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Determinants of Scientist Entrepreneurship: An Integrative Research Agenda

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Chapter 6

DETERMINANTS OF SCIENTIST ENTREPRENEURSHIP: AN INTEGRATIVE RESEARCH AGENDA

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1. INTRODUCTION

The purpose of this paper is to synthesize the literature to guide an incipient research focusing on the links between innovation, universities, regions, individual entrepreneurs and public policy to discuss implications for scientist entrepreneurship. This literature review identifies that there has been no single literature dealing with this issue. Rather, distinct literatures have emerged which have provided considerable insights. However, most of the insights have been restricted to the one dimension, or unit of analysis, being analyzed, rather than the nexus of multiple levels of analysis.

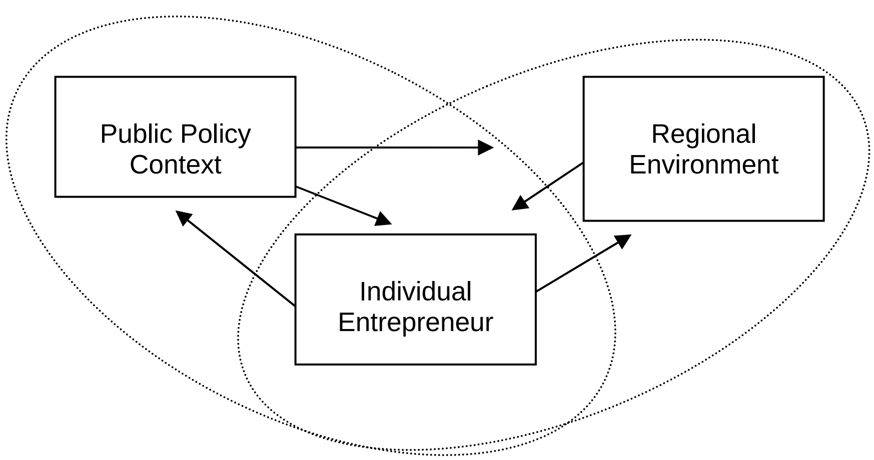
As not much is known about the cognitive process leading scientists to pursue entrepreneurial paths, research in this area is sorely needed. In an effort to gain new insights into what shapes the career paths of scientists to become entrepreneurs and commercialize their research, a research agenda probing the formation and evolution of scientist career trajectories is put forward. A central element of this research agenda is to learn about what factors shape the career decisions of scientists which involve the decision to become an entrepreneur.

This research can be informed by four literature streams that have developed parallel to each other but need to be integrated so that significant influences on the entrepreneurial choice of university scientists can be addressed in a holistic manner. These four literature streams focus on four distinct units of analysis: the firm, the individual entrepreneur, the region and the public policy context. A research agenda is proposed for examining scientist entrepreneurship based on the integration of these four literature streams while taking into account the four types of entrepreneurship market failures: networks, knowledge, learning and demonstration.

An analytical approach common among most studies examining the impact of universities on entrepreneurship is to analyze the influence of various university programs, such as incubators or technology transfer offices on firms that already exist. Yet, a different type of impact from the programs may arise by inducing scientists and engineers to become entrepreneurs who otherwise would never have become involved in commercialization. For example, *Nature Magazine* reports, "Jeff Alberts, a psychology professor, was trained as a scientist, not an entrepreneur. But with the help of government funding, he turned his knack for designing animal cages and other experimental apparatus into a successful small business. Alberts made the move in the 1980s after working on part of a Soviet space project that involved developmental biology experiments using rats. The only problem was that Alberts knew little about business, so he turned to the recently established SBIR programme for help in getting his company off the ground."[1]

Such impacts on the career trajectories of scientists could be an important impact of public policy, because recent studies (Audretsch, forthcoming; Audretsch, Keilbach and Lehmann, forthcoming; Audretsch and Keilbach, 2003; Acs, Audretsch and Carlsson, 2003) have identified entrepreneurship and new-firm start-ups as a key mechanism that reduces the filter impeding knowledge spillovers. Because entrepreneurship can serve as an important mechanism facilitating knowledge spillovers, policies that induce scientists to become entrepreneurs may have a significant impact on economic growth.

FIGURE 6-1 *The public policy-individual entrepreneur-regional environment nexus.*



Source: Adapted from Feldman et. al., 2001

As the following sections show, there has been no singular literature examining the linkages between public policy, individual entrepreneur and regional environment. For example, while there is a compelling literature stream in psychology analyzing the cognitive process by which individuals make the decision to become an entrepreneur; this has never been linked, at least explicitly, to the public policy context. Similarly, while there is a growing literature examining the impact of universities and university research on innovation, most of the studies focus on firms but not necessarily on the decision by scientists and engineers to start a firm (Shane and Stuart, 2002; Mowery, 1999; Audretsch & Feldman, 1996 & Acs, Audretsch and Feldman, 1992).

The paper will first introduce some of the main research questions, methodologies, and insights gained in the distinct literature streams focusing on innovation from the perspective of the firm, the individual entrepreneur, the region, and public policy. Based on the void that is found in the nexus among these four research perspectives, four main research questions are then introduced that explicitly focus on the factors shaping the decision by scientists to alter their career trajectories and become an entrepreneur, and the role that universities, and public policy at the regional and national level can play. In the last section, a summary and conclusions are provided. In particular, the importance of understanding the impact of the policy and university context in altering the career trajectory decision of scientists is emphasized.

2. LITERATURE STREAMS INFORMING KNOWLEDGE CREATION AND INNOVATION

2.1 The Firm—Innovation Relationship

The question of why some firms generate more innovative activity than others has been the subject of considerable research in economics. The answer to the question is just as important to public policy and the strategic management of firms as it is to understanding the economic process of innovation and technological change. The conventional approach to analyzing innovative output at the microeconomic level has been at the level of the firm. The fundamental questions addressed in this literature are *"What do firms do to generate innovative output?"* and "*Why are some firms more innovative than others?"*

2.1.1 Griliches Notion of Knowledge Production Function

In what Zvi Griliches (1979) formalized as the *model of the knowledge production function*, the firm is assumed to be exogenous. The strategies and investments of the firm are then modelled as choice variables generating innovative activity, and are therefore modelled as being endogenous. Thus, the model of the firm knowledge production function starts with an exogenously given firm and examines which types of strategies and investments generate the greatest amount of innovative output. Griliches, in fact, suggested that it was investments in knowledge inputs that would generate the greatest yield in terms of innovative output.

Subsequent to Griliches' seminal article, a massive series of studies empirically testing the knowledge production function emerged. Numerous measurement issues confronted this research agenda. Innovative output had to be measured and knowledge inputs had to operationalized. While the economic concept of innovative activity does not lend itself to exact measurement (Griliches, 1990), scholars developed measures such as the number of patented inventions, new product introduction, share of sales accounted for by new products, productivity growth and export performance as proxies for innovative output. Developing measures that reflected investments in knowledge inputs by the firm proved equally as challenging. Still, a plethora of studies (Cohen and Klepper, 1992a and 1992b, Griliches, 1984), developed proxies of firm-specific investments in new economic knowledge in the form of expenditures on R&D and human capital as key inputs that yield a high innovative output.

2.1.2 Cohen and Levinthal Absorptive Capacity Argument

The literature empirically testing the model of the knowledge production function generated a series of econometrically robust results substantiating Griliches' view that firm investments in knowledge inputs were required to produce innovative output. Cohen and Levinthal (1989) provided an even more compelling interpretation of the empirical link between firm-specific investments in knowledge and innovative output. According to Cohen and Levinthal, by developing the capacity to adapt new technology and ideas developed in other firms, firm-specific investments in knowledge such as R&D provided the capacity to absorb external knowledge. This key insight implied that by investing in R&D, firms could develop the absorptive capacity to appropriate at least some of the returns accruing to investments in new knowledge made external to the firm. This insight only strengthened the conclusion that the empirical evidence linking firm-specific investments in new knowledge to innovative output verified the assumptions underlying the model of the knowledge production function.

2.2 The Individual Entrepreneur—Innovation Relationship

Audretsch (1995) challenged the assumption underlying the knowledge production model of firm innovation by shifting the unit of analysis away from the firm to the individual. In this view, an individual, such as a scientist, engineer or other knowledge worker is assumed to be endowed with a certain stock of knowledge. She is then confronted with the choice of how best to appropriate the economic return from that knowledge. Thus, just as Cohen and Levin (1989) identified the appropriability question confronting the firm, there is an analogous appropriability question confronting the individual knowledge worker.

Under the assumption of no uncertainty about knowledge, no asymmetries involved in the expected value of that knowledge, and no costs of transacting that knowledge across economic agents, a convergence in the economic valuation of any new idea would be expected to occur between the individual and an incumbent firm.

However, as Arrow (1962) pointed out, new economic knowledge is inherently uncertain, characterized by significant asymmetries and is costly to transact across economic agents. This can lead to divergences in the valuation of new ideas between the individual economic agent and the decision-making hierarchy of an incumbent firm. Convergence in valuation would provide little incentive to start a new firm. If the scientist or engineer can pursue the new idea within the organizational structure of an incumbent firm and appropriate roughly the expected value of her knowledge, she has no reason to leave the firm. On the other hand, if she places a greater value on her ideas than does the decision-making bureaucracy of the incumbent firm, she has an incentive to start a new firm to appropriate the value of her knowledge.

As Audretsch and Stephan (1996) point out, the start-up of a new firm can actually provide the conduit for a knowledge spill over. In this spill over mechanism, the assumption underlying the knowledge production function is actually reversed. The knowledge is exogenous and embodied in an economic agent. The firm is then created endogenously in the worker's effort to appropriate the value of her knowledge through innovative activity.

Thus, entrepreneurship can be an important mechanism by which knowledge spills over and becomes commercialized. Within the economics literature, the prevalent theoretical framework has been the general model of income choice. The model of income choice dates back at least to Knight (1921), but was more recently extended and updated by Lucas (1978), Kihlstrom and Laffont (1979), Holmes and Schmidt (1990) and Jovanovic (1994), and addresses the fundamental question, *"Why and how do individual economic agents decide to start a new firm?"*. Thus, the unit of analysis is at the level of the individual economic agent. In its most basic rendition, individuals are confronted with a choice of earning their income either from wages earned through employment in an incumbent enterprise or else from profits accrued by starting a new firm. The essence of the income choice is made by comparing the wage an individual expects to earn through employment, W*, with the profits that are expected to accrue from a new-firm start-up, P*. Thus, the probability of starting a new firm, Pr(s), can be represented as:

$$Pr(s) = f\,(P^{*}-W^{*}) \tag{1}$$

The model of income choice has been extended by Kihlstrom and Laffont (1979) to incorporate aversion to risk, by Layear (2002) to include characteristics of human capital, and by Lucas (1978) and Jovanovic (1994) to explain why firms of varying size exist, and has served as the basis for empirical studies of the decision to start a new firm in a broad range of countries, time periods and contexts (Audretsch, 2003).

This view of entrepreneurship corresponds to that in a different scholarly tradition- management- provided by Gartner and Carter (2003), "Entrepreneurial behaviour involves the activities of individuals who are associated with creating new organizations rather than the activities of individuals who are involved with maintaining or changing the operations of on-going established organizations."

Both the field of management and psychology have provided insights into the decision process leading individuals to start a new firm. This research trajectory focuses on the emergence and evolution of entrepreneurial cognition. Stevenson and Jarillo (1990) assume that entrepreneurship is an orientation towards opportunity recognition. Central to this research agenda are the questions, *"How do entrepreneurs perceive opportunities and how do these opportunities manifest themselves as being credible versus being an illusion?"* Kruger (2003) examines the nature of entrepreneurial thinking and the cognitive process associated with opportunity identification and the decision to undertake entrepreneurial action. The focal point of this research is on the cognitive process identifying the entrepreneurial opportunity along with the decision to start a new firm. Thus, a perceived opportunity and intent to pursue that opportunity are the necessary and sufficient conditions for entrepreneurial activity to take place. The perception of an opportunity is shaped by a sense of the anticipated rewards accruing from and costs of becoming an entrepreneur. Some of the research focuses on the role of personal attitudes and characteristics, such as self efficacy (the individual's sense of competence), collective efficacy, and social norms. Shane (2000) has identified how prior experience and the ability to apply specific skills influence the perception of future opportunities.

The concept of the entrepreneurial decision resulting from the cognitive processes of opportunity recognition and ensuing action is introduced by Shane and Eckhardt (2003) and Shane and Venkataraman (2001). They suggest that an equilibrium view of entrepreneurship stems from the assumption of perfect information. By contrast, imperfect information generates divergences in perceived opportunities across different people. The sources of heterogeneity across individuals include different access to information, as well cognitive abilities, psychological differences, and access to financial and social capital.

One of the best data sources available to analyze the cognitive process triggering the entrepreneurial decision is provided by the Panel Study of Entrepreneurial Dynamics (PSED), which consists of a longitudinal survey study on 830 individuals that were identified while they were in the process of starting a new business. The unique feature of the data base is that it provides information on how the entrepreneurial opportunity and action was conceived and operationalized (Gartner and Carter, 2003). Kim, Aldrich and Keister (2003) use the PSED to test the theory that access to resources, in the form of financial resources, such as household income and wealth, and human capital, in the form of education, prior work experience, entrepreneurial experience, and influence from family and friends, affect the decision to become an entrepreneur.

As the Kim, Aldrich and Keister (2003) paper suggests, the external environment has been found to strongly influence the entrepreneurial decision. The greatest focus of research has been on the influence of networks on the cognitive process involving entrepreneurship. Thornton and Flynn (2003) argue that geographic proximity leads to networking, which both creates opportunities as well as the capacity to recognize and act on those opportunities. They suggest that networks in which trust is fostered involve a context facilitating the transmission of tacit knowledge. In comparing Route 128 around Boston with Silicon Valley, Saxenian (1994) documented how entrepreneurial advantages are based on differences in network structures and social capital.

Research has considered both the formation as well as the impact of networks on entrepreneurship. Hoang and Antoncic (2001) characterize research as systematically focusing on network content, network governance and network structure. Thus, there is considerable evidence and theory suggesting that external linkages and influences will shape the context of the entrepreneurial decision made by the individual.

Accordingly, there is a solid research tradition focusing on the decision confronting individuals to start a firm. Theory and empirical evidence provide compelling reasons to conclude that both characteristics specific to the individual as well as context external to the individual help shape the cognitive processes guiding the entrepreneurial decision.

2.3 The Region—Innovation Relationship

Recognition of the role that firm-specific knowledge investments could play in accessing and absorbing external knowledge, and therefore enhancing the innovative output of the firm, triggered an explosion of studies focusing on potential sources of knowledge that are external to the firm. Some studies examined the role of licensing, cooperative agreements and strategic partnerships, all of which involve a formal agreement and a market transaction for the sale of knowledge. Thus, these all represent mechanisms by which a firm can access knowledge produced by another firm. As Cohen and Levinthal (1989) emphasized, presumably internal investments in knowledge are a prerequisite for absorbing such external knowledge, even if can be accessed.

A different research trajectory focused on flows of knowledge across firms where no market transaction or formal agreement occurred, or what has become known as knowledge spillovers. The distinction between knowledge spillovers and technology transfer is that in the latter a market transaction occurs, whereas in the case of spillovers the benefits are accrued without an economic transaction.

While Krugman (1991) and others certainly did not dispute the existence or importance of knowledge spillovers, they contested the claim that knowledge spillovers should be geographically bounded. Their point was that when the marginal cost of transmitting information across geographic space approaches zero, there is no reason to think that the transmission of knowledge across geographic space should stop simply because it reaches the political border of a city, state, or country.

However, von Hipple (1994) explained how knowledge is distinct from information and requires geographic proximity in transmitting ideas that are highly dependent upon their context, inherently tacit and have a high degree of uncertainty. This followed from Arrow (1962), who distinguished economic knowledge from other economic factors as being inherently non-rival in nature, so that knowledge developed for any particular application can easily spill over to generate economic value in very different applications. As Glaeser, Kallal, Scheinkman and Shleifer (1992, p. 1126) have observed, "Intellectual breakthroughs must cross hallways and streets more easily than oceans and continents."

Thus, a distinct research trajectory developed in the late 1980s and early 1990s trying to identify the impact of location on the innovative output of firms. These studies addressed the question *"Holding firm-specific knowledge inputs constant, is the innovative output greater if the firm is located in a region with high investments in knowledge?"* The answer to this question was provided in a series of studies shifting the unit of observation for testing the model of the knowledge production function from the firm to a spatial unit of observation, such as a city, region or state.

Studies identifying both the extent but also the localization of knowledge spillovers were also based on the model of the knowledge production function. Jaffe (1989) modified the knowledge production function approach to a model specified for spatial and product dimensions:

$$I_{si} = IRD^{ß_1} * UR_{si}^{ß_2} * (UR_{si} * GC_{si}^{ß_3}) * \varepsilon_{si} \tag{2}$$

Where I is innovative output, IRD is private corporate expenditures on R&D, UR is the research expenditures undertaken at universities, and GC measures the geographic coincidence of university and corporate research. The unit of observation for estimation was at the spatial level, s, a state, and industry level i. Estimation of equation (1) essentially shifted the model of the knowledge production function from the unit of observation of a firm to that of a geographic unit.

Compelling and consistent evidence provided first by Jaffe (1989), but later confirmed by Acs, Audretsch and Feldman (1991 and 1994), Feldman (1994), Jaffe, Trajtenberg and Henderson (1993), and Audretsch and Feldman (1996) suggested that, in fact, the presence of external knowledge sources in geographically bounded regions increased the innovative output of firms located in those regions. Thus, there was clear and compelling econometric evidence suggesting that external investments in geographically bounded regions would yield an increased level of innovative output by the firms located in that region as a result of knowledge spillovers.

The new findings from the studies on spatially bounded knowledge spillovers, in two main ways, supported the knowledge production model of firm innovation. First, the firms were still assumed to be exogenous, and second, knowledge inputs were still found to be important determinants of innovative output. The main distinction lies in the unit of analysis. Because of knowledge spillovers, the link between knowledge inputs and firm innovative output was found to be more important for spatial units of observation than at the level of the firm.

2.4 Public Policy—Innovation Relationship

A different strand of literature has focused on the impact of public policies and the role of universities in influencing the innovative output of firms. This literature typically addresses the question, *"What is the impact of the institutions/policy on innovative output?"* These studies generally focus on the effect of universities/policy on performance measures at the level of the firm, industry or region. Performance measures include indicators of growth, employment change, patents, and productivity change (Rosenberg and Nelson, 1994; Jaffe, 1989; Abramson et al., 1997).

One approach has tried to link universities and/or public policy to performance at the regional level. For example, Florida (1999) proposed the hypothesis that the role of universities as a source for innovative activity in regions has increased over time. His methodology consists of measures such as the number of university-industry research centres, expenditures undertaken by these joint research centres, the share of academic research accounted for by industry funding, the number of faculty and graduate students involved in these joint research centres, and academic patenting. The trend of these indicators leads him to conclude that the role of the university as a source of economic growth has shifted away from knowledge transfer to knowledge creation. However, the absorptive capacity of the region also plays an important role in determining the impact of the university. While Feldman and Desrochers (2003) find less enthusiastic results for Johns Hopkins, the approach is not dissimilar in that they link university research activities to regional economic development.

An important strand of literature (Mowery, 1997; 1999; Mowery and Ziedonis, 2000 and forthcoming; Mowery, Sampat and Ziedonis, 2001) has identified the impact of the Bayh-Dole Act in generating university-based entrepreneurship. These studies generally find that enactment of Bayh-Dole has greatly increased the number of scientist based start-ups from universities.

Other studies (Wessner, Binks and Lockett, 2003; Wessner, 2003; Feldman and Kelley, 2002; Lerner, 1999, Di Gregorio and Shane, 2002; Lockett, Wright and Franklin, 2003; Nerkar and Shane, 2003 and Shane and Stuart, 2001) link universities or public policy to firm performance. These studies have generally found that both universities and national public policies, such as the ATP and SBIR enhance firm performance. Lerner (1999), for example, documented how the SBIR has increased the growth rate of firms. Other studies have focused on technology transfer as the measure of performance from universities. These studies generally analyze the number of licenses granted to firms as a measure of commercial success.

Only a handful of studies have examined the impact of public policy and/or universities on the career trajectories of scientists and engineers. Early studies by Audretsch and Stephan (1996) and Zucker, Darby and Brewer (1998) focusing on university-scientist linkages, led to subsequent research by Audretsch, Weigand and Weigand (2002) who examined how the Small Business Innovation Research Program (SBIR) impacted the career trajectory of scientists in making a decision to become an entrepreneur. Still, the impact of regional public policy and universities on the career trajectory and decision to become an entrepreneur remains relatively unknown.

3. MOVING TOWARDS A HOLISTIC APPROACH

The four separate strands of literature focusing on technological innovation each make a distinct contribution to understanding the determinants of firm innovation. In particular, these different approaches to innovation, suggest that four key units of observation are crucial in understanding the innovation process – the firm, the region, the individual and the institutional/ public policy context.

New-firm start-ups are important to innovation, because they embody a mechanism facilitating the spill over of knowledge that was produced with one intended application in an incumbent corporation or university laboratory, but is actually commercialized through the process of starting a new and different firm. Without new-firm start-ups, there would be fewer spillovers of knowledge and therefore less innovative activity.

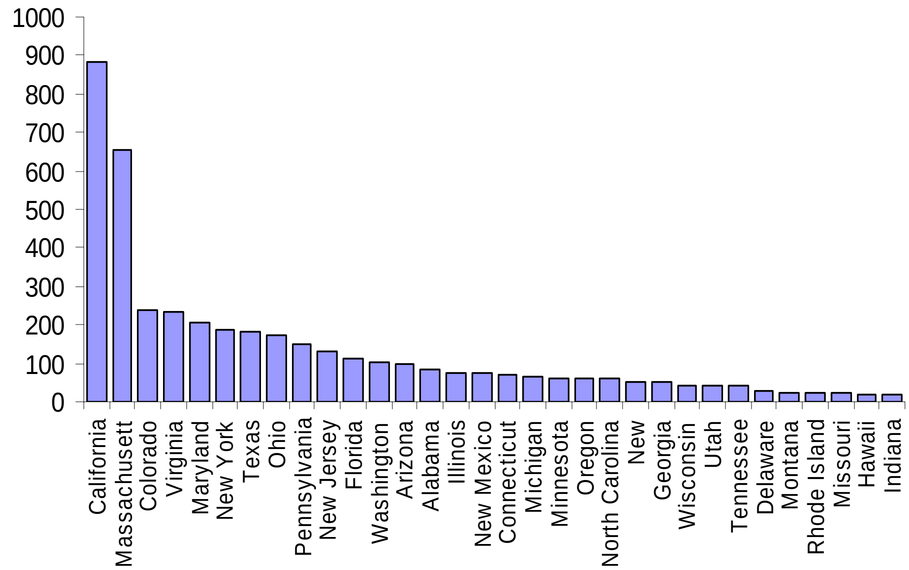
The individual matters to innovation, because the individual scientist or engineer is confronted with a career trajectory decision – should she remain in a university laboratory or incumbent corporation, or should she start a new high technology enterprise? If no individual scientist or engineer makes the decision to start a new high technology firm, there will be fewer knowledge spillovers and therefore less innovative activity.

Geography matters because the region provides the spatial platform in which knowledge spillovers are generated, absorbed and ultimately commercially exploited and appropriated. The decision to start a new high technology enterprise is shaped by the presence of knowledge, financial, and other complementary assets that are available in the region.

While scholarship has provided striking insights in each of these research trajectories, the role of public policy in influencing this confluence among the firm, the region/university and the individual remains ambiguous, unclear and largely underdeveloped. This is partially because most of the studies evaluating public policy and universities have tended to focus on the impact of the policy on the performance of either existing firms, or on the entire region. Very little is known about the impact on the cognitive process of the individual scientist or engineer in (re)shaping her career trajectory in making the decision to become an entrepreneur. Yet, as has already been explained in this paper, new-firm start-ups are an important conduit for knowledge spillovers. Research has identified a number of ways that public policy and universities have influenced the performance of existing enterprises. However, not much is known about the manner in which universities and public policies influence the cognitive processes of scientists and engineers at universities in recognizing entrepreneurial opportunities and reaching the decision to become an entrepreneur.

This oversight is particularly striking for public policy, because an implication from the literature on regional agglomerations is that knowledge spillovers generating new firm start-ups tend to be particularly prevalent in high-technology clusters. It is already well documented that not only does university research, venture capital, scientists and engineers, high-technology firms and start-ups tend to cluster in such spatial agglomerations (Saxenien, 1994), but federal support of innovation, such as the ATP and SBIR, also tends to be spatially concentrated in exactly these areas (Wessner, 2002; Black, 2003).

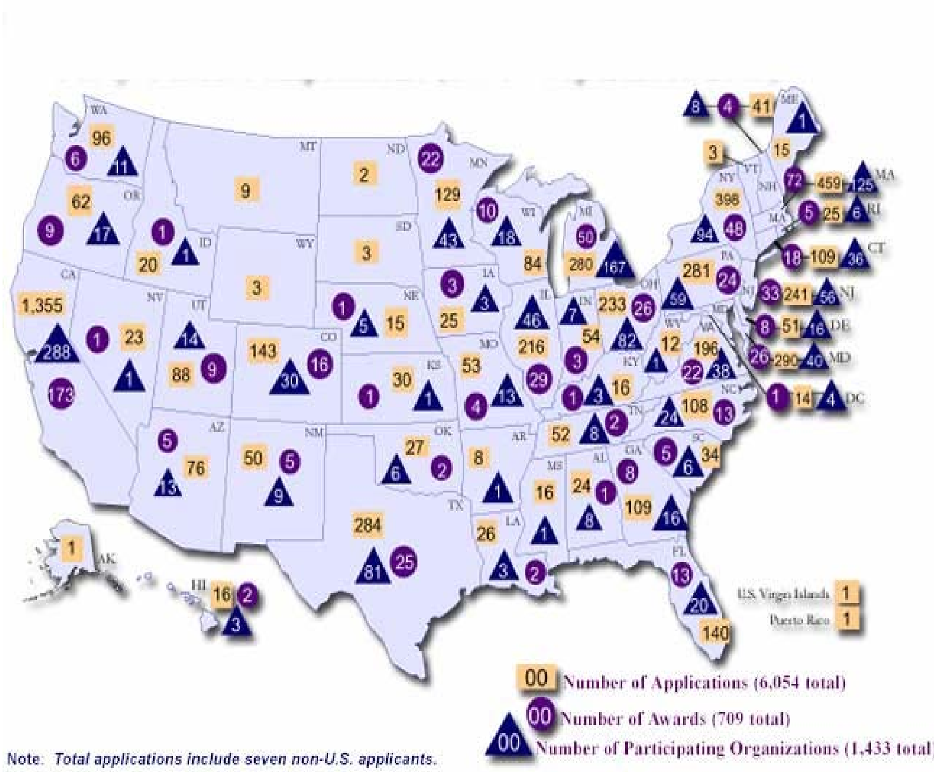
FIGURE 6-2 *SBIR Program, Total Awards by State, 2000*



Source: The National Academies, Board on Science, Technology and Economic Policy

The spatial correlation of knowledge assets, high-technology programs and federal programs such as ATP and SBIR suggest that a "winner take all" policy may be emerging across regions. Those regions that have already established a successful high technology cluster are able to generate knowledge spillovers, attract firms, scientists and engineers, as well as draw a high share of federal support for innovation to their regions. By contrast, regions that have been technologically disadvantaged, or have not yet developed knowledge based clusters; tend to experience difficulties in procuring a high share of federal support for innovation. This raises the question about the relative contribution made by public policies at the federal level that have a local impact: Is there impact greater in existing successful high technology agglomerations, where the technology firms are already established and knowledge spills over without being imbedded by a filter; or would public policy at the federal level have a greater, or at least different, impact in regions that have not yet established viable high technology agglomerations.

FIGURE 6-3 *ATP Applications, Awards and Participants by State, 43 Competitions (1990-September, 2003)*



Source: Advanced Technology Program, National Institute of Standards and Technology

In fact, there are theoretical reasons to conjecture that the contribution of public policy support may actually be greater in regions that already have some of the knowledge and human capital assets, but knowledge spillovers and successful commercialization, along with science-based entrepreneurship is limited as a result of the four fundamental sources of market failure impeding high technology entrepreneurship – network externalities, knowledge externalities, learning externalities and demonstration externalities.

3.1 Network Externalities

Network externalities result from the value of an individual's or firm's capabilities being conditional upon the geographic proximity of complementary firms and individuals. As Saxenien (1995) pointed out, local proximity is essential for accessing these complementary inputs. This makes the value of an entrepreneurial firm greater in the (local) presence of other entrepreneurial firms. The value of any individual's or firm's capabilities is therefore conditional upon the existence of partners in a network. Firms and workers place a greater value on locations within clusters which contain complementary workers and firms than on those outside of clusters. Such market failure can occur where there is a potential for geographic, inter-sectoral linkages, or networks. Thus, this source of market failure involves the geographic context which provides the (potential) platform for interactions and networks.

3.2 Knowledge Externalities

The second source of market failure involves knowledge externalities. As Arrow (1962) pointed out, knowledge, which involves new ideas, is inherently a public good, so that its production generates externalities. However, as Porter (2000) identified, local proximity is essential for accessing these knowledge spillovers. This source of market failure involves the units of analysis of the individual scientist and firm, since these generate knowledge. It also involves the unit of analysis of the region because knowledge externalities have been shown to be spatially bounded.

3.3 Learning Externalities

The third source of market failure associated with entrepreneurship is that positive economic value for third-party firms and individuals is created even when entrepreneurial firms fail. The high failure rate of new-firm start-ups has been widely documented (Caves, 1998), and the failure rates in knowledge-based activities are especially great. This is not surprising since knowledge activities are associated with a greater degree of uncertainty. However, the failure of a high technology firm does not imply that no value was created by the firm. Ideas created by failed firms and projects often become integral parts of successful products and projects in other (successful) firms. This unit of observation involves the individual scientist and firm since they are the conduits for learning. Once again, such learning may be greater within a geographically bounded context.

The externalities accruing from failed firms also create a market failure in the valuation of (potential) new enterprises by private investors and policy makers. Whereas the private investor can only appropriate her investment if the particular firm succeeds, a failed firm that generates positive externalities contributes to the success of other third-party firms. The private investor, however, does not appropriate anything from the original investment. Likewise, individual firms and workers would have no incentive to invest in the development of a cluster, which is the creation of other entrepreneurial firms, due to their inability to appropriate returns from such a cluster.

From the public policy perspective, on the other hand, it does not matter which firm succeeds, as long as some firms do, and growth, along with the other benefits accruing from entrepreneurship, is generated for that particular region.

3.4 Demonstration Externalities

The fourth source of market failure involves the demonstration effect emanating from high technology entrepreneurial activity. This is particularly valuable in regions where entrepreneurship has been noticeably lacking and where no strong tradition of entrepreneurship exists. Entrepreneurial activity involves not just the firm or the entrepreneurial scientist making the decision to start the firm. Rather, other colleagues will observe the process of opportunity recognition and action in the form of starting a new high technology firm, along with the results accruing from this entrepreneurial activity. The demonstration externality is in the form of learning by third-party individuals that entrepreneurship is a viable alternative to the status quo. As a result of this demonstration effect, others will be induced to also develop entrepreneurial strategies, and perhaps alter their own career trajectories to include an entrepreneurial activity. Thus, there is a strong and compelling positive externality associated with entrepreneurship as a result of the demonstration effect, particularly in regions with no strong entrepreneurial traditions. The demonstration effect focuses primarily on the individual scientist, but is also linked to the post-start-up performance of the firm. We would expect the demonstration effect to be greater within a geographically bounded regional context.

As a result of the market failures inherent in the externalities involved in high technology entrepreneurship – which stem from networks, knowledge, learning and demonstration – a gap is created in the valuation of entrepreneurial activities between private parties and the local public policy makers. Just as Branscomb and Auerbach (2003) identified the existence of liquidity constraints (Audretsch and Elston, 2002) in the form of what they term as “The Valley of Death” and the “Darwinian Sea”, it may be that the financing constraints confronting not just the new and young high technology enterprises but also potential entrepreneurs are even more severe in regions outside of a high technology cluster than for their counterparts located within a high technology cluster.

The role that high-technology entrepreneurship plays in knowledge spillovers, combined with the strong propensity for those knowledge spillovers to be geographically bounded and remain localized, suggests a special focus of public policy on the impact of local institutions, universities and policies on the cognitive process of changing career trajectories and making a decision to become a high technology entrepreneur. By filling the gaps created by the inherent market failure, public policy can create a virtuous entrepreneurial circle, where entrepreneurs become networked and linked to each other, and provide strong role models of high technology entrepreneurship for the local scientific community to emulate.

4. THE RESEARCH AGENDA

The importance of understanding the impact of public policy on the nexus between the start-up firm, the individual, the university and the region, combined with the absence of research and knowledge regarding how the entrepreneurial decision is made and acted upon in the high technology context of university based research, suggests four main research questions:

4.1 Career Trajectory of Scientists & Engineers

What are the career trajectory influences shaping the entrepreneurial decision to start a high technology company in a university context, and what are the key factors motivating the individual scientist and/or engineer to commercialize new technology? What factors, including, but not restricted to ATP and SBIR, but also regional public policies, have influenced and altered the career trajectories of university scientists and shaped their decision to commercialize research in the form of a new firm? Addressing this question will involve linking the units of analysis of individual scientists to the three other units of analysis discussed in this paper – the region, the firm and public policy, because all of these can shape the career trajectories of scientists and engineers.

4.2 The Demonstration Effect

To what degree have other scientists altered their career trajectory to include entrepreneurial and commercialization efforts because of the demonstration effect spilling over from colleagues involved in entrepreneurship and commercialization? This research question again involves linking the unit of observation of the individual scientist to the behaviour of scientist entrepreneurs observed within the other three analytical contexts – the firm, the region and public policy.

4.3 Network Effects

To what extent are networks critical in fostering academic entrepreneurship and commercialization? To what extent do public policies at the region, state and federal levels facilitate such networks. Are both networks and collaboration important for facilitating entrepreneurship and commercialization? This research question links the unit of observation of regions, or groups of scientific entrepreneurs within a geographic context, to the cognitive decision making process of the individual scientist.

4.4 Public Policy Context

In what ways have public policy influenced the entrepreneurial decision process of scientists? This research would link the dimension of the external policy environment and specific incentives to the entrepreneurial behaviour of individual scientists. Questions would be addressed such as what types of entrepreneurship and commercialization policies are being implemented by regions and universities and what impact have they had in generating new technology start-ups?

5. CONCLUSIONS

This paper was written with the goal of explaining what the academic and other research approaches have learned about the role of universities in the innovative activity of firms. The paper identified four distinct literatures focusing on four distinct units of observation – the firm, the region, the individual entrepreneur, and public policy. To some degrees, each unit of observation has fallen within the research domain of different fields. For example, while the individual entrepreneur has been the focus of research more in the disciplines of psychology and management, research on firm performance has been of greater concern in economics. Sociology has had a particular interest in the role of regional networks. However, very little research has been done focusing on the nexus between these four units of observation. This has created a significant vacuum for public policy, because the process by which individual scientists start a new technology firm is a vital mechanism for knowledge spillovers. Yet, there is little known about the cognitive process shaping the entrepreneurial decision, and even less known about the influence of the regional and policy context in the making of such an entrepreneurial decision.

This paper has also explained why the policy need to overcome the market failures inherent in entrepreneurship may be particularly acute in less technology developed regions. As a result of the four types of entrepreneurial market failures identified in this paper – networks, knowledge, learning and demonstration – scientists may face greater barriers to entrepreneurship in universities and regions that are not included in high technology clusters than do their counterparts located within high technology agglomerations. This may suggest that the impact and potency of technology and entrepreneurship policies may be spatially dependent, or at least sensitive to location.

In an effort to gain new insights as to how public policy might help to alter the career paths of scientists and engineers to become entrepreneurs and commercialize their research, a research agenda probing the formation and evolution of scientist career trajectories is proposed. A central element of this research agenda is to learn about what factors shape the career decisions of scientists which involve the decision to become an entrepreneur, and the role that the university, along with local and federal policies play and can play.

NOTES

[1]Eugene Russo, Making the Switch from Science to Business, *Nature Magazine*, October 30, 2003, pp. 988-989.

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