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Global networks of clusters of innovation: Accelerating the innovation process

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Abstract This article presents a framework for understanding new patterns of innovation and commercialization that are most easily observed in Clusters of Innovation (COI) and in the global connections established among them. We define COI as environments that favor the creation and development of high potential entrepreneurial ventures. COI are characterized by heightened mobility of resources (principally people, capital, and information—including intellectual property); increased velocity of business development; and a culture of mobility that leads to an affinity for collaboration, development of durable relationships, and the formation of Networks of Clusters of Innovation (NCOI). These networks are distinct sets of relationships. When the connections progress to the point of mutual dependence and business integration among participating enterprises, such covalent bonds form tightly interrelated business communities, or Super-Clusters of Innovation (Super-COI). In this article, we analyze the characteristics of COI and the nature of the relationships that arise between them to form NCOI and Super-COI. Further, we present an integrated model to better understand the global innovation system.

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1. What's new in clusters of innovation?

Clusters of innovation (COI) are frequently observed as concentrations of interconnected organizations—including suppliers, service providers, universities, trade associations, and so forth—whereby proximity leads to shared advantages through the aggregation of expertise and specialized resources (Porter, 1990).

Although this definition has been helpful in explaining the structure of different industrial concentrations around the world, it has also been thought to be vague (Martin & Sunley, 2003), superficial (Rugman & Boyd, 2003), biased (Cooke, Gomez-Uranga, & Etxebarria, 1997), and not suitable to analyze some real cases of firm agglomerations; see Lundequist and Power (2002) for the case of Sweden.

In this article, we are not concerned whether Porter's cluster model is sufficiently comprehensive. We agree that Porter's model is useful for justifying and explaining certain agglomerations of companies. More importantly, we believe that

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Porter's model provides a fundamental framework that, when extended, can properly explain the emergence and characteristics of other specialized clusters not previously understood in this context. In particular, as historically applied, Porter's model does not explain why new and apparently unrelated industries have emerged in specialized clusters already existing, such as the growth of a new biotechnology industry in Silicon Valley. Nor does it explain how new technology clusters, such as Israel and Taiwan, have emerged so rapidly and robustly in indigenous environments, attracting large concentrations of venture capital (Saxenian, 2006), or how their development was accelerated through interactions with other clusters.

In clusters of innovation other agglomeration benefits dominate, defined not by industry specialization, but by the stage of development and innovation. COI are characterized by mobile assets—such as money, people, and information, including know-how and intellectual property (IP)—which facilitate rapid innovation utilizing new venture formation, experimentation, scaling and, if necessary, failure (Freeman & Engel, 2007). Entrepreneurship is the core competence of COI, where innovation is augmented and accelerated through new firm creation, and urgency demanded by competition and limited resources.

This culture of innovation and new venture development, based on mobility of resources, gives rise to business practices whereby mobile assets frequently cross regional boundaries in order to foster international collaborations far earlier in the venture development cycle than the historical norm. In COI new startup ventures are said to be “born global,” taking advantage of international markets and resources extraordinarily early in their development. As a result, new and complementary industry clusters have emerged in different regions around the world, and a network of formal and informal collaborations among their entrepreneurial firms has been created. This multidimensional web of interrelationships includes weak ties, durable bonds, and covalent bonds, and constitutes the global Network of Clusters of Innovation (NCOI) and—in certain highly interrelated circumstances—Super-Clusters of Innovation (Super-COI).

NCOI and Super-COI may emerge in geographically close but distinct regions; over time, distinctions between these regions may become blurred, and result in the merging of a larger contiguous region. For example, consider the Northeast corridor of the United States or perhaps Silicon Valley, which is often deemed to embrace San Francisco and portions of the East Bay. For clarity, in this article we will focus on geographically dispersed examples since they

are not only more distinct, but also exhibit indications of the ability of these dispersed COI to bridge the spatial divides that are most strategically significant to business leaders and policy makers.

Herein, we provide an integrated analysis of this innovation system, consisting of geographically dispersed COI and the linkages among them. Previous studies have identified Silicon Valley as an example of a COI, and have described the impact of migrations in the transfer of venture creation and innovation processes. What has not been clear is how the continuing linkages among COI form a robust framework for ongoing collaborations—or NCOI—and how these linkages can at times become so strong that elements of the two clusters become mutually dependent on the other, operate in a highly coordinated fashion, and form a network that operates as a single community as a Super-COI. We postulate that these connections go beyond the entity level, and operate through interrelationships between the clusters more generally.

We also provide an integrated framework to better understand these new patterns of innovation in the global system of NCOI. In order to achieve our goal, we anchor our observations in the existing literature that describes entrepreneurial clusters, new cluster emergence, patterns of local and international mobility, and relations among high-technology firms (Florida & Kenney, 1990; Saxenian, 1985, 1989, 1994, 1999, 2006; Scott, 1986; Scott & Angel, 1987; Scott & Paul, 1990). Specifically, we seek to explain:

- What constitutes a COI and what makes these COI similar to, or different from, industrial clusters defined by the agglomeration of firms participating in an industry;
- What are the processes that facilitate the spontaneous emergence of indigenous COI;
- How firms in geographically dispersed COI get connected;
- What is the nature of these often global connections, and how connections can at times become interdependent; and
- How these connections between firms are supported by a less apparent, but ultimately more flexible and more generalized, network of relationships between the individuals and resources operating within these communities.

In addition, we provide examples for all of these characterizations, and suggest directions for

further research and analysis at the network, cluster, business entity, and individual unit of resource level. Much will be learned by understanding the contributions of individuals, firms, and communities to the innovation processes described.

This article is organized in four sections. In the first section we analyze the patterns of a COI, and study practices in Silicon Valley to explain what makes a cluster of innovation different from a pure agglomeration of firms with a common industry focus. Specifically, we study differences related to resource mobility, goal alignment, and global network externalities. In the second section we analyze how the mobility of resources and global approach of born global startups, operating within a COI, facilitates the creation of global NCOI. In the third section we analyze the relationships and the types of ties which link the COI within a NCOI, and introduce the concept of the Super-COI. Finally, in the fourth section we provide some concluding thoughts and propose further studies that can explore how global NCOI work, how their development can be facilitated, and how involvement of indigenous COI in NCOI can be enhanced.

2. Clusters of innovation (COI)

The concept of the business cluster has been widely studied since Porter (1990) defined it as a geographic concentration of a critical mass of interconnected companies and institutions in a particular field. Firms in a cluster gain many performance advantages (Doeringer & Terkla, 1995) due to the external economies of scale (Fujita, Krugman, & Venables, 2000; Krugman, 1991); eased access to information; proximity to specialized suppliers and customers; and reduced transaction costs, among others (Porter, 1998, 2000). In a cluster, firms have free access to local information and networks simply because of their physical proximity (Gertler, 1995, 2003). However, the agglomeration of businesses by industry does not explain the nature and idiosyncrasy of certain clusters; specifically, it does not explain the ability of certain regions to support the continuous emergence of startup high growth entrepreneurial firms almost independently of industry alignment. Why are new industries emerging within dense and highly specialized clusters? Why are these new industrial concentrations comprised of startup firms, or firms that matured from startups? One example is the San Francisco Bay Area; its common business cluster name, Silicon Valley, reflects its role as home to the semiconductor, computer, software, and related electronics industries. From this matrix has sprung seemingly unrelated

concentrations of biotechnology, nanotechnology and—more recently—biofuels, solar energy, and other “green” industries. Silicon Valley is more than just an agglomeration of specialized firms that benefit from being located close to each other. The emergence in Silicon Valley of businesses in new industries that do not benefit from agglomeration externalities indicates the presence of several factors that characterize a COI, namely:

- Intra- and inter-firm mobility of resources;
- New firm creation as a rapid and frequent mechanism for innovation, technology commercialization, business model experimentation, and new market development;
- Early global strategic perspective; and
- Alignment of incentives and goals.

2.1. Mobility of resources

In a COI, resources—the most important of which have been characterized by Timmons (1994) as people, money, and technology—are not tightly held within the firm. Mobility and rapid repurposing of resources within and among high potential entrepreneurial firms make innovation processes in a COI continuous and rapid (Freeman & Engel, 2007). Silicon Valley is a COI where the dense formal and informal network structure (Saxenian, 1994) is a channel through which collective learning, knowledge, and information are rapidly exchanged (Saxenian, 2006). As internal and external boundaries are blurred (Saxenian, 1994), a culture of common heritage legitimizes high rates of inter-firm mobility and information exchange (Saxenian, 2006).

Mobility of people is also radically different in Silicon Valley, compared to many places around the world (Saxenian, 1994). In the San Francisco Bay Area, it is very common for an engineer or entrepreneur to move rapidly through various employment scenarios, from large firm to startup. The fluid and frequent inter-firm mobility of entrepreneurs, engineers, and other professionals influences the local transfer of knowledge (Almeida & Kogut, 1999), the cycling between tacit knowledge and articulated knowledge (Lawson & Lorenz, 1999) and, therefore, new product development and innovation (Nonaka & Takeuchi, 1995; Saxenian, 2006).

2.2. Entrepreneurial process

As in other clusters, companies in Silicon Valley benefit from their proximity to other specialized

firms, suppliers, and customers among whom information and other resources are easily moved. The differential part of Silicon Valley's cluster behavior is that mobile people, their knowledge, and the information they are expert in are preconditioned for entrepreneurship, and that innovation is augmented and accelerated most notably through new firm creation. In this "incubator region" (Schoonhoven & Eisenhardt, 1989), the supporting infrastructure of professional service providers—including lawyers, bankers, venture capitalists, and a myriad of consultants—is well versed in the needs of startups and small technology companies (Saxenian, 2006).

In a COI the entrepreneurial process is a mechanism for continuous and rapid innovation, technology commercialization, business model experimentation, and new market development, and the process is encouraged by a dense venture capital cluster and the related facility for the creation of well structured, funded, and connected startups. Startups benefit from being co-located with other companies, suppliers, and service providers specialized in or compatible with entrepreneurship.

Most of the established firms of Silicon Valley (e.g., Hewlett Packard, Intel, Apple, Cisco, Google, Genentech, eBay, Sun Microsystems, ALZA) have emerged from relatively recent entrepreneurial beginnings. Entrepreneurs and professionals who were involved in the successful creation and growth of these now established companies frequently redeploy their expertise to found, invest in, advise, or manage young startups. As the semiconductor and IT industries matured, successful entrepreneurial founders and managers funneled the capital created and controlled through their stock ownership from these ventures into new opportunities either related or unrelated to their previous success.

The experienced judgment of these entrepreneurs and their knowledge of the entrepreneurial process, augmented by their networks of resources, facilitated the emergence of companies in technologies or markets—such as biotech, solar energy, nanotech, and cleantech—apparently unrelated to semiconductors and IT. The value-added contribution of the successful entrepreneur is their knowledge of the entrepreneurial process and their reputation; this provides the new venture with credibility and accelerates its access to critical resources, perhaps even at reduced costs. In these circumstances, the nature of the Bay Area cluster changed from a cluster of businesses in a related field to a COI where innovation is encouraged by the entrepreneurial process, and where new industry concentrations, unrelated to the leading sectors that benefit from agglomeration externalities, emerge.

Vinod Khosla is an example of this phenomenon. As an experienced entrepreneur, Khosla used his expertise and knowledge—acquired as co-founder of Daisy Systems and Sun Microsystems, and as a General Partner at the venture capital firm of Kleiner Perkins Caufield & Byers—to establish Khosla Ventures, which focuses on nanotech, energy, and cleantech opportunities. Khosla moved from the computer industry to the venture capital industry, initially investing in IT and now investing across a broad portfolio of renewable energy and resource opportunities, assisting a new generation of entrepreneurs to build companies in industries unrelated to his original core expertise.

2.3. Born global

Frequently, mobile resources in a COI cross regional and national boundaries in order to take advantage of international opportunities. Startups are *born global* when they consider from their inception the use of international resources and markets in multiple countries (Knight & Cavusgil, 1996; McDougall, Oviatt, & Shrader, 2003; McDougall, Shane, & Oviatt, 1994; Oviatt & McDougall, 1994). These companies plan their businesses based on global strategic perspectives; they look globally, and use global opportunities when suitable. For startups in a COI, global opportunities are increasingly not only a competitive challenge but also a business imperative. This predisposition contributes to the international mobility of resources, and supports the internationalization of startups at very early stages in their development.

As part of a COI, many of Silicon Valley's startups are born global. Furthermore, some startups have been able to specifically raise capital because they demonstrated they could effectively take advantage of global resources and cost efficiencies through subcontract manufacturing or software development, or because they were able to market their product services outside the United States (Saxenian, 2006). One example is PortalPlayer Inc., a semiconductor company that supplies system-on-chip semiconductors, firmware, and software for personal media players. The company was founded and headquartered in Santa Clara, California, in 1999, and located a development team in Hyderabad, India, shortly thereafter.

Globalization facilitated the circulation of people, money, and technology from abroad, and contributed to Silicon Valley's success (Saxenian, 1994). It also has been a potent force in fostering born global startups. International mobility of people facilitated immigration of talented engineers, scientists, managers, entrepreneurs, and other

professionals from all over the world; today, most companies consist of a multicultural workforce. The mix of cultures requires additional efforts toward integration and understanding, and management of linguistic and cultural differences (Saxenian, 2006).

Multicultural and open-minded workforces offer competitive advantages to companies. First, diversity imparts excitement, energy, and creativity, which are transformed into continuous innovation (Florida, 2002). Professional entrepreneurs (Freeman & Engel, 2007), investors, and employees from various countries and industries can interact with each other and form new networks of people, from the same or divergent industries, cultures, languages, and identities. Despite any potential differences, they all share other commonalities, such as the stage of growth of their ventures, common venture capital investors, or professional service firms. Additionally, the power of diverse shared identities eases collaboration with research centers, customers, and other organizations located in their countries of origin (Castells, 1997). Engineers and managers in such companies have an advantage in global opportunity recognition, resource acquisition, and market access. They can more easily access engineers, managers, suppliers, and customers in both the United States and overseas. An international workforce provides startups, from their beginning, with a global perspective (Saxenian, 2006).

2.4. Alignment of interests

Certain traditional barriers to collaboration tend to be weaker in a COI. In fact, there is a bias toward collaboration both within and among firms. This culture of collaboration is anchored in an alignment of interests, fostered by unique equity compensation mechanisms characteristic of COI. The interest of all parties is the creation of value that is harvested principally through the sale of ownership interests in the venture.

Within the firm, traditional differences between owners and employees are diminished through stock option plans that provide for broad equity participation. Sophisticated shared ownership arrangements, with provisions that motivate and reward accomplishments as well as longevity—such as the vesting of stock options for employees, sales restrictions, and buy back provisions for founders' stock, preferred stock, and the related liquidation preferences for investors—are key to strong bonds and alignment within the venture, and among its founders, managers, employees, advisors, and investors (Freeman & Engel, 2007).

Inter-firm collaboration includes collaboration not only with suppliers and customers but, at times, also with competitors (Florida & Kenney, 1988; Kenney & Florida, 2000). The reason for cooperation between suppliers and customers is clear. Cooperation among emerging competitors—or *co-opetition*—however, is fostered by the innovation process due to the need to establish critical mass, formal or informal standards, and effective customer solutions in a competition with established incumbent practices. Similarly, venture capitalists share deal flow and co-invest as a regular practice. Their investments are staged in such a way that a creative tension is established: entrepreneurs are consistently challenged by investors, who may not make follow-on investments and may move to new opportunities if the agreed milestones toward greater value and an effective liquidity path are not achieved. Broad adoption of these practices contributes to the creation of a common culture of entrepreneurial engagement and collaboration among members of the COI community.

3. Networks of clusters of innovation (NCOI)

If we go back and rely strictly on Porter's definition to analyze Silicon Valley, one would expect that this highly specialized and dense cluster would grow rapidly based on economies of scale and positive externalities, and attract capital and talented people from all over the world. Likewise, the follower economies would be expected to always lag (Saxenian, 2006). However, reality has shown that the dynamism of countries such as Japan, China, and India is not reducible to cost advantages (Saxenian, 2006). These regions have taken world-class tracks in finance, design, and high technology, and are likely to become strong centers for innovation and creativity (Florida, 2008). Beijing produces about as many patents as Seattle or Phoenix, and Shanghai produces about as many as Toronto or Salt Lake City (Florida, 2008). Meanwhile, Israel and Taiwan boast numerous successful technology startups and the largest venture capital pools outside of North America (Saxenian, 2006).

The emergence of new technology and innovation centers has been observed and often been attributed to the leverage of multinational corporations (Mathews, 1999); to the fragmentation of industries (Saxenian, 2006); and to the mobilization of superb knowledge, people, and other resources around the world (Bresnahan, Gambardella, & Saxenian, 2001; Doz, Santos, & Williamson, 2001; Saxenian, 2006) supported by a suitable economic policy

(Kuada & Sorenson, 2000; Mathews, 1997). This phenomenon has to do with human migrations and the consequent “brain circulation” (Saxenian, 1994, 2006), and helps to explain how countries such as China and India emerged so rapidly as international technology and innovation powers.

A COI such as Silicon Valley attracts entrepreneurial, creative, and ambitious people who seek to leverage their talent (Florida, 2008). Although immigrants have often served as a source of relatively low-cost labor, in the Silicon Valley foreign-born engineers have made a substantial contribution to regional job and wealth creation. By 1990, one-quarter of the engineers and scientists employed in California’s technology industries were foreign-born, and up to 24% of the technology companies started between 1980 and 1998 in Silicon Valley were headed by Chinese and Indian technologists and engineers (Saxenian, 1999). Table 1 lists the nationality of the founders of some important Silicon Valley startups; this illustrates the significant role played by mobile people in the creation of Silicon Valley’s ecosystem.

Many immigrants move to Silicon Valley after receiving university degrees, and complete their education at the region’s leading research universities such as U.C. Berkeley, Stanford, or U.C. San Francisco. These individuals become embedded within the entrepreneurial culture and processes of a COI. They experience and learn the mechanisms of goal alignment and relatively non-hierarchical management. They experience a culture of mobility, individualism, and teamwork. Moreover, they get a post-graduate real world education in how startups work, including how startups can be born global.

Technically-expert immigrants working at startups can effectively contribute to mobilize global technology, capital, and people. They have a relative advantage in accessing resources from their countries of origin: not only do they share the culture and language, but also have a network of contacts from college, previous businesses, and family and friends. Beyond this enhanced access to resources, as they gain experience they also gain an enhanced ability to capture and capitalize on opportunities. They combine local knowledge with external knowledge, and therefore are likely to create new value (Bathelt, Malmberg, & Maskell, 2004). They bring a broad perspective which aids in identifying good business opportunities in their home countries, and their experience helps them employ global resources to capitalize on them.

The immigrants who return from Silicon Valley to their home countries have been involved in a highly dynamic innovation system, and have learned and experienced the routines and operations of the entrepreneurial process. If they are able to adapt this tacit knowledge to the new institutional framework (Florida & Kenney, 1990; Saxenian, 2006), returning entrepreneurs may operate from diverse countries but maintain multiple ties with entrepreneurs and professionals in Silicon Valley. They have access to the wide formal and informal network of entrepreneurs which facilitates hiring managerial and technical talent from the United States; collaboration with other businesses, research centers, and universities from the Silicon Valley; accessing of American institutions; and even raising venture capital from the U.S. (Saxenian, 2006) on a low transaction costs basis (Williamson, 1981, 1985). As the new startups in these countries grow, a greater number of entrepreneurial, skilled, and productive people are attracted by the preferential attachment (Florida, 2008) forces, and a new nexus and indigenous COI emerges around them.

For example, Ning-San Chang—who holds a PhD in electrical engineering from Purdue University—moved to Shanghai after working for 20 years in the U.S. semiconductor industry. In 2002, Chang and two Chinese colleagues from Silicon Valley founded BCD Semiconductor Manufacturing in Shanghai to design and manufacture low-cost analog semiconductors for phones, computers, and consumer electronic products. The entrepreneurs’ ties with professionals and investors in Silicon Valley gave them the opportunity to raise venture capital in the United States, and to recruit a multinational world-class management team (Saxenian, 2006).

Collaborations and agreements between individuals and institutions in geographically dispersed COI are frequent, and constitute the global NCOI. These

Table 1. Nationality of famous Silicon Valley startup founders

Company (foundation year)	Founder	Nationality
Sun (1982)	Vinod Khosla	India
	Bill Joy	Michigan
	Andy Bechtolsheim	Germany
	Scott McNealy	Indiana
Google (1998)	Larry Page	Michigan
	Sergey Brin	Russia
eBay (1995)	Pierre Omidyar	France
	Jeff Skoll	Canada
Yahoo (1995)	David Filo	Louisiana
	Jerry Yang	Taiwan
Intel (1968)	Robert Noyce	Iowa
	Andy Grove	Hungary
	Gordon Moore	California

Source: Adapted from Le Bret (2007, pp. 113-114)

networks connect clusters that are organized around associated teams of people and capabilities (Doz et al., 2001), but which consist of mobile resources engaged in the creation of high potential born global startups. The NCOI connect individuals, startups, universities, research centers, associations, mature corporations, and other organizations that are globally oriented and which excel in rapid innovation, experimentation, and commercialization.

The basic elements of the NCOI are individuals, firms, and the relationships among them. Domestic and international relationships in the NCOI are supported by both formal and informal networks of contacts. An important sub-group of these networks is social organizations. They are easily observable, and their presence infers the larger network of which they are just a small component. These network organizations often start as informal gatherings of industry, professional, and affinity groups, and at times mature into strong professional associations. Some of these networks have national or ethnic identities—such as Indian, Iranian, Israeli, and French networks—and have expanded from local operations to support global connections. Following are two examples in Silicon Valley:

1. TiE, The Indus Entrepreneurs, was founded in 1992 by successful entrepreneurs and professionals with roots in the Indus region to foster cultural and business collaboration among this affinity group. TiE has gone on to become a multinational organization with over 12,000 members in 1,800 chapters, and is going through a metamorphosis evolving away from its ethnic identity. This network's tag line, "Fostering Entrepreneurship Globally," pays implicit inference to the organization's role in the global NCOI.
2. SVCEA, The Silicon Valley Chinese Engineers Association, was founded in 1989 and now has more than 6,000 members in the United States, Europe, and Asia. Originally designed with the limited agenda of connecting entrepreneurs, engineers, investors, and other professionals in Silicon Valley, this organization has clearly evolved to serve broader audiences, and to aid the creation and support of ties with like-minded populations in COI in their home countries and around the world.

To use today's Internet terminology, the global NCOI may be envisioned as a global cloud with formal and informal relationships that facilitate and accelerate innovation and entrepreneurship within and among COI around the world (see Saxenian, 2006).

4. Weak ties, durable bonds, and covalent bonds: The emergence of super-clusters of innovation (Super-COI)

While the location of new COI may be considerably remote from existing COI, ventures within COI may tend to collaborate as entrepreneurs seek the best opportunities worldwide. Born global startups exploit mobility to gain access to international assets and collaborations that fulfill their resource needs. International connections go beyond religious, ethnic, territorial, and national identities and affinities, and give startups a global advantage based on orchestrating diverse networks to exploit opportunities or secure resources (Doz et al., 2001).

The global NCOI is essentially a web of individual and institutional relationships. Within the network, connections are created by mobile people and their personal relationships. Apart from familial and close friends' relationships—typically known as *strong ties* (Granovetter, 1973)—we have defined three types of relationships which create the linkages that allow for the formal and informal exchanges of value and the web of NCOI: weak ties, durable bonds, and covalent bonds.

Weak ties are the most frequent connections created by mobile people using networking and face-to-face relationships. They connect people working in the same business, or in the same or related industries, or doing business together, who share information and often communicate face-to-face. International trade fairs, conventions, and other professional gatherings create unique opportunities to share information face-to-face for a short time with people working in the same or related industries around the globe (Malmberg, 2003; Maskell, Bathelt, & Malmberg, 2006). These ties do not impose high management costs (Granovetter, 1973) and provide easy access to information, resources, influence, and opportunities (Chaskin, Brown, Venkatesh, & Vidal, 2001). When these weak ties between players in different COI get stronger, when the contacts occur more frequently, and when the partners exchange not only information informally but share technology, services, and other resources explicitly, the weak ties become durable bonds.

Durable bonds may be established between communities, entities, businesses, or people in geographically dispersed COI. These durable bonds are often accompanied and strengthened by a dense mass of weak ties that enhance the longevity of the relationships among COI. Such relationships are dynamic and fluid, as is the nature of the

interrelationships of their underlying units: the born global entrepreneurial ventures, which themselves are comprised of relatively mobile assets.

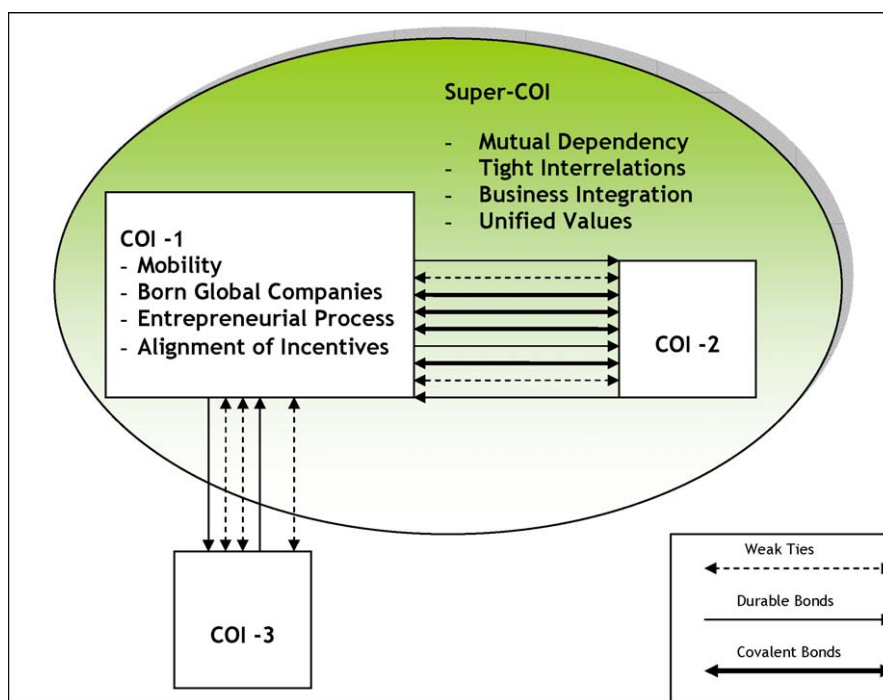
To borrow a concept from physical chemistry, durable bonds and the multidimensional web of weak ties in a NCOI may act as electrons that form covalent bonds in a lattice. *Covalent bonds* emerge if the relationships are permanent and the role of each COI is embedded in the business and processes of the other. In these circumstances, the connections themselves often manifest with single actors performing vital functions in multiple locations—and even multiple businesses—simultaneously.

One exemplar of this mutually beneficial covalent bond is John Woolard, CEO of BrightSource Energy Inc., an emerging leader in the solar energy industry headquartered in Silicon Valley, with research and development in Israel. After experiencing success as a founder of a previous energy related firm, Woolard joined VantagePoint as an Executive in Residence to help the firm develop its cleantech strategies and to identify new opportunities. BrightSource was founded by Woolard, and funded by VantagePoint, to exploit what Woolard identified as an emerging opportunity for utility grade generation using solar thermal technology and an undercapitalized extant plant owned by a firm in Israel. As CEO of BrightSource, Woolard continues as a Venture Partner at VantagePoint and as a member of its Advisory Council. This covalent bond, whereby a single

individual plays contributing roles in two or more ventures simultaneously, forms more permanent and stronger bonds which are not single transactions or exchanges, but strategically effective connections that enhance resource mobility to reduce the costs of innovation, sourcing, manufacturing, customer acquisition, and support.

COI connected through covalent bonds benefit as the flow of information, capital, and commodities is bidirectional. When new additional and multiple covalent bonds are continuously created and recreated between individuals and entities in two or more geographically dispersed COI such that they operate in a coordinated fashion, the NCOI may become a *Super-Cluster of Innovation* (Super-COI); this is derived from the cosmological term “supercluster.” Figure 1 shows the connections and relationships among geographically dispersed COI. The COI are connected through multiple weak ties, and therefore are part of the same global NCOI. COI-1 and COI-2 are also linked through covalent bonds and function as a Super-COI. Even though two COI are geographically disparate—as COI-1 and COI-2 in Figure 1—if they (1) are connected by multiple covalent bonds that make many individuals and businesses in the COI dependent to each other, (2) have mutual respect, (3) share business and management know-how, knowledge creation processes, and network structure, and (4) seek similar benefits and have aligned incentives, they may be considered part of the same Super-COI.

Figure 1. COI, NCOI, Super-COI, and the linkages among COI



For example, Israel and Silicon Valley have a long history of collaborations. Initially, larger established technology firms in Silicon Valley sought to acquire new products and technologies from Israel's rich base of engineering and scientific talent. Because of its military needs, and due to the immigration of relatively large numbers of engineers and scientists from the-then Soviet Union in the late 1980s, and subsequent wave of immigration after the breakup of the USSR, this expertise was plentiful and economical. Exposure to United States business practices, and growing familiarity with commercialization and new product marketing processes, led to a growing interest within Israel for the creation of born global entrepreneurial companies. This was also fostered by an aggressive government policy that provided financing and incubation assistance.

This activity attracted the interest of some Silicon Valley venture capitalists who, starting in the 1990s, established operations to invest in these opportunities. Often, the strategy employed was to identify promising products and technologies in Israel, and to marry this to marketing, sales, financing, and general management talent operating from offices in the United States. Market entry into the U.S. was planned from inception, and this exposure also facilitated follow-on financing from United States sources. These companies are truly born global, and the cluster in which they operate is clearly neither simply Silicon Valley nor Israel, but a Super-COI of both regions, bound by covalent bonds and weak ties. Ultimately—as would be expected—Israel developed an indigenous venture capital community, and it appeared that the reliance on Silicon Valley would weaken. This has proven not to be the case. The small size of the Israeli economy, and the benefit of facilitated entry into the United States' commercial and capital markets, have proven to be a far superior venture development pathway, and the Silicon Valley-Israeli Super-COI now appear to be a permanent fixture of the global NCOI.

5. Future challenges

Herein, we have analyzed new patterns of innovation employed in networks of individuals and organizations in Clusters of Innovation (COI). We have also explained how in COI, new and unrelated industries can emerge rapidly as agglomeration benefits that are defined by stage of development and rapid innovation domination instead of by industry specialization. Further, we have analyzed the nature and differential characteristics of a COI, and explained how they foster born global startups with a heightened affinity for collaboration, due to their

shared practices and need for rapid innovation, leading to the emergence of a multidimensional web of interrelationship, known as Networks of Clusters of Innovation (NCOI).

Some authors have already explained how cultural links, immigration, and transplantation of talented people results in the knowledge, behavioral, and management transfer of entrepreneurial venture creation and innovation processes. That these transfers accelerate and enable the creation of indigenous COI has also often been analyzed. What we add is the characterization of the linkages among ventures and, ultimately, among the clusters themselves. We also contribute an explanation of how the nature of these linkages—weak ties, durable bonds, and covalent bonds—relates directly to the underlying attributes (i.e., the mobility of assets, people, and information, and the compelling need for rapid innovation) that make COI enablers of innovation and entrepreneurship. Further, we identify how these bonds can form a network of ties that are so strong that elements of the two clusters can become mutually dependent on the other, operate in a highly coordinated fashion, and form a network that operates as a single community, or a Super-Cluster of Innovation (Super-COI).

We established a framework that integrates the underlying drivers of entrepreneurship and innovation in COI, the linkages among these clusters—or NCOI—and examples of mutually beneficial interdependence that can achieve global competitive advantages efficiently—or Super-COI. This framework identifies significant organizational and structural characteristics of business communities that are providing for the global diffusion of the excellent innovation processes that characterize COI, such as Silicon Valley. Immigrant entrepreneurs and professionals have transferred Silicon Valley's system of open networks and decentralized experimentation to their countries of origin. COI in China, Taiwan, and Israel have emerged rapidly, and are tightly linked to geographically dispersed but strong innovation nodes. Other countries around the world have the opportunity to get involved in these networks of COI as a means of accelerating their domestic progress. In the absence of immigration and transplantation, however, impediments remain due to differences in legal and economic structures, belief systems, values, and attitudes. Governments face a challenge in overcoming these obstacles.

We suggest that while COI differ from each other, many of these clusters share entrepreneurial styles and management practices that enhance their likelihood of collaboration, namely through structures that permit and encourage the mobility of resources and alignment of interests. Further research and

analysis may identify the crucial elements that are necessary to enhance collaboration among COI, enhance the value derived from participation in the global NCOI, and facilitate the creation of highly efficient Super-COI when they are appropriate. Practical application of this work will provide useful business practices for entrepreneurs and venture investors, and policy direction for regional and national government policy makers. We can look forward to a greater understanding of the innovation processes of COI, the mechanisms of involvement of indigenous COI in the global NCOI, and the benefits of increased interdependence and independence.

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