Building Research Clusters: Exploring Public Policy Options for Supporting Regional Innovation

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ABSTRACT
Governments at all levels are showing great interest—and some are spending lots of money—in developing research clusters that they hope will benefit their local and national economies. Clusters are complex, however, and this chapter aims to help policy-makers maximize their benefits. The chapter offers a taxonomy of countries and their potential for cluster development and explains a five-stage process for realistic cluster building. Stage one assesses capacities, resources, and opportunities. Stage two involves choosing an anchor strategy. In stage three, organizational and institutional leaders are identified to take the lead in developing the cluster. In stage four, proactive tactics are chosen. Stage five identifies the cluster's lifecycle and the strategies needed to sustain it. Cluster building is knowledge-based development, which is inherently different from traditional industrial development. For one thing, cluster building requires global links. Companies and skilled employees are less interested in fiscal incentives, public infrastructure, or other government support than in the innovation community and its networks.

1. INTRODUCTION
Theory suggests that competing companies and their related industries often concentrate in a few locations and generate higher value, more jobs, and more innovation than companies that do not locate near clusters with companies in related businesses. Ultimately, those that do are benefiting from some traded or untraded interdependencies: economies of scale in related or supporting industries, economies of scope in labor and capital markets, or knowledge spillovers from competitors and collaborators.[1]

Some analysts estimate that the benefits of scale, scope, and—perhaps most importantly—tacit knowledge spillovers are usually limited to between 10 and 100 miles of the epicenter of a community. Given that the cities, regions, and countries that host these clusters would likely benefit, all levels of government are greatly interested in doing whatever is appropriate to spur local development of these clusters.

While analysts do not agree about much, they generally accept that clusters are complex. Subject to industrial evolution, changes in global markets, the knowledge bases that drive them, and the geopolitical forces that influence their development and success, clusters are diverse and their characterizations are open to interpretation. Additionally, clusters go through cycles. There are periods when they require high reinvestments (public, private, or both) of money, time, and resources. At other times they provide high payouts. No one cookie-cutter approach or measure can be employed to develop and manage a cluster.

Assuming that the cluster is a dynamic phenomenon and subject to a lifecycle, a number of important factors come into play when assessing and supporting innovative capacity. This chapter first examines a taxonomy of countries and their potential for cluster development. It then looks

Phillips PWB and CD Ryan. 2007. Building Research Clusters: Exploring Public Policy Options for Supporting Regional Innovation. In *Intellectual Property Management in Health and Agricultural Innovation: A Handbook of Best Practices* (eds. A Krattiger, RT Mahoney, L Nelsen, et al.). MIHR: Oxford, U.K., and PIPRA: Davis, U.S.A. Available online at www.ipHandbook.org.

at a five-stage process for cluster building. Stage one involves using an array of common analytical tools to assess a candidate for a cluster: these tools include an overview of discrete measures along with some more general analytical tools, such as social network analysis and emerging markets analysis. Stage two involves choosing one of the strategic options. Stage three identifies and mobilizes actors or organizations within the region (public, private, and others) to take a lead in the cluster. Stage four involves choosing from a set of proactive tactics for encouraging companies to cluster. Stage five identifies the lifecycle of the chosen cluster and the strategies needed to sustain the initiative.

2. THE CONTEXT

According to Mashelkar,[2] building indigenous technological capacity, in any context, requires a number of conditions: a conducive policy environment, entrepreneurship, promotion of a culture of innovation, access to technology (where necessary, through international technology transfer), an educated and skilled workforce, and a "learning by doing" mentality. Although Mashelkar explores indigenous technological capacity exclusively from a developing country perspective, his approach can be applied to examine, not only the disparities between developed and developing countries, but also disparities within and between developed countries as well.

Morel and colleagues[3] present a taxonomy to assess economic strength and innovation capacity in health and health-related organizations. Six dimensions (manufacturing capacity, domestic market, export market, R&D, IP system, and drug regulatory system) are explored across three stages of development that, in combination, are used to measure the capacity for developing countries to progress in terms of innovation. We have adapted this taxonomy to assess the capacities of different groups of nations for supporting cluster development and growth (see Table 1).

Most countries can be relatively cleanly assigned to one of Mashelkar's four quadrants. Quadrant I countries consist of leading industrial nations, such as the United States, Canada, Australia, Japan, and E.U. countries. Quadrant II countries, which have relatively low per capita incomes but high innovative capacity, include Korea, China, Brazil, India, and some eastern European countries. Quadrant III includes resource-rich and resource-dependent countries such as those in the Middle East. Finally, Quadrant IV consists of developing nations, such as those in southeast

Table 1: Taxonomy for Determining Nation/State Cluster Capacity

	Quadrant I countries	Quadrant II countries	Quadrant III countries	Quadrant IV countries
Economic strength	high	low	high	low
Innovative capacity	high	high	low	low
Comprehensive cluster policies	advanced	emerging	n/a	n/a
Incidence of formalized clusters	high	moderate	low/none	low/none
Degree of specialization	high	moderate to high	moderate to low	low

Source: Adapted from Mashelkar[4] and Morel[5] and colleagues.

Asia countries, Sub-Saharan Africa, and south and central America.

Quadrant I countries rank highly in terms of economic strength and science and technology capacity: by most measures they have the lion's share of the clusters and are the most aggressive supporters of cluster development. A closer look at the United States shows that there are more than 160 clusters identified across 25 states, with cluster activity ranging from narrowly defined categories such as oil and gas (for example, Louisiana) or gun manufacturing (for example, South Dakota) to more broadly based categories such as biotechnology[6] or life sciences.[7] Moreover, nine state legislatures in the United States have either written into law, or at the very least recommended, that the State apply a cluster approach to economic development,[8] while seven other states[9] have nonlegislated, cluster-based economic development strategies in place. In contrast, while Canada has no formalized national cluster policy,[10] most of the provinces have examined and attempted to support clusters in their jurisdictions; there would appear to be at least 25 clusters or emerging clusters in nine sectors across Canada.[11] In Australia, a national cluster policy has been proposed that advocates for strategic, proactive polices rather than the current laissez-faire approach, but the program has yet to be formally implemented.[12]

On the opposite end of the continuum, Quadrant IV nations rank low in terms of economic strength and innovative capacity. This is due to a range of limitations, including weak infrastructure and incomplete IP regimes. However, some cluster activity is emerging. Several small artisan or trade-type clusters (for example, the garment industry in Kenya) have emerged in Sub-Saharan African regions,[13] but these clusters are characterized as low in terms of specialization and are often composed of networks of "petty commodity producers."[14] Another approach has been to create export-processing zones. Mauritius was the first African country to establish an export-processing zone (EPZ) in the early 1970s.[15] Meanwhile, in Asia, despite the financial crisis of the 1990s, countries such as Indonesia, Malaysia, and Thailand have encouraged significant economic development by emphasizing industrial exports.

The middle quadrants (II and III) include countries that have low to medium capacities in terms of economic strength and innovation. Clusters, if present, often exhibit low technological or industrial application. The exception is Korea. Although categorized as a Quadrant II country, it has developed significant cluster capacity in such specialized areas as movies and animation, information technology, and digital media.[16] Similarly, China and India are growing in terms of economic strength and innovative capacity. In India, the United Nations Industrial Development Organization (UNIDO) and the national government support over 350 small-scale industry (SSI), rural and artisan-based clusters. India has also had some acknowledged success in creating world-class clusters in Bangalore in biomedical research and software engineering.[17] Some Middle Eastern countries, although ranked high in terms of economic strength, are often solely dependent upon the extraction and processing of natural resources such as oil and petrochemicals; scientific and technological capacity is limited in these countries.[18]

In short, while clusters are both stronger and more prevalent in Quadrant I countries, all countries have the potential to benefit from clusters. Every region needs to evaluate its capacities and opportunities, make strategic choices about which areas to nurture, choose specific tactics, and identify and support indigenous leadership. Such choices, moreover, will need to be tailored to the capacities and opportunities of the individual countries and regions.

2.1 *Step 1: Evaluation*

The first and most important step in developing clusters is to assess capacities, resources, and opportunities. Given the importance of planning, the tools are surprisingly weak. No one tried-and-true acid test for cluster capacity or potential exists. A number of methods have been used—ranging from ad hoc to formalized consulting and opinion formation, to valuing or analyzing cluster capacity through descriptive or institutional analysis, to empirical, statistical analyses of detailed industrial data—but to truly understand or evaluate the potential efficacy of a cluster likely requires a blend of quantitative and qualitative approaches.

Given that clusters are to some extent self-defining, one approach often used is to convene an industrial, expert, or community forum to identify common interests and opportunities. While useful for identifying actors, or at least companies that would willingly participate, these processes are simply a starting point. In the first instance, they will likely determine whether the necessary number of interested/engaged actors can foster effort to develop a cluster. The processes can also be valuable for identifying the scale and scope of current traded or untraded interdependencies, as well as for planning future development that may either require or generate greater connections in a community. They often run the risk, however, of becoming either subject to groupthink (where everyone goes along with the most important or loudest participant) or unfocused debates about what is, is not, could be, or should be happening locally. Every process needs to move beyond rhetoric. Depending on local capacities, two main approaches have been tried.

One common analytical approach is to look at the institutional composition and leadership of the industry, supply chain, technology, or market. Generally speaking, clusters always represent a high concentration of people and activity within a particular region. Thus, a quantitative analysis of clusters would use measures that reflect those concentrations relative to benchmarks or other regions. A foundational theory that underlies any number of quantitative approaches is central place theory, a geographical theory that seeks to explain the size and spacing of human populations. The theory relies on the notion that centralization is a natural principle of human order and that nested hierarchies of people and institutions will follow this principle.[19] In the context of that theory, many communities will seek to identify the community's array of industry (for example, leading companies and suppliers), supply chain (the linked suppliers ranging from input industries through production to transportation, wholesale, and retail trade), and functional actors (finance, marketing, research, and labor services).

Both of the above approaches can be used by all countries in all quadrants. As data becomes available (often only as a country becomes more developed), a number of other approaches can be used, including location quotient measures, shift/share analyses, and emerging-industry cluster analyses.

The location quotient (LQ) measures competitiveness by comparing a region's relative share of a particular activity to the share of that activity in some reference economy. This identifies specializations in a given regional economy. A commonly utilized economic-analysis method, it was developed in part to offer a slightly more complex model to input/output analysis.[20] A location quotient of less than one indicates that there is lower share of activity or nominal competitiveness within that region—in other words, the area has less than its share of activity or is less competitive than the larger region or country. A location quotient equal to one indicates the area has a share of activity in accordance with its share of the base. Finally, a location quotient greater than one indicates that the area is more competitive relative to other regions or the nation-state as whole. The location quotient can be applied similarly to regional wage levels relative to national or state levels. Additionally, the measure may be used to highlight policy impacts (for example, federal funding initiatives or support of science and technology) within a cluster or region. If a location quotient for support activities is significantly less than one, but the LQ for the cluster is greater than one, then there may be a case for reallocating effort more in line with natural competitiveness. The Boston Consulting Group adapted this methodology and examined year-to-year changes in location quotients to test the specialization of regions in particular industrial sectors. It arranged the results into four categories of clusters: stars (specialized with increasing specialization), mature (specialized with decreasing specialization), emerging (unspecialized with increasing specialization) and transforming (unspecialized with decreasing specialization). This methodology was then used to analyze Indiana's cluster data: of the 15 Indiana-based clusters identified, most were categorized as stars or "transforming."[21]

Shift/share analysis is another technique used to determine how much of an area's employment change is due to the nature of the national economy, the industrial mix, and local competitiveness. This approach makes it possible to separate growth into three components: national growth, industrial structure, and regional competition.[22] The shift/share analysis tool is composed of three components or equations. First, the national growth component measures the effect of national growth on a given local economy. Second, the industrial mix component identifies the relative growth or decline of local industries as compared to overall economic performance. Third, the differential shift component measures the change in the local economy that is attributed to local economic advantages, such as natural resources, or disadvantages, such as low wages. Shift/share analysis was used to analyze the composition of the growth of the southern United States in the 1980s.[23] More recently, shift/share analysis has been used to assess the competitiveness level of Singapore's exports.[24]

Emerging cluster analysis is a broader tool. It begins by using employment levels to identify a dominant industry or a fast-growing, emerging industry. The measure compares employment and wage changes in an area's cluster over a defined period of time with the larger region, state, province, or even the nation. Overall, if the net change in employment and/or wages is greater than or equal to 100%, the cluster is considered to be emerging. However, if the change is between zero and 99%, the cluster is considered to be relatively stable. A cluster is considered mature when the percent change is less than zero.[25]

Social networks analysis (SNA) is yet another diagnostic tool for cluster analysis. It is primarily used to collect and analyze data about relationship patterns among individuals, though it does not simply examine the economic consequences of those relationships. According to Wellman, it is a powerful method for "*explaining variances in resources, social behavior and socio-economic outcomes.*"[26] SNA is guided by a focus on the dialectical relationships between agents, nodes, and actors. It makes the invisible work visible.[27] When applied to knowledge management, it can identify patterns of interaction and knowledge-exchange flows within a network. It shows how knowledge-intensive work is done and can illustrate complex communication channels within a network. As a tool for analysis, SNA views "*actors and actions … as interdependent*" units and acknowledges that the "*relational ties*" between actors are "*channels for transfer or flow of resources.*" It can also provide "*opportunities for or constraints on individual action,*" which is antithetical to more traditional economic approaches.[28] SNA helps to identify boundary spanners, gatekeepers, and knowledge bottlenecks, as well as under- and overutilized individuals or organizations. So many things are coordinated in networks (for example, workplace environments, clubs, and memberships) that SNA appears to have almost universal application. Indeed, multiple levels of analysis can be employed: the dyad, the node itself, or even the entire network. The entire incidence matrix (agent by agent or agent by event) can become the target of analysis, or it can merely become one variable in an adjacency matrix to explore correlations between variables.

A number of measures inherent in SNA help to illustrate realities that cannot otherwise be observed in the social setting. *Density* measures how many potential linkages within a social setting (that is, pairings of different actors) are actually operational. Theory suggests that some nontrivial amount of density is required, but that too dense a community can stifle innovation and change. The concept of *centrality* refers to the importance of particular actors and the hierarchical nature of an entire network. In general, centrality measures are used to "*… describe and measure properties of 'actor location' in a social network.*"[29] Centrality (applied to the node level) is a family of three measures, each answering a different theoretical question. *High degree centrality* refers to a high number of ties and the level of power or informal leadership capacity of an actor, agent or node. *High closeness centrality* builds upon high-degree centrality but also looks to the nature of the distance between nodes. *Betweenness centrality* identifies the critical route for flows in the network and the dominant node or agent that has more close relationships to other dyads. In terms of centrality, it is not just how many connections an agent or node has, but how central its connected actors or agents are.[30] The power of a node or actor can be measured as a function of its position within a given network.[31] The eigenvector measure is useful for this analysis. An actor or agent who is high on eigenvector centrality is connected to many actors who are themselves connected to many actors, thus multiplying their risk and/or opportunity: this is their power indicator.[32] While the data requirements for SNA can be large, there are a number of generally available proxies. Co-publications (bibliometrics) and co-patents (technometrics) are often used as proxies for social interactions among agents.[33]

These discrete measures and analytical approaches have been employed to varying degrees in a number of regions or countries around the world. Table 2 provides a provisional assessment of analytical approaches and measures used to analyze regional competencies across a select number of regions worldwide. Upon closer examination, it appears that when multiple clusters are analyzed within a region, more analytical approaches are required or undertaken. Also, specialized or knowledge-based clusters often demand a more complex blend of analytical methods. For example, Minnesota's (low technology) industrial clusters were analyzed using location quotients and input/output analysis alone, while Iowa's

Table 2: Cluster Analysis Methods across Select Countries and Regions

Cluster(s) or region(s) of interest	knowledge intensiveness	Shift/Share analysis	Location quotient	Emerging industry analysis	SNA	I/O or descriptive analysis
Indiana (1) (multiple)	med to high	√	√			√
Iowa (2) (multiple)	high	√	√	√		√
Pennsylvania (3) (multiple)	low to high	√	√			√
Minnesota (4) (multiple)	low		√			√
Canadian communities (50+ cmas) (5)	low to high		√			
Calgary wireless cluster (6)	high		√			√
Mississauga's ICT cluster (7)	high		√			√
Quebec photonics cluster (8)	high				√	√
Saskatoon's canola research cluster (9)	high				√	√
Singapore's export industry (10)	low to high	√				

Sources: See endnotes for full list of sources.[34]

more-advanced technological clusters were analyzed using a combination of approaches. SNA appears to be less commonly used as a cluster analysis approach, at least partly because the process can be resource and time intensive and frequently requires gathering primary data, which is often not pragmatic from a practitioner's point of view. Past practice suggests that input/output and institutional or descriptive-based analyses are the most commonly used approaches for exploring clusters. Additionally, the location quotient appears to be the quantitative tool most commonly used in this selection of regions or clusters.

No matter what approach or tool is used to analyze a given cluster, the efficacy of such measures depends upon the quality of the data. Knowledge-based industries in particular, such as biotechnology, often are not adequately reflected in data collected through North American Industry Classification System (NAICS) codes. Furthermore, there is no consensus on where to draw lines or pull together multiple codes to best represent a cluster. Cluster boundaries, particularly in advanced technology sectors, cannot be defined by conventional product-based industrial or sectoral boundaries. This limitation is particularly important with respect to biotechnology.

2.2 *Step 2: Choosing a cluster strategy*

Table 3 outlines a chronological typology of cluster definitions, beginning with Porter's industrial approach. Different cluster approaches will have a different set of requirements, a different mix of leaders and tactics, and will fit better with some categories of countries than others. Economic development agencies in developed and developing countries have usually applied Porter's generalized approach to clusters, customizing it to the particular geopolitical region (see chapter 3.12 for examples). Indeed, despite the lack of consensus about what a cluster does and how it operates, Porter's version of a cluster has been rapidly adopted by practitioners from all over the world.

Porter's industrial managerial characterization focuses heavily on the local and regional relationships between competing and collaborating companies, often without any specific industrial, product, or technological core. These types of clusters appear to emerge and succeed where there are a number of highly competitive companies or competing supply chains that rely on the economies of scope and scale delivered by related and supporting industries. Porter emphasizes that the most successful clusters of this type have either a direct local or a strong link to demanding, leading-edge consumers. Few centers in the world (especially in Quadrants II–IV but even in some of the more-advanced Quadrant I countries, such as Australia, Canada, and New Zealand) can meet this criterion. In this sense, these types of clusters have a greater chance of success in Quadrant I nations, such as the United States, European Union, and Japan, all of which have large, wealthy, and demanding (that is, trend-setting) indigenous local markets.

The product/market, flagship company, and value chain models are all variations on clustering focused around a technology, product supply chain, or product market. As companies in these types of clusters seek greater efficiencies, they begin to formally and informally acknowledge their local and regional interdependencies with other competing and completive companies. Over time, various types of nontrade interdependencies arise, which strengthen the collective. This model has perhaps more applicability to a wider range of countries because all economies, regardless of their local capacity, are fundamentally linked to a technology, product, or market through some form of supply chain or industrial structure. The difference in the three approaches is who takes the lead. In the product/market cluster there often is no single formal leader; instead, varying combinations of companies and civic leaders will work to build the needed infrastructure, scale, and scope to realize the cluster's potential. A number of clusters actually have sole leadership vested in a flagship company or national champion. The value chain model usually vests leadership in some "integrator." This can vary widely depending on the nature of the supply chain: it can be the largest enterprise in the chain; a logistics, wholesale, or retail actor; the owner of some key technology, infrastructure, or product in the chain; or it can be a leader of some industrial, technical, research, educational, or financial organization. This type

Table 3: Chronological Typology of Cluster Definitions and Examples

Cluster type	Definition/description	Example(s)
Industrial/managerial characterization	a geographic concentration of competing and cooperating companies, suppliers, service providers, and associated institutions based on industrial interdependence (supply and demand linkages)	Italian textile districts, Third Italy[36]
Product/market focus	characterized as networks of production of strongly interdependent companies, knowledge producing agents, and customers linked to each other in a value-adding production chain	Italian footwear cluster Australian wine cluster
Flagship/company	Multinational-enterprise-ledclusters/anchor; act as flagships	Monsanto-led St. Louis, Missouri, BioBelt Cluster
Value chain (horizontal and/or vertical)	includes final market producers, and first-, second-, and third-tier suppliers that directly and indirectly engage in trade (A value chain cluster is an industry cluster identified as an extended input/output or buyer/supplier chain. The cluster comprises multiple sectors or industries.) system of market and nonmarket links between geographically concentrated companies and institutions (The links enable cooperation among suppliers and competitors on business processes, purchases, investments, strategies, and technical research.)	Silicon Valley Boston Life Sciences Cluster
Networks	most salient in a domain between the flexibility of markets and the visible hand of organizational or political authority	Biovalley (borders France, Switzerland, and Germany)
Innovative entrepôt	geographic specialization in a few linked stages in the innovation supply chain (for example, research, development, gestation, and adaptation)	Saskatoon canola research cluster (Canada)

Source: Adapted from Phillips[37]

of model would appear to be scalable to all of the categories.

Finally, some clusters are defined by their role in developing useful knowledge. The networked model is increasingly common in large centers in Europe and the United States. Examples include world-scale universities (for example, Stanford/UC Berkeley in San Francisco), critical research infrastructure (CERN in Switzerland), and often the head offices and research centers for large multinationals. Malerba[38] identified two discrete, independent systems of innovation that would fit the networked model. Typified by the computer software industry, one system is based on flexible networks of small- and medium-sized companies, often co-located in distinct industrial districts (for example, Silicon Valley), and coordinated by a range of commercial venture-capital corporations and angel investors. Companies in these communities tend to be significantly volatile and rapidly growing. The other type of system, which perhaps better reflects the biotechnology world, is based on the universities, public research laboratories, and large companies that perform and commercialize R&D. While clearly attractive, this model has limited scope to expand beyond the largest agglomerations. These are currently in the United States, the European Union, and Japan (and perhaps in the larger research centers at Melbourne, Australia, and Toronto, Canada). In time, however, it could be attractive, especially to Quadrant II countries with large populations (such as China, India, and Brazil), which are increasingly focused on adopting, adapting, and increasingly developing new technology.

An alternate "innovative entrepôt" model being adopted by some smaller, research-intensive communities concentrates on a narrower range of inventive areas and seeks to fashion some comparative advantages by being an expert in something in a particular location. While this model[39] requires most of the elements of the larger networked clusters, it relies on small, nimble, highly specialized networks to create a comparative advantage for the region. This has particular appeal to many communities because it does not require the scale of the networked model, and it can be adapted and adopted realistically in most countries. Scale is less important than focus and strong networking. The challenge of this model, however, is that it requires the capacity for a high degree of trade in people, knowledge, technologies, and products, making it less attractive to Quadrant III and IV countries where there remain significant economic, legal, social, cultural, and physical barriers to the flows necessary for such a model to work.

2.3 *Step 3: Finding institutional and organizational leaders*

Actors provide varying levels of leadership based on the dominant activity of different stages of the industrial life cycle. Key actors in most clusters are often the university, public sector research laboratories and institutions, and the private sector. The first two categories of clusters—Porter's industrial managerial model and the product, market, value chain approach—tend to be led by private companies, while more innovative networks or entrepôts will have varying arrays of leaders, depending on the rate of innovation. Zilberman and colleagues[40] undertook a conceptual analysis of agricultural biotechnology, proposing a five-stage linear development process (including discovery, development, gestation, production, and marketing), with different actors (universities, public labs, and corporations), taking the lead at different stages. In early stages, public labs and universities tend to lead, with corporations doing little beyond marketing any resulting products. The model suggests that as the technology matures, corporations contribute more and increasingly take the lead.

Almost all scholars and practitioners agree that competitive, profit-seeking companies are at the core of any cluster. While some clusters seem to be able to operate without a clear dominant player, many scholars have noted that some of the strongest clusters are formed around multinational enterprises (MNEs).[41] Rugman and D'Cruz[42] argue that MNEs frequently act as flagships to lead, direct, coordinate, and manage strategic, value-added activities of collaborative companies in combined business and social networks. According to their research, 14 of the world's 20 largest international MNEs (defined by revenues and global presence) were largely home-based organizations with strong regional strategies and networks. Gassman and Gaso[43] argue that regardless of whether the MNE is home-based or not, it can act as a broker of knowledge in a cluster. Some MNEs contribute information in disembodied forms: they set up "listening posts" in many regions around the world and distribute information. Other MNEs transfer knowledge embodied in new technologies, new processes, and new products. Regardless of the method, companies are a necessary condition for a cluster.

The regional university can also directly or indirectly drive the evolution and success of a technology cluster. According to Niosi and Bas,[44] innovation in emerging technologies and industrial clusters can be spurred indirectly through decentralized, horizontal policies that include the creation of both government laboratories and research universities. A source for skilled labor, the university acts as a magnet (directly and indirectly) for "stars" and business. Moreover, its publications can be a conduit for local and nonlocal knowledge exchanges. The traditional role of a university is to generate and diffuse basic or explorative (know-why) knowledge and generate a skilled academic and technical labor force. However, these traditional roles are evolving. As Cooke[45] argues, a strong local science base needs to be complemented by a rich entrepreneurial culture not only within the regional business community but also within the academic community. He further suggests that "*… the science base is a magnet, even if only indirectly ... for biotechnology business.*" This is supported in previous research, which found that the existence of a diversified, mainly academic, knowledge base is a prerequisite for successful, localized innovative activity in knowledge-based sectors like biotechnology.[46] Niosi suggests also that universities are a foundational element of the "*virtuous cycle*" embedded within the cluster phenomenon—star scientists become entrepreneurs and spinout commercial ventures.[47]

Regional leadership is not limited to just organizations and companies. Key individuals can be ambassadors or civic entrepreneurs for regions and/or act as catalysts for change. For example, Robert Mondavi altered the face of the wine industry when he founded the wine cluster in the Napa Valley in California. Wine producers were already in the region, but most guarded their operations with secrecy. Mondavi opened the doors of his winery to tourists, customers, and competitors alike, effectively transforming the regional wine industry into an open platform of pooled knowledge and diverse products that eventually spelled success for the region.[48]

Finally, collaborative leadership has been another powerful tool in some regions. For example, the BioValley network (located in the Rhine valley where France, Germany, and Switzerland meet) was initiated in 1996 following the merger of Ciba-Geigy AG and Sandoz AG, both of Basel, Switzerland, to form Novartis AG. The region had lost jobs from the merger, so advocates, both key individuals and existing organizations, led revitalization efforts. The original BioValley concept, developed by Georg Endress and Hans Briner, was to re-create the region as a "Silicon Valley" dedicated to biotechnology and chemical technologies.

Cooperation or collaboration among public/private actors and individuals is important for the innovation process. Cross-fertilization through partnerships, either in projects or in efforts to build innovative regions, alerts the public sector to market demands and provides companies with access to basic research.

2.4 *Step 4: Choosing tactics*

While many purposive, directed strategies can help, perhaps a cluster's most important requirement is that the economic and business climate support market efforts. Because clusters involve both traded and untraded interdependences that can thrive only with strong underpinnings for market and social activity, centrally planned markets are unlikely to develop a true cluster. Minimally, a country needs to have the legal and social structures that create certainty for what would otherwise be risky transactions: the rule of law; effective and efficient mechanisms to protect and adjudicate property; the lowest possible barriers for entering or exiting any of the key input and output markets; the ability to trade domestically and internationally; and effective tax, regulatory, and trade rules. Moreover, clusters tend to thrive best when at least a base investment has been made in education, training, and general community infrastructure. Clusters do not go in search of the lowest cost site; rather, they locate where things can get done. Unfortunately, such basic conditions are absent in many regions of the world, but especially in Quadrant IV countries. Any proactive measures to create a cluster without most if not all of these basic preconditions would likely be useless. In some instances, one or more of these foundational conditions may be missing (or weak) and a cluster might emerge, but generally proactive efforts will only succeed if markets can function.

Beyond ensuring an appropriate climate, an almost limitless array of proactive investments can nurture one or more cluster types. Some are more appropriate for some types of cluster than others. (Of course, there is no guarantee that the efforts will create the benefits envisaged.) A favorite tactic is to start with a cluster's core actors. All successful clusters appear to have a hub or anchor. Depending on whether the cluster is industrial/managerial or product, technology, or supply-chain-focused, this could be a set of competing companies, a leading company, a university, a public laboratory, or an industry association. If an anchor does not already exist, most regional planners and politicians will instinctively think of an investment-attraction program; virtually every jurisdiction in the world has someone marketing their location as a place to do business. But while expectations are often high, prospects are poor. Few companies are truly mobile. Most that are mobile would need inducements: large subsidies that could have a higher impact in other areas and that, in the end, would add little to job creation and wealth generation in the long term. In the absence of an obvious anchor, it usually makes more sense to build on potential local candidates than to try to lure others with subsidies. In lieu of a dominant companies, regions have sometimes been able to nurture Porterian or supply-chain type models, as long as they have been able to tap into distribution systems that provide access to global markets.

A second common model is to build potentially attractive infrastructure on the assumption that "*if we build it they will come.*" Unfortunately for many of these ventures, infrastructure is only a minor attraction: "*You will build it and they will not come.*" Increasingly, infrastructure needs to be tailored to the specific needs of a user, so if it is built on speculation, it often can be far more costly than if it is built to suit. Having said that, industrial actors often cite infrastructure, in the form of labs, incubators, and sophisticated machinery that benefits a wide range of users, as a key reason for their presence in a community. The physical plans for any infrastructure may be less important in the long run than the business model. An operator of infrastructure—be it a research park, special laboratory, or experimental facility—will need to tailor the terms of access and use to ensure that highly volatile and competitive research and development programs are able to access the facilities at the right time and under the right terms (for example, clearly defined IP rules). In research today, timing and terms are often more important than cost. Nevertheless, there is no single infrastructure set that is necessary or sufficient to make any cluster work.

Some think money is the key to the problem: If only more programs were created and more money made available, a cluster would emerge. It is true that money drives activity, but not all activity is desired. While in theory money is fungible—it shouldn't matter where it comes from—in practice money comes with strings attached. Who provides it and under what conditions can influence what others are able to accomplish with it. MNEs and other for-profit companies provide the lion's share of capital in almost all markets, so engaging profitable operating enterprises is almost a prerequisite for creating a sustainable cluster. During growth phases, however, public and private venture capital can be a critical contributor to the success of new technologies, products, and ventures. In the early stages of research, public funding tends to dominate, with private capital taking over as technologies, products, and processes mature and get closer to the market. In fact, public funds at later stages can be both good and bad. Government decision-making processes (designed to ensure accountability and transparency) are generally inimical to effective and efficient financing: many companies ultimately supported by government grants or subsidies find the benefits are dissipated by slow decisions and inflexible terms. Furthermore, governments often have difficultly exerting the same influence as private investors. For example, it is hard for most governments to change management in a venture they have invested in or to divest or write down their equity. Public funds tend to be most effective when they are partnered and leveraged with private funds or private management skills (for example, microcredit systems and public/private venture pools with private management).

Locations lacking an anchor, an irresistible piece of infrastructure, and unlimited financial resources often look to their public research institutes or universities, especially in the early stages of developing a new technology area. Particularly with knowledge-intensive industries such as biotechnology, universities' public investment in R&D facilities is arguably a crucial precondition for a knowledge-based innovation system. Their capacity to create social capital, nurture and support stars, and provide a basis for collaboration and innovation—while harder but not impossible to measure—is ultimately the real value of such investments. As previously mentioned, the regional university can drive (directly and indirectly) the evolution and success of a technology cluster. Niosi and Bas[49] assert that universities do four main things: they generate know-why knowledge; they provide skilled, educated labor; they draw (directly and indirectly) stars and business; and they facilitate local and nonlocal knowledge exchanges (for example, publications and joint research). Many argue that a university's most important output is the base that it provides for the "absorptive capacity" of an economy. While the university is vital, it will only be able to perform this function in conjunction with a number of other essential elements. First, there must be an effective mechanism to both practically and legally transfer knowledge. At a minimum, this requires a domestic research community with international collaborations, companies with proprietary technologies, and an appropriate national system to legally protect IP. Second, there must be open and accessible labor markets for skilled and educated workers. Third, an institutional platform, such as a major national laboratory, a university, or a big research institute/program, is needed for community-based interaction and synergies to develop. These provide the foundation for absorbing global knowledge. Other elements, such as preferential financing and specialty commercial services, may be important but appear to be second-order requirements.

Ultimately, many theorists and practitioners are looking to "people policies" to nurture clusters. People are at the heart of generating new ideas and technologies, people lead and work in companies and institutions, and people are the core of networks. Some clusters seek to build up their local talent by creating new educational and skills training programs focused on the market needs of their local companies and clusters. Others work on building bridges to attach graduating students to the local labor market. These programs range in focus from technical training, entrepreneurial training, and mentoring to specialized advanced research techniques. Some clusters seek to attract highly skilled, educated, motivated, and experienced stars from elsewhere to populate their community and provide new ideas and leadership. Florida and Gates50 have suggested that the most vital and vibrant communities in the United States and Canada are those that value and support tolerance and talent. They suggest that creative, entrepreneurial people will tend to vote with their feet and move to communities with the most accommodating lifestyle. Other researchers suggest that good climate, culture, civic amenities, tax levels, and other quality-of-life measures are vital to creating a cluster. There is, however, some contradictory evidence: attraction to clusters may be less about quality of life and more about the depth of local labor markets (for example, the potential of there being more than one employer for one's specialized skills in the area) and the nature of the job (for example, one that is on the cutting edge of a technology or market).[51]

A closely related people-policy strategy is to target local stars in a community. Zucker and colleagues[52] have noted that in the U.S. biotechnology field, academic and professional research stars (that is, those with a significant number of patents or publications) appeared to be instrumental in attracting major peer-reviewed grants, were key players in translating knowledge between academic and applied research, and were major contributors to the spinout of many new biotechnology companies. These stars assisted other researchers and industry. When the stars became affiliated with new spinouts, this signaled the presence of an opportunity to the marketplace. Some regions have attempted to collect more clusters of stars by collecting research expertise in national centers of excellence in public labs or universities. These regions and stars have also provided added incentives for the scholars and scientists to engage in more external activities, on public and private boards and commissions, or through consulting work. Similarly, many communities promote or nurture civic entrepreneurs. Often in university, industry, or industry associations, these individuals undertake efforts to defend, explain, or inform the entire cluster to its members and others outside. These civic entrepreneurs are highly valued—they will often personify and coalesce a cluster's spirit and aspirations. The regional entrepreneurial culture is also considered important, but it is not clear whether it is an independent variable or is simply determined by local economic development.

2.5 *Step 5: Sustaining a cluster through its life cycle*

Clusters appear to have life cycles. Sometimes strong centripetal forces pull activity to the community (for example, through knowledge spillovers and economies of scale and scope); at other times, centrifugal forces will dominate (for example, diseconomies and congestion costs).[53] Lundvall[54] offered a neo-Schumpeterian model of industrial development that explains localization patterns based on the degree of technological development: innovative clusters have the highest incentive to agglomerate, but markets become concentrated and profits stagnate as benefits decline, costs rise, and products are standardized. Sustaining a cluster, therefore, is not ensured. Successful clusters continue to focus on innovation (rather than on production efficiencies), which requires sustained investment in R&D.

The cycle of investment and return in clusters has been explored also by Davis and Schaefer,[55] who outline a five-stage evolutionary process. In the first stage, assets are accumulated, with investments often coming from the public sector (for example, the recent worldwide infusion in genomics research). In the following stage, assets are converted into business resources through entrepreneurial effort. Next, the cluster is established and companies grow by exploiting new resources and capabilities in external markets. Then as production and markets mature, collective efficiencies are realized. Finally, various market and non-market selection processes lead to local specialization. Crone offers a more formally delineated and stylized five-stage cluster-development model: precluster, protocluster, emerging cluster, established cluster, and restructuring or renewal states.[56] According to Crone, these stages are not intended to constitute a deterministic life cycle model but to serve as an analytical tool. Rosenfeld[57] alludes to yet another life cycle model in his exploration of clusters and cluster policy in less favored regions of the European Union. According to Rosenfeld, clusters progress from an embryonic stage through growth and maturity until they finally decay. The embryonic stage is stimulated through innovations, inventions, or inward investment. During the growth stage, markets develop sufficiently to spinout and attract imitators and competitors; entrepreneurship is also cultivated. In the maturity stage, the activities of the cluster have become more routine. More imitators enter the market, and lower costs become the key competitive advantage. The decay stage is when products or processes become expendable and are easily substituted in the marketplace by more cost-effective alternatives.

Just as in the industrial life cycle, clusters differentiate according to scale, scope, character, and activities. Regardless of how a cluster is characterized, it is still likely to be subject to the evolutionary dynamics of markets. At any given point in the developmental cycle—cluster or industrial—activities must shift. Different actors take on differentiated roles. At some points, activities may be concentrated or centralized within one institution. At other times, activities may be carried out collectively by a number of actors working in collaboration. Such responses to global market signals and industry developments must be orchestrated to avoid the declining stage of industrial development or the decay of a cluster.

3. CONCLUSIONS

Cluster strategies would appear to be high-risk, high-return economic policies. While not all types of clusters are appropriate for all countries, most countries could attempt at least one or more options. If thoughtfully and prudently undertaken, the investments in analysis, strategizing, building local leadership, and pursuing various tactics would generate positive social returns even if a sustainable cluster did not develop. Indeed, most of the options appropriate for clusters are also just good economic policy. One point that anyone interested in economic development should keep in mind is that most sectors are becoming more knowledge intensive. Even in low specialized areas, such as garment industries in developing nations, technologies are being adopted to increase productivity and flexibility. In short, while clusters are attractive economic development tools, they must be nurtured with an appreciation for their partial and incomplete nature. Fundamentally, they are part of a global innovation system, and cannot thrive if cut off from the lifeblood of the system—ideas, skilled labor, capital, and competing and collaborating companies and organizations.

Knowledge-based development is inherently different from traditional industrial development. While infant industry protection made some sense in the industrial context, it is not clear whether it has any value in a knowledge-based world. The imperatives of innovation pose some serious challenges for development policy. Many current development efforts have a strong mercantilist orientation, with a focus on self-sufficiency. In an effort to generate higher-value exports or to replace imports, governments at all levels in many countries are using their tax and fiscal policy to encourage greater local R&D or to attract global companies to relocate their R&D programs into their jurisdiction. This often involves preferential support for national champions or exclusive deals to encourage MNEs to relocate their activities. Usually governments do this without considering the corresponding relationships and interactions that knowledge-based companies require to succeed. If innovation can happen within a company, companies, or a regional or national community, then such a narrow approach might have some chance of success. But if innovation is truly global, as appears to be the case in many of the life sciences, then narrow, mechanistic self-sufficiency strategies may either simply fail or be counterproductive. This is why both companies and skilled employees are more interested in the innovation community than in fiscal incentives, public infrastructure, or other government support. By extension, a mercantilist policy that discourages global links could not only fail to attract global companies but could also drive out local companies or researchers as they seek access to the global community. ■

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31 It is important to qualify the term *power*. Power can be endowed or it can be "referential" in nature, built up over time based upon a sound track record of good performance.

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