms. First of all, policy makers need to make an effort to identify serial innovators in their jurisdiction. They can do this by conducting a patent analysis on each small firm in their jurisdiction. Such an analysis will also reveal the knowledge bases on which the technologies developed by serial innovators rest. Regional economic development officials can subsequently design policy instruments that assist serial innovators in their up- or down stream innovation activities, policy interventions that fully leverage and exploit the range of knowledge sources and other resources already present in the region and over which the policymaker has some degree of control (i.e. universities). Specific policy initiatives range from local or state support for research in a field of relevance to the local serial innovator(s) through a grant system, the support of relevant education programs, tax credits, to the recruitment of similar firms with specialized or generic complementary assets by the local economic development agency. More specific policy initiatives that can be formulated and implemented to foster the creation and growth of serial innovator firms will be suggested throughout the remainder of this chapter

Turning to the second principal finding of the first essay which indicated that firms with high levels of innovative prowess were consistently located in MSA's with a larger number of research universities, we can make the following observations regarding policy implications. The disproportional importance of the science base for firms with high levels of innovative prowess has obvious and clear implications for policy makers at several levels. The discussion will be structured around four topics: 1. University Entrepreneurship; 2. Efficiencies in the innovation process through usage of external knowledge sources; 3. Universities as major sources of knowledge spillovers; 4. Increased effectiveness of the innovation process if it is localized and in close proximity to universities

University Entrepreneurship - A significant number of serial innovator firms (thirty two percent) are spinoffs from universities versus only ten per cent of non-serial innovator firms. This observation indicates that university entrepreneurship is very important to fostering and maintaining a larger population of serial innovator firms. This suggests that these university spinoffs who likely maintain formal and/or informal linkages with the parent university will continue to emphasize innovation, and arguably the more radical variant of innovation. The Bayh-Dole Act of 1980 formalized university ownership of intellectual property developed by university scientists and funded by the federal government (Mowery et al, 2001; Mowery and Ziedonis, 2002). This institutional change has contributed to more sophisticated strategies pursued by universities to exploit their intellectual property assets in the form of technology licensing or company start-up formation (Shane, 2004).

Serial innovator firms- particularly in the IT hardware and biotechnology sectors- founded by faculty in entrepreneurial universities can be found in Seattle, San Diego, Austin, Silicon Valley, Boston, and Princeton among others. All these cities are home to research universities with very active university technology transfer offices, in addition to a number of locally-based and experienced risk capital providers. University officials can create policies to foster university entrepreneurship such as attractive royalty-sharing policies, support services for start-up formation and incubation, and the provision of initial seed investment through equity participations (Siegel et al, 2003). However, having well-funded university-based incubators that nurture and churn out firms that seek to commercialize university-invented technologies is one thing, retaining these firms in the local community is quite another as can be illustrated by well-known incubators managed by the Georgia Institute of Technology and other research-intensive universities (Markman et al, 2005; Rothaermel and Thursby, 2005). A substantial number of university spinoffs are being lured or forced to relocate to areas with higher levels of venture capital, since venture capitalists are reluctant to fund ventures far away from their headquarter offices. Serial innovator firms in the life sciences and IT hardware industries are disproportionately present in the strongest industry clusters (that are home to venture capitalists and other risk capital providers) and located in close proximity to universities. It may be the case that some of these serial innovator firms might have been spun out of universities located in areas with low levels of risk capital and relocated to stronger clusters. University science parks are another policy instrument for local or regional policy makers to look at although these initiatives have had a mixed record in the past (Lofsten and Lindelof, 2002). Finally, the regional or even state authorities should consider financial support for basic and applied R&D in strategic areas such as nanotechnology and stem cell research as is the case in California or photonics and optics in Florida, to name just two state initiatives. A combination of these policies will *increase the likelihood* of fostering and creating more serial innovator firms.

Efficiencies in the innovation process through usage of external knowledge sources – The results of the first essay suggested an asymmetric pattern in terms of access to and usage of external scientific knowledge between firms with different levels of innovative prowess, specifically in the biotechnology and IT hardware industries. The innovation processes to develop leading edge technologies are becoming increasingly complex, uncertain, and expensive while at the same time competition on a global scale intensifies and product & technology life cycles shrink (Archibugi and Iammarino, 2002). Firms' internal resources, and specifically serial innovator firms', are being augmented by those in the external environment – notably resources provided by other firms and universities – in a way that will increase the efficiency and reduce the cost of the technological learning process (Gulati, 1999). Policy makers therefore need to understand the systemic character of the innovation process and how the upstream innovation processes of serial innovator firms differ from those of their less innovative peers. Case study-based evidence indicates that serial innovator biotech and IT firms are disproportionately located in very strong industry clusters such as Silicon Valley (IT and biotechnology) and South San Francisco (biotechnology), San Diego (biotechnology), Boston (IT and biotechnology), Northern New Jersey (biotechnology) etc. and develop more pioneering technologies (medical drugs) that require intense systemic interaction with other spatially proximate actors than other serial innovators (that focus on medical diagnostics and assays) or non-serial innovators that are more dispersed across the US.

Policies can be crafted to increase interaction with the science base through such initiatives as a grant system that encourages collaboration with a university or setting up University/Industry research centers at the local universities, very few of which are already located in the strongest industrial clusters in the US (Santoro and Chakrabarti, 2001)[39]. The main objective is to maintain existing linkages with serial innovators and increase the absorptive capacity of their less innovative peers. In doing so, the pace of technological learning within non-serial innovator firms will pick up and the likelihood for these firms to create patentable frontier technologies will increase.

Universities as sources of major knowledge spillovers – Theoretical knowledge produced in university research laboratories is being spilt over into the public domain in various formats using a variety of communication media (Anselin et al, 1997). The uses of this knowledge vary along the innovation spectrum from incremental to radical

[39] See for a list of Industry and University Cooperative Research Centers http://www.nsf.gov/eng/iip/iucrc/directory/index.jsp

innovation. Collaborative research, licenses, patents, trained scientists and engineers, the academic literature are all media through which knowledge diffuses, providing inputs at the early or later stages of the innovation process (Cohen et al, 2002). Knowledge spillovers in biotechnology and IT are especially prominent and appear to benefit serial innovators in those sectors as demonstrated by the results of the first essay.

Nowadays universities - as a networked actor in the regional or local innovation system - produce knowledge in a Mode-2 type of knowledge creation process that is transient, transdisciplinary, socially accountable and reflexive in nature (Gibbons et al, 1994). Furthermore, this process and the knowledge it creates is viewed in the context of application and blurs institutional boundaries. Serial innovator firms are a key participant in this Mode 2 knowledge creation process, more so than non-serial innovator firms, a key reason why these firms arguably have higher levels of absorptive capacity that allows them to evaluate, assimilate and integrate relevant knowledge originating from the science base.

Increased effectiveness of the innovation process if it is localized and in close proximity to universities – Incipient knowledge has high levels of tacitness, is complex, and is sticky (Von Hippel, 1998). Face-to-face interaction with university-based scientists and engineers facilitates the effective transfer of knowledge and will shape the technological profiles of the firms that interact intensively with research universities. Such localized interaction will influence the region's scientific and technological profile over time (Zucker et al, 1998). Furthermore, proximity to a university will place firms with high levels of innovative prowess into a more privileged position to observe promising researchers and scientists that can later be recruited by the firm. Policymakers at the state or regional level can facilitate the co-location of small, highly innovative firms – serial innovators or firms with the potential to become one – by instituting and supporting university-based business incubators or technology parks.

In addition to what has been discussed above there is evidence that the *birth of some technology clusters* could well be attributed to some of these serial innovator firms who put technological trajectories 'on the map' in a particular location (see the short profiles of a selection of serial innovator firms above) and may subsequently have instigated a bandwagon effect when similar firms or firms with similar technologies either emerged in the same location or relocated from other locales. Furthermore, entirely new markets or market segments have been created by serial innovator firms that have resulted in a geographical agglomeration of firms who specialize in a specific technology. Given the average age of the serial innovator firms in the dataset and the continuing technological leadership role assumed by these organizations since their inception it might well be conceivable that a disproportionate number of serial innovator firms have had this effect on their local environments. More detailed qualitative survey and case study research is needed to probe the role of some of the serial innovator firms in the emergence and early growth of a technology cluster.

Performance differentials and geographic clustering

The principal findings of the second essay indicate that the strength of clusters does positively impact innovation performance measured as the rate of new product announcements in a particular year i.e. 2002, but has no bearing on the speed of technology development in the population of serial innovator firms.

There is probably little local and regional policymakers can do to influence firm performance beyond providing a local environment conducive to doing business. Policymakers might apply both supply- and demand-side incentives to nurture, sustain or revitalize the dynamics of a cluster (Porter, 1998). Supply-side strategies assist producers and the market rewards the most efficient and/or innovative ones. A demand-side focus targets customers, both in consumer and industrial markets, and their consumption of goods and services.

Supply-side incentives or initiatives develop or upgrade input factor conditions such as stronger support for local universities, research institutes, or vocational training institutes and the bridges of these institutes with the business community can be influenced by local/ regional policy makers. One important factor that is crucial to the innovative success of serial innovators is the availability of high quality human capital. Serial innovators clearly have a need for top notch scientists and engineers and technically schooled individuals with a keen understanding of market needs and trends and who have the social capital to tap into relevant networks to ensure the long-term viability of their businesses. Regional policymakers could facilitate the formation of social capital and regional business networks by initiating forums, workshops, seminars and formal and informal gatherings sponsored by the local economic development agency. The supply of high quality skilled labor is a necessary though not sufficient condition to attract, nurture, and retain serial innovator firms. Regional policymakers therefore must support local universities, research institutes and vocational schools in areas relevant to serial innovators. Another factor critical to the creation, sustainable development and survival of serial innovators is the availability of sufficient levels of risk capital. Serial innovators – at the very least in the biotechnology and IT hardware sectors - are disproportionately present in MSAs with stronger levels of technical specialization with ample numbers of venture capitalists, business angels and other private investors with an interest in those industries. In MSAs with a lesser endowment in risk capital, the local or regional economic development agency could serve as investor or co-investor in promising new ventures that may develop in serial innovator firms. Innovation, and especially the development of pioneering technologies is both risky and expensive and the availability of and access to financial resources is a precondition for developing new products based on these breakthrough technologies and the rate at which this process occurs. Serial innovators particularly in the biotechnology and IT hardware sector are on average located in MSA with significantly lower levels of technical specialization and are therefore disadvantaged by not having as many specialized risk capital providers around to nurture, sustain and expand innovative (e.g. new product development) activities.

Finally, innovative performance – although not tested in the second essay - might well be determined by the access and quality of external knowledge sources such as research universities. From the results in the first essay it became clear that serial innovators are consistently located in MSAs with a significantly larger number of research universities than non-serial innovator firms. The rate of new product announcements is higher in MSAs with stronger levels of technical specialization since being located in such an area allows for more systemic interactions with other actors including other firms and customers and results in more efficient technological learning and innovation outcomes. Taking a ‘regional systems of innovation’ perspective, policymakers that can create, sustain, and improve the linkages between and among the various actors in the system will stimulate system-wide and firm-level technological learning that will result in enhanced innovation performance at both levels (Cooke, 2001). The creation and management of these linkages can be influenced by policymakers by creating bridging institutions (e.g. TTO offices at government labs, research institutes, and universities) or other tools mentioned in the first section of this chapter on the location of serial innovator firms.

On the demand side, government, both at the state or federal level may take the lead in serving as a sophisticated lead user for serial innovator firms pioneering output, as the Defense establishment, Homeland security or the Environmental Protection Agency have an enormous need for new technologies to address complex problems. This is certainly the case for serial innovator firms such as Secure Computing Inc (encryption and security related software tools), Evans & Sutherland Inc (avionics, UT), Xybernaut (wearable computing for defense, VA), Capstone Microturbine (low emissions microturbine systems, CA), Copytele (encryption devices, NY), Fargo Electronics (personal identification cards, biometrics, MN), American Science & Engineering (X ray inspection systems, MA) and many others who derive substantial shares of their annual revenue from public sector markets. This is not a pure market-based solution although the government constitutes an attractive market in its own right targeted by many private firms that develop sophisticated technologies. A cursory analysis indicates that serial innovator firms engaged in federal government contracting seem to be scattered across the US with no notable concentrations of firms around Washington, DC.

The federal government operates an extensive network of small business development centers that assists small firms[40] in general and serial innovator firms in particular in aligning their marketing strategies with the requirements of potential customers or serve as brokers to link serial innovator firms with other small firms that have a need for sophisticated cutting-edge technologies. The Small Business Administration, the government agency that administers the small business development center network issues periodically calls for proposals for setting up additional small business development centers (Buss, 2002). These Small Business Development Centers are key tools for regional policymakers to assist entrepreneurs and to link supply with demand across a range of industrial sectors, technologies, products and services.

Furthermore, the federal government must ensure the smooth working of the markets for technology in which many serial innovator firms operate. Small, technology-intensive firms often face power asymmetries when they seek to license their technologies to large, dominant companies. To mitigate such asymmetries could provide affordable and excellent legal counsel through e.g. a Small Business Development Center to these small firms when they enter licensing negotiations with much larger firms. Finally, the social capital of the entrepreneur will undoubtedly play a major role in developing new business within and outside of the region and raising initial funding. As indicated earlier, the regional authorities can play a constructive role in helping entrepreneurs build the social capital required to sustain and grow their firms.

Industrial agglomeration and small firm internationalization

[40] For more information on the network of Small Business Development Centers, a program by the Small Business Administration (SBA) see http://sbdcnet.org/

The principal findings of the third essay indicate that the export performance of serial innovator firms is positively related to the strength of the industrial cluster in which they are located and that serial innovator firms proportionately benefit more from industrial clustering than non-serial innovator firms. Serial innovator firms as indicated earlier are at the forefront of the technological revolution in their respective industries and are developing breakthrough technologies, some of which are application-specific while others are more generic in nature. Since the dawn of globalization and the technological revolution that facilitated and fueled this globalization process, international trade has been dominated primarily by large firms (Patel and Pavitt, 1991; Storper, 1992; Cantwell, 1995). Globalization as a transformation process affects different industries in different ways and some industries appear inherently more global than others as evidenced by both large number statistical studies and case studies, and that industries are globalizing over time, albeit at different speeds. The federal government should facilitate and promote free trade, including the trade of high technology products and services. Free trade facilitation and promotion with other countries should not be restricted to the federal government as states may initiate and develop their own trade programs that can be tailored to meet the needs of small firms in certain industries, subsectors or even technologies.

National security policy is an area that may pose a problem for serial innovator firms to export their product offerings to foreign markets and the US Commerce Department has long sought to impose export controls on sensitive technologies, although the viability of these restrictive trade policies is increasingly called in doubt since a significant portion of military technology is available on the commercial market. Anecdotal evidence from serial innovator in the dataset that are major suppliers of technology to the Department of Defense (DoD) indicates that indeed, these firms are rarely engaged in export activities for probably the reasons just alluded to and because of the current demand for their products and services in a time of war. The technologies developed by serial innovator firms therefore have clearly implications for national security policy, health policy at home and abroad (e.g. Trimeris, a serial innovator firm that developed a new class of HIV/AIDS drugs that can be used by infected people whose virus has become resistant to all other available drug regimens and uses Roche America Inc as commercialization partner) or environmental policy which all have inherently international dimensions.

Throughout the coding process of the dataset it became clear that a sizable number of serial innovator firms were founded by foreign-born entrepreneurs or had one or multiple foreign executives in their top management team. This should come as no surprise since a significant portion of serial innovator firms are located in the San Francisco Bay area, Boston, New York, San Diego, Austin, Minneapolis and Los Angeles MSA's, areas well known for their presence of networks of immigrant knowledge workers, many of whom hold advanced degrees in engineering or the sciences from the best US universities. Although not controlled for in this study, the presence of such individuals will likely have an impact on the propensity for these firms to internationalize their commercial operations. Korean, Israeli and Taiwanese entrepreneurs in Silicon Valley play an important role in the semiconductor and electronic components industry, while Indian entrepreneurs are primarily engaged in software-related ventures as demonstrated by previous research (Saxenian, 2002 and 2005). The presence of these individuals and their role as both catalysts for high-tech entrepreneurship or employment points to the fact that policymakers need to recognize the growing interrelationships between immigration, trade, and economic development policy. This is another interesting avenue to explore for further research in the context of serial innovator firms.

Another implication of the results in the third essay is that technology clusters do seem to positively impact export performance, at least for serial innovator firms. Governments do get involved in export promotion at several levels. The most extreme case of an outward trade policy is that of setting up export processing zones, a tool that has often been used for economic development, primarily in developing and emerging economies and that use low wages and tax incentives as policy instruments to stimulate exports in specific industries.

In contrast to artificial agglomerations such as export processing zones, this study exclusively deals with 'natural' technology clusters that in almost all instances have not been created through deliberate government policy. A softer trade policy tool are export promotion programs which are provided by the government (federal, regional, local) to help firms, especially small and medium-sized enterprises in an effort to overcome real or perceived obstacles to internationalize their commercialization processes. Empirical evidence offered in the third essay pointed to the fact that serial innovator firms are more export- intensive than their non-serial innovator firm counterparts in at least two important industries, semiconductors and communication equipment manufacturing. Serial innovator firms could benefit from such programs probably more since they offer in many ways unique technology solutions to customer's problems in ways that large and small, less innovative firms can't match.

Furthermore, another finding in the third essay indicates that some small technology-based firms, in our case serial innovator firms benefit more from industrial clustering than other small, less innovative technology firms. The policy implication of this finding can be framed as follows. Viable regional economic development policies seek to create self-sustaining regional economies, including technology clusters, and since serial innovator firms are successful innovators that have a unique ability to sustain their innovation efforts and have great export potential, they ought to play an important role in the regional economic development strategy with regional and spatial multiplicator effects (in terms of indirect job creation, technology spillovers etc) rippling through the local economy.

Finally, serial innovator firms who develop unique general purpose technologies may set (de facto) industry technical standards that may even be adopted by the National Institute of Standards and Technology (NIST) and which will certainly help diffuse the technology across national borders. Examples of serial innovators that have set actual technical standards or de-facto industry standards are Trimeris (HIV fusion inhibitors), 3 D Systems (3-D stereolithography rapid prototyping system), MIPS Technologies (RISC Processor technology), Roxio (CD and DVD burning software), VISX (Lasik laser vision correction technology) and others. Owning a strong portfolio of patents on a novel (general purpose) technology may help a firm establish a formal or de-facto technical standard (Funk and Methe, 2001). A US national technical standard will almost always be adopted by other countries, as is prominently the case in the IT, nanotechnology and telecommunications industry, among others.

Integration of the empirical results and policy implications

The results of the first essay suggest that the level of innovative prowess of small, technology-based firms is not a discriminating factor in deciding whether the firm is located in a strong industrial cluster or a weaker one. However, exceptions to this finding can be observed in the pharmaceutical and the IT hardware industries in line with many other findings reported in the literature. A comprehensive search of the literature on studies that pertain to industrial clusters or agglomerations reveals that 345 peer-reviewed articles have been published in journals adopted by the Science Citation Index. The vast majority (73 %) of these studies on industrial clusters focus on only two industries, the life sciences and the information technology industries. Economic development policies as a result have been informed primarily from the findings based on these two high-tech sectors.

The findings in the first essay are based on nine industries and suggest that the most innovative firms – those with the highest levels of innovative prowess – are not necessarily located in areas with higher levels of industrial clustering than their less innovative peers as much of the cluster literature suggests. Innovative prowess and its impact on geographical location does play a role in certain industries but not in others. Hence economic development policies should be industry-specific and even subsector-specific. As the population of serial innovator firms grows, more empirical studies applying standard regression analyses across many industries could pinpoint how cluster and economic development policies regarding small, highly innovative firms should be tailored by industry, subsector, and perhaps even technology. The approach and results reported in the first essay is a first important step in this direction.

Another finding from the first essay is that innovative prowess is associated with having many research universities located in the same MSA. Furthermore, significantly more serial innovator firms have been spun off from research universities than non-serial innovator firms, indicating that university entrepreneurship is a key mechanism for the creation of serial innovator firms and that the university 'DNA' is partly inherited by the spinout (as will be reflected in the serial innovator's continuing activities in technological innovation and perhaps even basic research, with company scientists extending their collaborations and publication activities with peers based at the university or other academic institutions). This observation is consistent with findings in the extant literature that demonstrated that technologies developed at research universities have a high science-content, are often more generic, and are of a radical nature. Indeed, research universities have been largely responsible either directly or indirectly for the creation of entirely new industries such as biotechnology, medical devices, nanotechnology and certain sub-sectors of the Information Technology sector. University spinouts typically tend to locate not far from the parent university with which they maintain informal or formal relationships.

Serial innovator firms that do not directly originate from a specific university have very often been founded by a highly educated scientist or engineer that spent part of his or her career in a technical position at an incumbent company. Proximity to research universities is important for serial innovator firms across all industries.

The second essay provides empirical evidence that innovation performance expressed as the rate of new product announcements is positively related with the strength of the industrial cluster. Another measure of innovation performance however – the speed of technology development – does not appear to be affected by the level of industrial clustering. In contrast, a measure for commercial performance – the export intensity of serial innovator firms – appears to be enhanced by the strength of industrial clusters.

Tying together the findings from all three essays we can state the following: innovative prowess – a defining characteristic of serial innovator firms – has no real impact as to where serial innovator firms are located (strong or weaker clusters) although we observe differences across industries. Furthermore, the strength of industrial clusters has a salutary effect on one dimension of innovative performance (new product announcements) but not on another (innovation speed). In contrast, the strength of clusters has always a positive impact on the commercialization success of serial innovators (as measured by their export intensity) – firms with high levels of innovative prowess. These unique firms appear to benefit proportionately more from industrial clustering in their commercialization activities than non-serial innovator firms.

From an economic development policy perspective, the fact that many serial innovator firms are spinouts from research universities is particularly relevant since policy makers, including those in charge of the local higher education system have a significant degree of control and potential impact on this specific mechanism for technology transfer from research universities. No one specific policy should be applied across the board since many different (contextual) parameters would inform and guide the policy formulation and implementation process on university technology transfer. Different policy options can be envisioned that take into account the specific context and environmental conditions of the region.

One policy option focuses on serial innovator firms spawned by rural research universities who develop great pioneering innovations but are not necessarily commercially successful since not all of them are located close to their customers, capital providers or other firms in the same line of business i.e. industrial clusters and therefore may not benefit from the advantages provided by industrial clusters. To ensure maximum impact on local economic development, policymakers try to craft favorable policies regarding technology transfer at such universities as well as create a local ecosystem that ensures the retention of these highly innovative firms. Specific examples are Third Wave Technologies, a genomics company and Bone Care International, a biotechnology firm, both located in Madison, WI and spinouts from the University of Wisconsin-Madison; and Oak Technology Inc, a semiconductor company based in State College, PA a spinout of the Pennsylvania State University.

A second policy that can be pursued is to facilitate the formation of serial innovator firms from research universities that develop pioneering technology that have the potential to initiate a new industry in the region. Policymakers should first be aware of the breakthrough technologies developed by serial innovator firms spun out from universities and the potential of these technologies for regional economic development. They subsequently may proceed with the formulation of a policy that includes both financial and non-financial incentives for highly innovative firms to assist in the growth and nurturing of these firms and maximize their survival chances. Notable examples of firms that had this transformative effect on specific regions include Evans & Sutherland (°1968), a computer vision firm spun out from the University of Utah; Myriad Genetics (°1991), a pioneering molecular diagnostics firm founded by Professor Walter Gilbert, Nobel Laureate in chemistry 1980; Sonic Innovations (° 1991), the world's leading digital hearing aid developer and spinout from the Brigham Young University; American Superconductor Technology (°1987), a developer and manufacturer of superconductor wires founded by three MIT professors and others.

Finally, a third economic development policy specifically for serial innovator firms is to stimulate local research universities to spin out firms in industries with a strong local presence i.e. strong industrial clusters. Policymakers should focus their policies on building up industry-relevant research capabilities in the local research universities across the basic-applied research spectrum. Examples are legion and include numerous serial innovators in Silicon Valley and South San Francisco that emanated from research laboratories at Stanford University, the Universities of California at San Francisco and Berkeley, and spinouts from the many academic institutions in the Boston area and the Research Triangle Park.

In reality, the last two economic development policy options are often indistinguishable as is prominently the case in e.g. Silicon Valley, Research Triangle Park and the Boston area where universities were both the source of new groundbreaking technologies that started new industries and where local and regional policymakers have channeled resources and crafted policies to further build research capabilities in local research universities relevant to the local industries to create a symbiotic relationship that benefits all actors in the regional innovation system.

Final thoughts

As described above, the policy implications of the findings regarding the spatial influences on some firm-specific measures of this population of small, highly innovative firms are diverse, multi-faceted and numerous. However beyond the implications and policy options discussed and suggested above, policymakers have only so much influence over firms that operate in a market economy as free as the one in the United States. In this last section, I like to highlight some additional implications that leave policymakers often in a bind as to what policy to formulate or what existing policy to tweak.

The importance of the presence of serial innovators in a specific locale has some profound implications for cluster and local development policies. A preliminary and cursory qualitative analysis indicates that clusters that do not feature small, highly innovative firms such as serial innovators – firms that can be viewed as engines of sustainable innovation – may show signs of premature ageing or even decline. For instance, the optics cluster in Rochester, NY area is dominated by a few very large incumbent firms (Eastman Kodak and Bausch & Lomb) and a host of smaller supplier firms (none of which are serial innovators) that are pre-dominantly focused on incremental innovations and routinely face hard times during economic slumps (with massive layoffs) and take longer to recover from market disruptions. Other clusters in a declining stage or that struggle with economic competitiveness are the textile and furniture clusters in South and North Carolina, the automotive cluster in Detroit, the golf equipment cluster in New England, and the large defense equipment cluster in Los Angeles (again clusters that do not house any serial innovators). However it must be noted that this claim essentially amounts to a conjecture and that a more rigorous analysis is required to test that hypothesis.

In contrast, the strong biotechnology and IT hardware clusters in which serial innovator firms are located (see results from the first essay) are vibrant centers of innovation that can continuously regenerate or revitalize themselves and quickly recover after an economic recession. The danger is that clusters without small, highly innovative firms that constantly develop novel, radical technologies and whose economic activity is dominated by a small number of large firms and their supply base, may lose their innovative luster, find themselves struggling for legitimacy or relevancy or in the worst case disappear entirely. Hence the task before policymakers to foster the creation, growth, and survival of a set of small, highly innovative firms i.e. serial innovators in their region by e.g. supporting university entrepreneurship.

The last essay suggests that serial innovators are better integrated in global value chains and this may aid in the continuous and discontinuous upgrading of the cluster if the serial innovator firm happens to be located in a strong or even a weaker cluster. Indeed it might well be that the suppliers (and part of its customer base) of these serial innovator firms are located in the vicinity and hence feel the pressure to upgrade their operations and offerings to conform to expectations set by serial innovator firms and indirectly by other (larger) companies in the global value chain. This is prominently the case for serial innovator firms in the IT hardware sector and in the biotechnology & pharmaceutical industry through large intermediaries (large pharmaceutical and biotechnology firms that are often co-located with serial innovator firms) who appear to be located in much stronger clusters than their non-serial innovator peers as suggested by the results in the first essay. Inclusion in a global value chain also guards a cluster against group-think, where cluster-based firms adopt an inward-looking attitude that prevents them from embracing truly novel ideas and developing radical technologies (e.g. the Detroit automotive cluster that very slowly adapts to developing and marketing more fuel-efficient cars).

This has important implications for policymakers in charge of economic development in the sense that they first need to be aware of the existence of serial innovator firms in their areas and elsewhere, the earlier the better. Second, policymakers must develop an appreciation of the importance of serial innovator firms for economic development and the fact that these firms drive competitiveness and innovation in a local cluster. Third, policymakers should also be cognizant of the international profile of these small firms as they are often integrated in global value chains and are operating at the global technological frontier and pick up shifts in customer requirements and preferences from disparate locations around the world (that are fed back to the local cluster and make other cluster-based firms aware of both opportunities, threats, and shifts that are taking place in global industries such as IT hardware and software and pharmaceuticals & biotechnology to name just two). Serial innovator firms therefore serve not only as local knowledge spillover generators but also act as a conduit for knowledge spillovers- often with a strong market-related component – that originate from locations outside the local cluster. Such knowledge spillovers contribute to the 'buzz' in industrial clusters that cluster-based firms filter for relevancy and incorporate it into their corporate strategies.

The policy implications described in this chapter represent by no means an exhaustive list and undoubtedly other implications not discussed here might have subtle, complex and obtuse direct or indirect influences on the behavior of this set of small, unique firms.

REFERENCES

Anselin, L., Varga A., and Acs Z. 1997. 'Local geographic spillovers between university research and high technology innovations' *Journal of Urban Economics*, 42(3), pp. 422-448

Archibugi, D., and Iammarino, S. 2002. 'The globalization of technological innovation: definition and evidence' *Review of International Political Economy*, 9(1), pp. 98-122

Bartlett, C., and Ghoshal, S. 1989. *Managing Across Borders: The Transnational Solution*. Boston, MA. Harvard Business School Press.

Buss, F. 2002. 'Emerging high-growth firms and economic development policy' *Economic Development Quarterly*, 16(1), pp. 17-19

Cantwell, J. 1995. 'The globalization of technology- what remains of the product life cycle' *Cambridge Journal of Economics*, 19 (1), pp.155-174

Cohen WM, Nelson RR, Walsh JP. 2002. 'Links and impacts: The influence of public R&D on industrial R&D' *Management Science*, 48(1), pp. 1-23

Cooke, P. 2001 'Regional innovation systems, clusters, and the knowledge economy'. *Industrial and Corporate Change*, 10 (4), pp. 945-974.

Funk, J., and Methe D. 2001. 'Market-and committee-based mechanisms in the creation and diffusion of global industry standards: the case of mobile communication' *Research Policy*, 30, pp. 589-610

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., and Trow, M. 1994. *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*. London: Sage.

Gulati, R. 1999. 'Network location and learning: the influence on network resources and firm capabilities on alliance formation' *Strategic Management Journal*, 20(5), pp. 397-420

Lofsten H., and Lindelof P. 2002. 'Science parks and the growth of new technology-based firms – academy-industry links, innovation and markets' *Research Policy*, 31(6), pp. 859-873

Markman, GD., Phan, PH, Balkin, DB., and Gianiodis P. 2005. 'Entrepreneurship and university-based technology transfer' *Journal of Business Venturing*, 20(2), 241-263

Mowery, DC., Nelson RR., Sampat BN, and Ziedonis AA. 2001. 'The growth of patenting and licensing by US universities: an assessment of the effects of the Bayh-Dole Act of 1980' *Research Policy*, 30(1), pp. 99-119.

Mowery, DC., Ziodonis AA. 2002. 'Academic patent quality and quantity after the Bayh-Dole Act in the United States' *Research Policy*, 31(3), pp. 399-418

Patel, P., and Pavitt, K. 1991. 'Large firms in the production of the worlds technology-An important case of non-globalization' *Journal of International Business Studies*, 22 (1), pp. 1-21

Porter, ME. 1998. 'Clusters and the new economics of competition' *Harvard Business Review*, 76(6), pp. 77-92

Rothaemel FT., and M. Thursby. 2005. 'Incubator firm failure or graduation? The role of university linkages' *Research Policy*, 34(7), 1076-1090

Santoro, MD., and AK Chakrabarti. 2001. 'Corporate strategic objectives for establishing relationships with university research centers' *IEEE Transactions on Engineering Management*, 48(2), pp. 157-163

Saxenian, A. 2002. 'Silicon Valley's new immigrant high-growth entrepreneurs' *Economic Development Quarterly*, 16 (1), pp. 20-31

Saxenian, A. 2005. ‘From brain drain to brain circulation: Transnational communities and regional upgrading in India and China’ *Studies in Comparative International Development*, 40 (2), pp. 35-61

Shane, S. 2004. ‘Encouraging university entrepreneurship: The effect of the Bayh-Dole Act on university patenting in the United States’ *Journal of Business Venturing,* 19(1), pp. 127-151

Siegel, D., Waldman D, and A. Link. 2003. ‘Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: an exploratory study’ *Research Policy*, 32(1), pp. 27-48

Storper, M. 1992. ‘The limits to globalization – Technology districts and international trade’ *Economic Geography*, 68 (1), pp. 60-93

Von Hippel, E. 1998. ‘Economics of product development by users: The impact of sticky local information’ *Management Science*, 44(5), pp. 629-644

Zucker, LG., Darby M., Brewer, M. 1998 ‘Intellectual human capital and the birth of US biotechnology enterprises’ *American Economic Review*, 88(1), pp. 290-306