Regional Studies
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/cres20

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Published online: 18 Aug 2010.

To cite this article: Maryann Feldman, Johanna Francis & Janet Bercovitz (2005) Creating a Cluster While Building a Firm: Entrepreneurs and the Formation of Industrial Clusters, Regional Studies, 39:1, 129-141, DOI: 10.1080/0034340052000320888

To link to this article: http://dx.doi.org/10.1080/0034340052000320888

Regional Studies, Vol. 39.1, pp. 129–141, February 2005

Creating a Cluster While Building a Firm: Entrepreneurs and the Formation of Industrial Clusters

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(Received June 2003: in revised form September 2004)

FELDMAN M. P., FRANCIS J. and BERCOVITZ, J. (2005) Creating a cluster while building a firm: entrepreneurs and the formation of industrial clusters, *Regional Studies* **39**, 129–141. The objective of the paper is to provide a theoretical model of cluster development that is informed by an appreciative interpretation of case studies. It argues that entrepreneurs are a critical element in the formation of clusters. Entrepreneurs are important actors in the development of clusters as complex adaptive systems, where the external resources associated with clusters are developed over time. Entrepreneurs who adapt to both constructive crises and new opportunities create the factors and conditions that facilitate their business interests and, in turn, contribute to the development of external resources. The paper examines the initial factors that influence the decision to become an entrepreneur and examine how external factors influence the formation and location of high-technology clusters.

Entrepreneurship Regional economic activity Growth Development and changes
Regional development policy Innovation and invention: processes and incentives

FELDMAN M. P., FRANCIS J. et BERCOVITZ, J. (2005) L'établissment d'un regroupement au fur et à mesure de la création d'entreprise: les entrepreneurs et l'établissement des regroupements industriels, *Regional Studies* **39**, 129–141. Cet article cherche à construire un modèle théorique du développement des regroupements guidé par une interprétation sensible des études de cas. On considère que les entrepreneurs constituent un facteur clé dans l'établissement des regroupements. Les entrepreneurs sont des agents importants dans le développement des regroupements en tant que systèmes complexes adaptables, où les ressources externes liées aux regroupements se développent sur le temps. Les entrepreneurs qui s'adaptent et aux crises avantageuses, et aux nouvelles possibilités, créent les facteurs et les conditions qui favorisent leurs affaires et, à leur tour, contribuent au développement des ressources externes. On examine les premiers facteurs qui influencent la décision individuelle de devenir entrepreneur, et on étudie comment les facteurs externes influencent l'établissement et la localisation des regroupements qui sont à la pointe de la technologie.

Esprit d'entreprise Activité économique régionale: croissance, développement, et changement
Politique d'aménagement du territoire Innovation et invention: processus et incitations

FELDMAN M. P., FRANCIS J. und BERCOVITZ, J. (2005) Schaffung eines Clusters in Verbindung mit dem Aufbau einer Firma: Unternehmer und Clusterbildung der Industrie, *Regional Studies* **39**, 129–141. Dieser Aufsatz beabsichtigt, ein theoretisches Modell einer Clusterentwicklung vorzustellen, das auf einer bewertenden Interpretation von Fallstudien beruht. Es wird die These aufgestellt, daß Unternehmer bei Clusterbildung ein kritisches Element darstellen. Unternehmer sind wichtige Spieler bei der Entwicklung von Clustern als komplexen Mittlersystemen, in denen die externen, mit Clustern in Verbindung stehenden Resourcen erst im Laufe der Zeit entwickelt werden. Unternehmer, die sich sowohl konstruktiven Krisen als auch neu auftauchenden Gelegenheiten anzupassen verstehen, schaffen Faktoren und Voraussetzungen, die ihren Geschäftsinteressen entgegenkommen, und selbst wiederum zur Entwicklung externer Resourcen beitragen. Die Autoren untersuchen die anfänglichen Faktoren, welche die Entscheidung, Unternehmer zu werden, beeinflussen, und inwiefern externe Faktoren Bildung und Standort hochtechnologischer Cluster bestimmen.

Unternehmertum Regionale wirtsehaftliche Betätigung Wachstum Entwicklung und Wandel
Regionale Entwicklungspolitik Innovation und Erfindung: Vorgänge und Ansporne

0034-3404 print/1360-0591 online/05/010129-13 DOI: 10.1080/0034340052000320888
http://www.regional-studies-assoc.ac.uk

FELDMAN M. P., FRANCIS J. y BERCOVITZ, J. (2005) Crear un cluster mientras se construye una empresa: emprendedores (*entrepreneurs*) y la formación de clusters industriales, *Regional Studies* **39**, 129–141. El objetivo de este artículo es ofrecer un modelo teórico de desarrollo de clusters basado en una interpretación apreciativa de estudios de casos. Sostenemos que los emprendedores son uno de los elementos críticos en el desarrollo de clusters como sistemas de adaptación complejos, donde los recursos externos que se asocian con los clusters se desarrollan a lo largo del tiempo. Los emprendedores, los cuales se adaptan tanto a crisis constructivas como a nuevas oportunidades, crean los factores y las condiciones que facilitan los intereses de sus negocios y, como resultado, contribuyen al desarrollo de los recursos externos. Examinamos los factores que influyen inicialmente en su decisión de convertirse en emprendedores y examinamos de qué forma los factores externos influyen la formación y localización de clusters de alta tecnología.

Empresarialidad Actividad económica regional: crecimiento, desarrollo y cambios Política de desarrollo regional Innovación e invención: procesos e incentivos

JEL classifications: M13, R11, R58, O31

INTRODUCTION

The economic success of well-known innovative industrial clusters such as Silicon Valley, California, and Route 128, near Boston, Massachusetts, have fostered attempts to transform and revitalize local economies, and in the process create economic competitiveness, wealth and jobs (OECD, 1993; DTI, 1998; TETHER and STOREY, 1998). Despite their economic importance, the amount of public resources and effort devoted to them, there is a limited understanding of how innovative clusters emerge, take hold and transform regional economies.

MARKUSEN (1996) draws a distinction between places that are *sticky* or able to hold on to new ideas and translate them into industrial clusters and places that are *slippery* or not able to benefit in the long term from innovation and investment. This provocative characterization does not address the process by which regions transform from slippery to sticky. Much of the economic development discourse attempts to replicate the characteristics associated with a fully functional regional system, including such attributes as a local research university that is pro-technology transfer, an active venture capital industry, active social networks and adequate support services. However, the role typically ascribed to these factors appears to lag rather than lead cluster formation (FELDMAN, 2001). In addition, the literature usually treats institutions as exogenous rather than as evolving, adaptive social constructs (NELSON and WINTER, 1982). The specific configurations and relationships between institutions, as shaped by evolving economic interests, may matter more than simply their presence. More importantly, this perspective ignores the importance of entrepreneurs as economic-change agents, able to create or attract the necessary resources and institutions to support their ventures, and able to draw on the rich historical and regional context in which they operate. Models of regional economic development have largely ignored the role of the individual change-agent in the development of regional economies (APPOLD, 2000), and have not considered how entrepreneurs actively interact with and shape their local environments (BOSCHMA and LAMBOOY, 1999).

The main perspective advanced in this paper is that entrepreneurs spark cluster formation and regional competitive advantage. Entrepreneurs, in the process of furthering their individual interests, may act collectively to shape local environments by building institutions that further the interests of their emerging industry. In this way, entrepreneurs help form innovative industrial clusters. The conceptualization draws from the literature on complex systems to emphasize that systems of innovation are not due to predictable linear processes but rely on the adaptive, self-organizing behaviour of entrepreneurs, who in turn rely on support from their local environment, including government resources. While many seek to emulate the sustained competitive advantage an industrial cluster represents, these dynamic systems cannot simply be imitated but require the temporal development of unique and not easily replicated assets and capabilities (FELDMAN and MARTIN, 2004).

By starting companies, entrepreneurs act as the agents of change, draw on existing resources in the local environment and, in turn, add new resources to the environment that others can draw upon. Entrepreneurial activity shapes the local environment through active learning and experimentation, the reinvestment of profits and expertise, the extension of relationships with universities and government laboratories, the building of local institutions such as industry networking associations and the subsequent pull of a new group of actors to the region. Over time, a cluster may succeed and become entrenched, but building a cluster takes time and there are no guarantees about its final configuration or ability to sustain itself.

It is hypothesized that the economic success and sustainability of entrepreneur-catalysed clusters will be a result of the policy environment and the adaptability of the growing resource base. This model is abstracted from empirical observation of cluster development in the US Capitol region. This area initially lacked attributes associated with an entrepreneurial environment;

yet despite this history, over the past 15 years innovative clusters in biotechnology and the Internet have become established (Feldman 2001; Feldman and Francis, 2004). The model used is based on appreciative history-friendly theorizing and is evolutionary in spirit (Boschma and Lambooy, 1999; Malerba *et al.*, 1999; Teubal and Andersen, 2000). For external validity, the findings are compared and contrasted with the literature on the genesis of Silicon Valley and other clusters. The intention is to provide a model of cluster formation that does not rely on trying to replicate wholesale the conditions of existing clusters, but instead focuses on cluster genesis as a process that moves through common stages with defined inflection points. The history of each cluster – including the early conditions and individuals involved – may be unique, but there are policy prescriptions that can be discerned from examining commonalities in the path of development of successful clusters. This paper emphasizes the ability of entrepreneurs to create a cluster as they build their firms, and build resources and community. The model advanced maybe specific for innovative, technology-intensive entrepreneurial clusters. It is suggested the literature would be enhanced with more comparative case studies that consider cluster genesis and produce nuanced typologies of the variations of cluster formation.

MODEL OF ENTREPRENEURS IN CLUSTER FORMATION

The term 'innovative cluster' is used to refer to a geographically confined collection of related firms. While many industries exhibit a tendency to cluster spatially due to a resource requirement or by historical accident, the paper focuses on the innovative clusters involved in the production of novel products and processes that add value to the economy. The ability to innovate provides long-term sustainable advantage for a firm or a region (Porter, 1989). Innovative industries are knowledge intensive and incorporate new advances that may originate in scientific discoveries, as in the biotechnology or nanotechnology industries, or in the application of know-how developed through practice, as in industrial equipment manufacturing or specialty foods. Clusters include firms working in related or supporting technologies, and an infrastructure of institutions and social relationships that provide resources and promote the interests of the whole cluster (Boschma, 1999).

Innovative firms often defy classification by standard schemes as they create an industry or industry segment by responding to market opportunities typically operating in niches not profitable for larger or established firms. One marker to identify new industries is the founding of a dedicated trade journal. For example, *Small Times*, launched in 2001, details technological advances, applications and investment opportunities in the rapidly developing business of nanotechnology. The launch of this journal heralded the arrival of nanotechnology as a community of common interest in an emerging industry for a technology that was previously associated with science fiction.

The nature of innovation makes it difficult to plan industrial clusters. At its earliest stages, before technological breakthroughs are generally appreciated and potential applications are known, locating at the centre of innovative activity may provide critical competitive advantage. Realizing the potential of a technology requires a sophisticated understanding of consumer needs, existing markets for product innovation and factor inputs, and prevailing production technology. Co-location increases the awareness of emerging trends and reduces uncertainty for firms: innovation clusters spatially in locations where knowledge externalities reduce the costs of discovery and commercialization. By the time an industry is sufficiently well known to be targeted for economic development, those jurisdictions where the technology was first developed have probably already captured the lion's share of the benefits and are positioned for greater advantage. The path of emerging industries is difficult to predict. New technology is extremely fluid, and planning efforts based on current assumptions will never be able to anticipate future scientific developments or the direction that a technology may take (Lambooy and Boschma, 2001).

Entrepreneurs, active agents who organize resources, are a critical element in the formation and viability of innovative industries and clusters. Entrepreneurship is a local event: individuals start companies in the location where they have formed business networks and have access to resources (Romanelli and Feldman, 2004). Many individuals have location inertia due to constraints on family mobility or locational preferences and may start a company in reaction to a downsizing, or while still employed. Since innovative clusters are simply collections of firms, when sufficient numbers of new firms in innovative technology are formed, the region could be described as entrepreneurial. Industrial turbulence, the creation of new firms, their failure or reconfiguration are measures of a vibrant local economy.

The decision to start a firm can be viewed from a variety of perspectives (for a review, see Bhide, 1999). Neoclassical economics assumes that risk aversion and uncertainty limit the supply of entrepreneurs (e.g. Holtz-Eakin *et al.*, 1996). Although entrepreneurial households report higher risk tolerance than non-entrepreneurs in surveys,[1] there is uncertainty about whether causality runs between risk taking and subsequent success or if successful entrepreneurship leads to lower risk aversion (Blanchflower and Oswald, 1998; Carroll, 2002).

Schumpeter (1939), Knight (1921) and Kirzner (1973) suggest that entrepreneurs have a greater ability to perceive opportunity, accept challenges and organize

resources. BLANCHFLOWER *et al.* (2001) draw on this tradition to theorize that the differential ability of perceiving opportunities and subsequently acting upon them are the most significant factors affecting entrepreneurship.

The present paper builds on the Schumpeterian tradition by assuming that the entrepreneurial decision is a complex mix of individual preferences, perceptions of opportunities, and access to capital and other complementary resources. SCHUMPETER (1911/34, 1942) placed entrepreneurship, with a connection to dynamic uncertainty, at the centre of economic reasoning by tracing all disrupting economic change to innovations and identifying the entrepreneur as the innovator (BLAUG, 1985). The entrepreneurial decision is predicated on both the break with routine and incentives that lower the cost of resources and opportunity: entrepreneurial individuals will move to capitalize on them by organizing resources. Entrepreneurship may be a response to constructive crises as the environment changes. To induce an entrepreneurial response from individuals also requires technological and market opportunities and incentives to pursue opportunities. This convergence generates a reduction in the risk for start-up ventures in a new field, which can affect the probability of success.

The policy question is how to translate latent entrepreneurship (individuals who desire to become entrepreneurs but who do not act) into active entrepreneurs. SCHUMPETER (1942, pp. 82–83), in his emphasis on the evolutionary nature of capitalism, proposes that a shock to the system of production or discontinuity is required to motivate individuals to take the risk to bring innovation to the market. In the local context, the discontinuity may be exogenous factors such as downsizing or layoffs or may be due to in the unwillingness of large organizations to fund new ideas.

If the entrepreneurial decision is sensitive to exogenous factors rather than being only a function of individual preferences, then it can be influenced both positively and negatively by government policy. Our model posits that some initial change – whether a crisis, a discontinuity in industry or an opportunity – drives latent entrepreneurs to start companies. This sets into motion interactions in the institutional, economic and policy environments that, in turn, influence the success of a region by maintaining start-ups and furthering the maturation of the cluster to create stickiness in MARKUSEN's (1996) typology. The dynamic between the types and quality of resources and the networks and institutions that further business interests ultimately affects the sustainability of start-ups. Thus, an industrial cluster is an agglomeration of mutually reinforcing firms and aligned interests.

Fig. 1 presents a schematic that incorporates the above ideas. It depicts the interdependent relationship among entrepreneurs, government policy and the local environment (i.e. social and commercial institutions,

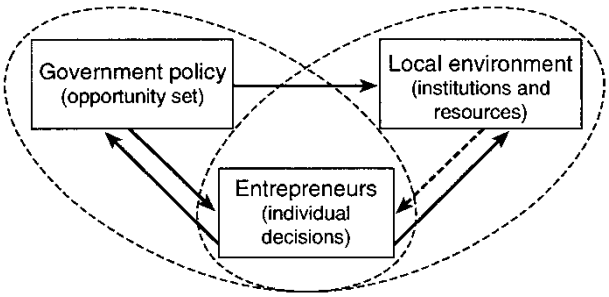

Fig. 1. *Factors in the formation of the region*

physical and human capital resources). It depicts the decision to start a company as multifaceted. Although the components evolve – from emergence to stability to maturation – the essential interconnectedness remains constant. In a well-functioning entrepreneurial system, each component reinforces the other to promote firm, industry and cluster development.

This model stands in contrast to the typical stories describing the evolution of Silicon Valley, Route 128 or Research Triangle Park, North Carolina – stories that highlight the role of strong directed efforts. For example, KARGON *et al.* (1992) emphasize the early input of Frederick Terman as the founder of Silicon Valley who orchestrated the creation of a world-class research institute with strong ties to the business community and an environment that encouraged students to become entrepreneurs or at least to take active involvement in corporate research programmes. Similarly, Route 128 may be traced to a long tradition of university–industry interaction and leveraging of government contract work (KENNEY and VON BURG, 1999), while Research Triangle Park was built on dedicated public-sector efforts (LINK, 1995). These stories may not be easily adapted to other regions. In contrast, it is posited that the underlying formation of a cluster is predicated on an entrepreneurial environment that is more organic and self-organizing and progresses through cumulative stages.

Fig. 2 shows the evolution of a high-technology industrial cluster over time as a series of three phases. The first, the emergent phase, occurs when entrepreneurial innovation is ignited by a confluence of exogenous events. The self-organization of the cluster and the deepening of self-reinforcing feedbacks among entrepreneurs, enterprises, institutions and resources characterize the second phase. The third phase is the maturation of the industry into the well-functioning and rich innovative and entrepreneurial system. Each phase is examined in turn.

In the earliest stages, although a region may have the type of human capital or prominent research universities that is often associated with industrial clusters, few start-ups would exist, and there would be little or no venture capital activity in the area. Combining SCHUMPETER's (1939) dynamic role for the entrepreneur with KNIGHT's (1921) interpretation of the

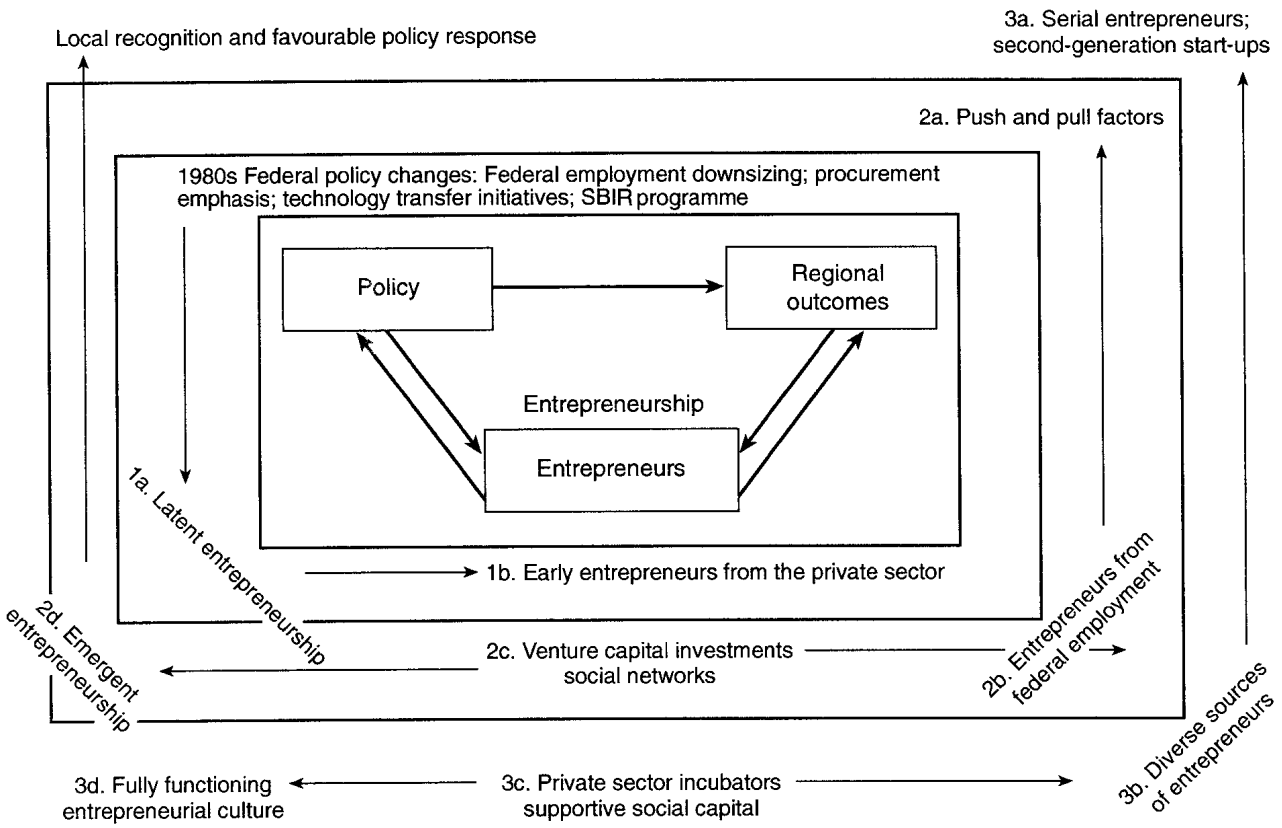

Fig. 2. Evolution of the entrepreneurial cluster

entrepreneur as the bearer of risk, an exogenous shock sparks the entrepreneurial response. Here, the entrepreneur both shapes and is shaped by the local environment. In this view, the entrepreneur is seen as an active and integral component of the cluster.

The characteristics of the cluster therefore emerge from the individual activities of entrepreneurs and organizations and institutions that co-evolve to support them. Once the first ventures have been started, the process of entrepreneurship is a classic trial-and-error or learning-by-doing process (Zaltman *et al.*, 1973). In this way, the ability of local firms to learn and adapt to new events is an important determinant in the development of the cluster. Maskell and Malmberg (1999) propose that technology clusters may be conceptualized as ecologies of mutually dependent firms and institutions dedicated to learning and knowledge creation. In the first stages of cluster development, these relationships begin to form.

The second phase is dominated by increased entrepreneurial activity. During this stage, entrepreneurs define resources to promote and protect their interests. In this way, the independent actions of entrepreneurs are catalytic components of a self-organizing system. Commercializing technology requires a vision of how that technology will be used, who the consumers will be, what attributes consumers might value and how to introduce the product to the market. Epistemic communities of local entrepreneurs and others from the developing infrastructure play a role in these decisions. The direction of the cluster's evolutionary path and whether the cluster successfully matures are a function of the collaboration and shared vision of this community.

At the second stage, the nascent cluster enters a critical time in which networks and community act as essential factors in the further development of the cluster. The organization of the cluster and entrepreneurial ventures evolve simultaneously and even symbiotically. Having the experience and example of the initial start-ups, the successful cluster becomes self-sustaining: entrepreneurs attract physical and human capital to the area, public and private networks are built up to support and facilitate the ventures, relevant infrastructure is created through public and private initiatives, and services grow to feed these companies. The entrepreneur, then, operates in and stimulates the local environment to further innovation and local learning. It is in the creative response of the entrepreneur to his environment that the nature and stability of the cluster are determined. Looking at clusters such as Silicon Valley, the Texas conurbation, Research Triangle Park and the Capitol region, entrepreneurs responded to their unique environments, creating clusters with their own signature characteristics and with differing abilities to withstand external shocks

(Saxenian, 1994; Link, 1995; Leslie and Kargon, 1996; Engelking, 1999; Feldman, 2001). In other regions, what started as a promising industrial cluster may redirect toward research and development where only one or two large firms establish themselves – such as the case of the New Jersey electronics industry (Leslie and Kargon, 1994).

The ultimate result, following Fig. 2, is stage three, where a fully functioning entrepreneurial environment within an innovative and adaptable industrial cluster emerges. The success of the initial start-ups and the synergy between them generates new possibilities for new start-ups as well as new spin-offs. The success and experience of the initial activity generates local recognition of the nascent industry. Local recognition, a reduction in risk and increased opportunities created by the first wave of companies also contribute to new start-up activities. Networks of entrepreneurs, policy-makers and secondary industry contractors spring up. Universities, colleges and technical centres recognize the need for high-technology-trained personnel and offer programmes to satisfy that demand.

Fig. 2 shows that the performance and positive outcomes of the initial set of start-ups feed back into the system, generating opportunities for new start-ups. At this stage, one sees the creation of regional public sector financing and grant-giving programmes. Government policy creates further incentives for investment. Incubators and other technology partnerships are created to promote the growth of the industry. Mergers and acquisitions begin to thin out the companies. Successful entrepreneurs also move from their initial start-up to start other companies, becoming serial entrepreneurs with deep roots in the community. Additionally, venture capitalists relocate to the area or open branch offices, signifying that the region has succeeded in one of the factors the literature cites as characteristic of innovative clusters. The maturing cluster spurs policy changes as governments seek to attract and provide a flourishing environment for even more high-technology development. Added together, the factors described above represent a dynamic system that may be self-sustaining and reinforcing. The mature state of this cluster differs little from Silicon Valley in terms of venture capital, major research university involvement, university–technology transfer practices, and the types of social capital and entrepreneurial efforts observed.

Although brilliantly successful clusters highlight high technology in the USA, there are also examples of cluster failures – clusters that could not adapt to shocks and whose entrepreneurs and start-up activity folded or went elsewhere when the environment changed (for an example, see Leslie and Kargon, 1994). The ability to promote and sustain entrepreneurship, to offer incentives to reconfigure resources and to adapt to changing circumstances yields long-term economic growth, regardless of geographic scale. In the terminology of economics, the success of firms and the success of the region are endogenous or interrelated. When entrepreneurs engage in building external resources, they certainly further their own interests, but in the extent that these resources benefit others, local entrepreneurs also contribute to the development of a cluster.

The next section offers an interpretative history of the relatively organic emergence of high-technology clusters in biotechnology and information and communications technology (ICT) in the US Capitol Region as an illustrative example of the model.

INTERPRETATIVE HISTORY OF CLUSTER GENESIS IN WASHINGTON, DC

The area around Washington, DC, holds industry concentrations in biotechnology and ICT.[2] The activity observed today is the result of more than two decades of development (for a fuller description of the example abstracted here, see Feldman 2001). Two basic features of its history stand out: although the Capitol region did not have the generally regarded prerequisites for high-technology development, a confluence of unrelated events created the opportunity for entrepreneurial individuals to create start-ups. Second, the support organizations and the entrepreneurial ventures co-evolved. Both the biotechnology and ICT industries had humble beginnings in the region with a low level of activity. However, as entrepreneurship caught hold, the cluster began to emerge and the necessary components to sustain it grew in the region, in large part due to the self-organizing efforts of individuals. The three stages presented in the theoretical model are each discussed in turn.

Emergence of a cluster

Unlike the vibrant entrepreneurial culture of the San Francisco Bay area, California, and Silicon Valley, the Capitol region was known as a sleepy bureaucratic town where scientists pursued a scientific programme without thought to commercial application. Positive conditions existed in the Capitol region such as a long tradition of federally funded science at national laboratories, institutes and agencies.[3]

Despite the importance of the federal government as an employer, the earliest entrepreneurs hailed from large corporations, government suppliers or were military retirees. Government institutions, which are prominent in fields related to ICT and biotechnology, did not generate many start-ups until government policy changed to institute employment downsizing and introduce policies that promoted technology transfer (Feldman, 2001). The earliest start-ups were service firms not originally involved in the types of research and development-intensive activities that

generate new industries. Firms such as Bethesda Research Labs and American Management Systems (AMS), while not launched as product development firms, evolved in that direction over time. Thus, the cluster had humble beginnings – service firms are not typically attractive targets for venture capitalists or for local economic development activities. However, service firms were relatively low cost to launch and provided a means for entrepreneurs to get started and generate finances that could expand into product development. Service firms did not need to draw on research at local universities for product development.

Between 1970 and 1990, the Capitol region was affected by a series of exogenous policy shifts that, while intended to address national concerns, had dramatic ramifications for the region. During the administration of President Jimmy Carter in the 1970s, a pronounced downsizing of federal employment began that continued through the presidency of Ronald Reagan. As a result, federal employment became less secure, compensation levels were frozen and future prospects for federal employees deteriorated. The relative cost of changing careers and becoming an entrepreneur decreased. Effected individuals with strong personal ties to the region suffered from locational inertia. Simultaneously, opportunity and incentives that promoted entrepreneurship arose. The Civil Service Reform Act of 1978 contained an initiative to outsource the production of goods and services to the private sector, creating demand potentially to sustain new companies. For individuals in the prime of their careers and with a base of knowledge in governmental operations, entrepreneurship emerged as an increasingly viable employment option. Government downsizing and outsourcing had, in effect, lowered the threshold for entrepreneurial risk taking. Federal procurement spending in the Capitol region grew by 114.3% from 1983 to 1997, while federal procurement spending nationally increased by only 3.1% during the same period (Haynes *et al.*, 1997, p. 149). The Reagan administration's defence initiative in the 1980s was materially different as it focused on the technological attributes of defence, specifically with a reliance on computers and software.[4] This initiative stimulated economic growth throughout the USA and the Capitol region was a major beneficiary (Stough *et al.*, 1998).[5]

In addition to shifts in demand, other policy changes influenced the knowledge resources available to small businesses and entrepreneurs. In 1980, as a response to declining US competitiveness, a new era in the transfer of publicly funded intellectual property to industrial firms began with the passage of the Stevenson–Wydler Technology Innovation Act and the Bayh–Dole University and Small Business Patent Act. The large numbers of federal and university laboratories in the Capitol region were now allowed to license their innovations to private firms. While both sectors benefited from the increased opportunity for commercial products licensed from federally funded innovations, biotechnology further benefited through Cooperative Research and Development Agreements (CRADAs) opening opportunities for licensing and joint product development. ICT, in contrast, benefited largely from outsourcing opportunities.

The Small Business Innovation Development Act of 1982 established the Small Business Innovation Research (SBIR) Program. Under this act, all federal agencies with an annual research and development budget greater than US$100 million were required annually to set aside a percentage of research and development funds for small business. The act greatly increased the funding available to technologically oriented small business (Lerner, 1996). For public-sector employees, the chance of having a proposal accepted likely increased given knowledge and insight into agency needs. Not surprising, perhaps, the SBIR award data reflect a relatively high Capitol region concentration.[6]

Self-organization follows

In the emergent phase, entrepreneurs began by pursuing commercial projects that did not require high levels of investment and which were unlikely to generate high potential returns. Entrepreneurs started with government contracting, producing rather mundane 'bread-and-butter' products, such as medical test kits and reagents for biotechnology or by providing services such as computer system integrations and maintenance work in ICT. Most companies appear to have started with personal funds rather than with venture capital, a finding consistent with the literature (Bhide, 1999; Blanchflower *et al.*, 2001). The cluster began to coalesce and move into the second stage. The growing number of related firms in the region provided opportunities for subcontracting, work and asset sharing, making it easier for start-up firms to bootstrap and grow steadily without large doses of new capital. Second-generation entrepreneurs, leveraging the knowledge and experience gained in their initial endeavours, began to shift their attention to more exploratory projects that held a higher market potential. The profit potential of these projects caught the attention of the venture-capital community.

Venture capital seeks opportunity and where there is potential for profitable investment opportunities in a region, venture capital is attracted. Being able to monitor and mentor the entrepreneurial firms in which they invest makes close geographic proximity valuable for venture capitalists (Gompers and Lerner, 1999). In 1980, the few Capitol region venture-capital firms there were made investments elsewhere. Yet, there was the emergence of membership organizations that supported social capital and formed to promote networking. For example, the Mid-Atlantic Venture

Capital Association formed in 1986 with three members. Such activities were primarily private-sector initiatives, financed with private funds. By collaborating with state and local government programmes, these initiatives resulted in cross-fertilization and a common mission to promote the development of industry in the Capitol region. By 2000, there were six venture-capital firms headquartered in the region and numerous others that had opened Capitol region branches.

As the earliest start-up companies grew and went public or were bought out by larger companies, the resources in the region evolved. Successful local entrepreneurs who made large fortunes engaged in institution building to support their on-going activities and to encourage further entrepreneurship in the region. There are examples of early entrepreneurs who made personal fortunes and started private incubators to nurture new companies. These founders were motivated to share their expertise and build the region. For example, the Private Investors Network (PIN), the Capital Investors Club and the Washington Dinner Club are angel investors comprised of experienced entrepreneurs who actively invest in new companies and offer management advice. In addition, MedImmune, a prominent local biotechnology firm, created its own venture capital fund, MedImmune Ventures, Inc.

Universities in the region responded to increased entrepreneurial activity by offering new programmes and building branch operations closer to commercial activity. Johns Hopkins University, Baltimore, Maryland, offers a Master's degree in Biotechnology in Silver Spring – about 50 miles from the main campus, but only a few miles away from a major concentration of biotechnology firms. Virginia Tech University opened a branch campus in Northern Virginia about 250 miles from its main campus, although again within the ICT cluster. The draw for these educational institutions is the number of workers seeking additional training, the opportunities for industry-funded research and increased interaction with industry. Notably, local universities have benefited from the philanthropy of local entrepreneurs. For example, George Mason University began in Fairfax, Virginia, in 1950 as a commuter school and has grown into Virginia's second-largest university with 18 doctorate programmes and a focus on technology. Donors have given the university millions of dollars to endow 43 professorial chairs, allowing the university to recruit high-profile professors (O'Harrow and Lipton, 1996). All of the universities in the area have responded with incubator programmes to encourage entrepreneurship and training in related academic programmes and dedicated research programmes.

In the Capitol region, legislative programmes have increasingly addressed the needs of the newly established industry. In the 1990s, a group of Virginia technology executives organized a campaign to advocate state tax increases for education in order to provide greater infrastructure development. Rather than seeking specific requests for their own business, business leaders were promoting a broader, collectively responsible social agenda (Feldmann, 1997). The successes of these political efforts in changing the local environment are becoming apparent. In 2001, Maryland passed 12 legislative acts aimed at providing a supportive environment for technology-based economic development, covering the full gamut of infrastructure development, training programmes and tax incentives. In Virginia, Mark R. Warner, a successful technology entrepreneur, currently serves as Governor.

Critical mass and system maturation

The development of high-technology clusters is not a deterministic process. However, there are several factors associated with cluster maturation and stability: strong industry networks, supportive local culture, and the ability to withstand reconfiguration (Andersen and Teubal, 1999) or adverse shocks (Saxenian, 1998).

Critical to whether an initially promising cluster matures or declines is contingent on entrepreneurial 'spawning'. Gompers *et al.* (2003) focus on entrepreneurial spawning in the venture capital-innovation hubs of Silicon Valley and Route 128 and find that entrepreneurial experience and networks are critical factors in the creation of new firms. The results suggest that working in entrepreneurial firms exposes potential entrepreneurs to relevant networks of suppliers and customers and provide information about starting companies and attracting venture-capital backing. These factors lower barriers for individuals to create spin-offs. In effect, these firms act as incubators for entrepreneurial human capital. This result is consistent with phase three in our model, where the entrepreneurial human capital developed within earlier start-ups leaves their initial firms to create spin-offs. This research points to the paramount importance of developing venture capital within a cluster as a means to foster more successful spin-offs and prevent the cluster from stagnating or dissipating.

Also consistent with our model, Gompers *et al.* (2003) reject an alternative view – that individuals become entrepreneurs because their bureaucratic employers are unwilling or unable to fund their entrepreneurial ideas. They find that while this may explain entrepreneurial spawning in some cases, such as the example of Xerox's research park (Palo Alto Research Center, California), which developed a number of key technologies but was unable to capitalize on them, leaving product development to others who left to start their own companies, it does not explain the majority of modern entrepreneurial spawning. In our research on the Capitol region, it was found that while some individuals came from large, established firms or government laboratories initially, in the second and third

stages of the Capitol cluster's development, more entrepreneurs came from entrepreneurial companies.

There is evidence that the Capitol high-technology clusters in ICT and biotechnology have reached a point where they are self-sustaining. The factors that typically describe industrial clusters, such as strong industry networks and a supportive local culture, are in place. There are no quantitative measures to indicate when a mature cluster exists, but there are two important characteristics. The first relates to labour market thickness. A mature industrial cluster offers a myriad of job opportunities in an industry, making it possible for an employee to change jobs without changing residence. The second characteristic relates to the ability of the region to withstand economic downturns. The downturn that began in early 2001 and continued into 2003 affected the number of Initial Public Offerings (IPOs) and hence the supply of new venture capital investments. Yet, De Vol *et al.* (2004) note that the Capitol region recently had the highest rate of new firm creation among biotechnology clusters.

As industries evolve and change, it is expected that clusters would be able to remake themselves through continual reinvestment and reconfiguration of resources. Glaeser (2003) offers the example of Boston, which successfully remade its economy three times since the Colonial era, thanks to the availability of locally skilled capital. Of course, these transitions are costly to individuals and their families when skill sets become obsolete and jobs disappear, which underscores the importance of social policy as a backbone of industrial competitiveness and economic growth.

COMPARATIVE CLUSTER ANALYSIS: DO OTHER INDUSTRY CLUSTERS FIT THE MODEL?

A model of cluster genesis has been presented that suggests clusters have their origins in a confluence of events: opportunity, existence of raw materials (including ideas and skilled human capital, and the reduction of risk). But how common is this experience in the creation and evolution of other technology-intensive clusters?

Examination of other clusters reveals that their early genesis was path dependent and idiosyncratic – with entrepreneurial activity and firm strategy playing a decisive role. Feldman and Schreuder (1996) examine the historical origins of the pharmaceutical industry in the mid-Atlantic region and find that a series of serendipitous events created an early industry concentration. Over time, an infrastructure developed that provided firms in the region with competitive advantage. As a result, more firms and resources were attracted to the region. Indeed, the pharmaceutical industry still exhibits a strong geographic concentration in the state of New Jersey. Klepper (2002, 2004) considers the emergence of Detroit, Michigan, as the leading automobile cluster in the USA. His work highlights the successive generations of entrepreneurs working in the industry. Most importantly, Klepper finds the pedigree and experience entrepreneurs acquired from working for Olds Motor Works, a leading innovator at the time, was instrumental to their firm success and to the subsequent growth of the region. Scott (2004) examines the early genesis of the Hollywood motion picture industry in California. He finds that a highly successful business model was developed and diffused there – an example of the co-evolution of industry and technology. While each of these clusters had very different origins, over time they developed the supporting conditions that the literature associates with successful entrepreneurial environments. These regions are so successful that they are identified with the industries that are concentrated there.

The genesis of Silicon Valley's high-technology clusters, while often traced to the efforts of Frederick Terman, the visionary Dean of Engineering at Stanford University, California, who developed close industry–university partnerships, has roots that extend back to the early twentieth century. Sturgeon (2001) provides a long-term historical analysis of the development of firms well in advance of the renowned spin-offs originating from Fairchild Semiconductor. He argues that the strength of the region is thanks to a small group of people who had a vision for the region's development and who championed the aeronautical and electronic industries. More examples of comparative research is warranted and would aid in the understanding of the how clusters emerge and the appropriate government policy responses.

CONCLUSIONS

The economic success of Silicon Valley – in terms of individual wealth creation, corporate profits and job creation – has been so impressive that government officials try to imitate or replicate its success. Government policies aimed at replicating the conditions that exist in the Silicon Valley region today are based on the belief that other areas may capture the benefits of new high-technology firm formation, along with the attendant economic growth. Much of the prevailing wisdom is drawn from a snapshot showing the advanced stage of Silicon Valley's development, i.e. the workings of a fully functioning innovative system. Looking at a successful region in its full maturity, however, may not provide prescriptive information about how such regions actually develop. Conditions that one associate's with an entrepreneurial environment are the result of a functioning entrepreneurial environment and do not illuminate the early efforts by which such entrepreneurship first took hold and allowed the cluster to develop.

A great deal is known about the characteristics and functioning of mature industrial clusters such as Silicon Valley and Route 128 (e.g. Roberts, 1991;

SAXENIAN, 1994). Critically important, from a policy perspective, is the question of how a cluster is started in a region that previously would not be characterized as innovative. Understanding has been limited to how such clusters develop and why they occur in certain areas and not others. For example, looking at the electronics industry, LESLIE and KARGON (1994, p. 217) wonder, 'Why should the electronics industry evolve so differently in one place than in another, despite common technologies and national markets? Why, for instance, should Silicon Valley be located in northern California rather than in northern New Jersey?' The present paper develops the argument that the location of entrepreneurs with the skills and opportunity to capitalize on an emerging technology significantly affects where high-technology clusters emerge.

Is replication of a mature entrepreneurial environment sufficient to foster entrepreneurship? Notable failures in such places as San Antonio, Texas, suggest it is not (WALLSTEN, 2004). SAXENIAN (1994) analyses Silicon Valley from the perspective of how it adapted to restructuring in the semiconductor and computer industry and establishes the importance of social relationships in defining the capacity of the region to evolve, adapt to shocks and accommodate to new demands. The present paper has examined how one region, initially lacking an entrepreneurial tradition, accomplished a transformation into a fully functioning, rich regional system. Such a transformation entails a fundamental shift or phase change from an inert innovative system to an active system. Certainly, the Capitol Region was the site of a large government research infrastructure, classified as a State-anchored region using MARKUSEN's (1996) typology. In this regard, the concentration of resources and highly skilled labour, plus access to sophisticated, demanding technology users, were pre-existing conditions. The transformation to private-sector entrepreneurial growth did not appear to represent movement along a technological trajectory but was a product of cumulative capacity building brought on by exogenous shocks and involved human agency, adaptation and evolution.

In the development of an industrial system of innovation, there are many individually complex stories and personal motivations. In Washington, DC, it has been said that government employees and contractors could never become successful private businesses – the incentives of each group being very different. Government workers, the logic went, were too removed from the pressures of the market ever to be successful entrepreneurs. However, the earliest entrepreneurs in biotechnology and ICT were government contractors and employees who could adapt. What is critical is that conditions in the region simultaneously provided opportunities and pushed individuals towards opportunity exploitation.

The entrepreneurial event in the Capitol region was a response and adaptation to changes that were exogenous to the regional system. In this regard, Federal policies such as downsizing created slack and surplus resources that could find new and more productive uses. In this way, the gales of Schumpeter's creative destruction were unleashed. Policies that created a supply of potential entrepreneurs would not have been sufficient. A complementary set of government policies aimed at creating demand for ICT and biotechnology services, though no government procurement facilitated the transition. Other exogenous conditions were the policies that provided mechanisms or tools to enable companies to access resources. These policies affected the supply of new ideas by creating access to intellectual property.

Both biotechnology and ICT are high-opportunity technologies facing growing product demand and are therefore attractive to investors. Firms working in these technologies face favourable market conditions. The degree to which this is exogenous can be debated. Good entrepreneurs may create their own opportunity and thereby define an industry. The idea that technology development is endogenous to cluster development warrants more investigation. Through the actions of key individual change agents, the configuration of the cluster and the technological trajectory of the industry may be jointly determined. This suggests that companies, industries and regions benefit from the same factors and decisions – their evolution may be intricately interwoven.

Currently, a myriad of economic development policies attempt to encourage entrepreneurship. Rather than being actively promoted and encouraged by economic development policies, it has been shown here that the Capitol clusters had much more humble and pedestrian beginnings. The conditions associated with entrepreneurship developed over time. In the early stage of these new technologies, the trajectory of their further development was unclear and it would have been difficult to anticipate the types of specific assistance entrepreneurs needed. Individual entrepreneurs were in the best position to move forward the technology, industry and region. The role of local government policy in promoting entrepreneurship is unclear, and as no early examples presented themselves in the Capitol region, this question has not been directly examined here. Note that the Silicon Valley success is viewed as an outgrowth of intense technology transfer and interaction between industry and universities in that region. Local government policies played a role, but these tend to be implemented and effective in the later stages of cluster development. Are there general lessons to be learned from the development of the Capitol region or is this case unique? Is every case unique? Certainly, the Capitol region benefited from above-average household income and higher-than-average education levels, giving it very different resource endowments above other underdeveloped regions lacking an entrepreneurial culture. The general lesson then

is that entrepreneurs adapt, and when they are successful, they build the types of resources that support their activities: over time, a coherent system develops.

A distinction should be drawn between the conditions that support innovation and the conditions that support entrepreneurship. The two concepts are related: entrepreneurship facilitates the realization of innovation, as firms are formed to commercialize and advance new ideas. Conducive external environments and resources make innovative activity easier but may not be sufficient to induce new firm formation: this is where the concepts diverge. The critical condition for entrepreneurial enterprise is *opportunity*. Even if the regional conditions do not match those of successful clusters, incentive to develop locational opportunities welcomes entrepreneurial activity.

Once established, industrial clusters become virtuous, self-reinforcing cycles. Legal and tax frameworks, research institutions and social relationships as well as the local living environment are definitely areas for public policy intervention to help create supportive and positive environments for innovation and entrepreneurship. Specifically relevant are the conditions that affect the decisions of individuals to become entrepreneurs, and the ways in which an entrepreneurial culture develops and takes hold. Our understanding of regional economic systems may be enhanced by a consideration of entrepreneurs as economic agents who actively interact with their local environments, adapt to new situations, crises or opportunities using location-specific assets, and finally build and augment local institutions. Certainly, this is not the last word on the topic. It is the authors' hope that this historically informed theorizing will inspire others to take a more detailed look. It is only through an appreciation of the nuances of cluster development that one might begin to inform policy adequately.

Acknowledgements – The authors are indebted to those who agreed to interviews and generously shared their time and expertise in identifying salient issues as well as providing and validating information. An earlier version of the paper was prepared for the conference on 'Complexity and Industrial Clusters – Dynamics, Models, National Cases' organized by the Fondazione Montedison under the aegis of the Accademia Nazionale dei Lincei. The authors thank Ron Boschma and the anonymous referees for comments and suggestions.

NOTES

1. For example, in the Survey of Consumer Finances, wealthy households report they are more risk tolerant. For a description of these survey results, see Carroll (2002).
2. Recently, the US Capitol region ranked second in biotechnology business start-ups in the USA (De Vol *et al*., 2004). Leading companies in the region include Human Genome Sciences (HGS) and Celera Genomics Corporation – two key actors in the international effort to map the human genome. In addition, MedImmune, another local company, is the world's sixth largest dedicated biotechnology company with five US Food and Drug Administration (FDA)-approved products on the market (Contract Pharma, 2002, and http://www.MedImmune.com). The ICT industry also has a strong presence in the Capitol Region with a concentration in Northern Virginia. According to some sources, the region may be regarded as the birthplace of the Internet and companies in the region supply half of the worldwide Internet backbone (PriceWaterhouseCoopers, 1998). Prominent companies in the region have included MCI, AOL, NexTel and PSINet.
3. The National Institutes of Health (NIH), the US agency whose mandate is to oversee health and medical research. The NIH employs a large number of researchers at the agencies' home campus in Bethesda, Maryland (which currently employees 2000 PhD-level and almost 1000 MD scientists across its 27 research institutes), the Walter Reed Army Institute for Research (WRAIR), and the US FDA. The modern computer networking technologies that are the backbone of the Internet and ICT were developed in the early 1970s at the US Department of Defense Advanced Research Projects Agency (variously called ARPA and DARPA) (for more details, see Kahn and Cerf, 1999).
4. This affected ICT primarily, but also affected biotechnology firms. Consider the firm Martek, a spin-off from the defence contractor Martin Marietta that was primarily funded by the DOD but went on to develop pharmaceutical products and food additives.
5. For examples, see Feldman (2001).
6. Most notably, Virginia and Maryland combined to rank third in terms of total dollar awards and the number of awards received in each year between 1997 and 2002.

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