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## GLOBAL NETWORKS AND LOCAL LINKAGES: AN INTRODUCTION

*David A. Wolfe, Charles Davis and Matthew Lucas*

### INTRODUCTION

The goal of cluster development remains an elusive target for many local economic development agencies. The fascination with industrial clusters arises out of the perceived relationship between clustering and enhanced competitiveness and innovation performance. The sources of competitiveness do not lie solely within the individual firm, but are also in the firm's local or proximate environment (Porter 2000). These competitive environments are clusters of firms engaged in traded and untraded relationships with each other, with suppliers of specialized services and knowledge inputs and infrastructure, and with governments and consumers. Geographical proximity yields more benefits than costs through a variety of localization and urbanization economic effects. In fact, most industries exhibit clustering behaviour (Krugman 1994).

This perceived association among competitiveness, economic performance, and innovation accounts for the intense interest in clusters among policymakers and researchers practically everywhere in the world. An enormous scholarly, business, and policy literature exists on clusters and it is growing rapidly. The basic drivers of clustering, localization, and urbanization economies are known, although significant controversy about the nature of externalities occurs among holders of various disciplinary viewpoints. In general, the literature distinguishes between two key drivers that contribute to clustering: agglomeration economies and privileged access to knowledge flows.

For the past five years, members of the Innovation Systems Research Network (ISRN) in Canada have been engaged in a comprehensive examination of 26 case studies across the country (Wolfe 2003; Wolfe and Lucas 2004). We now possess descriptive case studies for most of these clusters by industry and by region. In the process of this study, we have developed a comprehensive knowledge base on cluster components, structures, linkages, governance, and interactive processes, although the qualitative and descriptive nature of the case studies poses a challenge for cross-cluster comparisons.

The cluster approach is a “systems” approach to understanding economic behaviour. To understand clusters as systems, we have to understand their internal workings: their components, their structures, their processes and routines, and their development pathways. One day it may be possible to inexpensively monitor such cluster behaviour with Web-based indicators, but at present, in practical terms, while some of this internal activity of clusters is knowable at any particular point in time, the rest is only partially accessible to individual actors who are part of the cluster. Bounded rationality is inevitable for players in complex adaptive systems such as innovation clusters. Detailed case studies of developing and existing clusters, such as those presented in this volume, provide an invaluable source of information about cluster dynamics and the challenge of formulating policy for national and local officials charged with cluster policy and management responsibilities.

## THE CLUSTER CHALLENGE

Clusters are difficult beasts to tame for economic development purposes. Despite the virtual proliferation of cluster case studies (Andersson *et al.* 2004) and cluster policy initiatives (Sölvell, Lindquist and Ketels 2003) in recent years, our knowledge of clusters is still imperfect. We lack an agreed upon definition of a cluster, there is considerable disagreement on the appropriate geographic contours of a cluster, and while most analysts agree that both firm-based and extra-firm dimensions are important elements of a cluster, they do not fully agree on what the extra-firm dimensions should include. To make matters more difficult, measurement problems abound in the study of clusters. Clusters do not benefit from anything similar to the highly developed statistics-producing apparatus and complex models that have evolved for tracking and managing other spheres of policy interest, such as the economy, the weather, or public health. National statistical agencies collect data based on a standard

industrial classification system that takes the industry sector, not the cluster, as its basic measurement unit. While there have been highly creative efforts to transform the sectoral classification system into cluster categories, this produces imperfect approximations, at best (Porter 2003).

A number of significant challenges remain for those interested in unleashing the competitive potential of industrial clusters. A key, but often unrecognized challenge, is that the role of government changes throughout the cluster development life cycle. In developed or mature clusters, framework policies may be suitable. However, in the early stages of cluster development, hands-on involvement by public or private champions appears necessary, as well as strategic investments in cluster-asset development to create pools of highly qualified labour or specialized research and development capability. These investments are often quite expensive and must compete with a host of other priorities for scarce public resources. The justification for such investments is problematic in the sense that no one can say with any certainty whether they will trigger the emergence of a cluster. We know that public intervention at this stage is a necessary element to stimulate cluster formation, but far from sufficient on its own (Wolfe and Gertler, forthcoming). The key intervening variable that is impossible to predict is an outbreak of entrepreneurial activity that successfully capitalizes on the research or skills base of the regional economy (Feldman, Francis and Bercovitz 2005). Since cluster development takes place over decades and the key variables are almost impossible to control, it is a challenge to maintain policy continuity, especially given that the policy cycle is usually only four or five years long.

Another key challenge involves the local versus global dimension of cluster development. Clusters are primarily viewed as local phenomena, and hence the focus of local economic development agencies. Ultimately, competition occurs between and among clusters in competing industries, often internationally. But we have only a few examples of international industry-wide comparisons of competing clusters and practically no knowledge of the international dynamics of cluster rivalry. By the same token, much more is known about the internal linkages of clusters than about their external linkages, which are usually market-related. However, there is increasing evidence, including some of the case studies conducted by the ISRN, that the external linkages drive the internal dynamics of clusters. A number of the most recent studies point to the increasing specialization of clusters within the global economy, as individual clusters in photonics, for instance, have come to

specialize in particular technology and sectoral niches (Hendry, Brown and Defillippi 2000).

The members of the ISRN are currently in the fifth and final year of a comprehensive study of industrial clusters covering a wide cross-section of regions and sectors in Canada. The papers presented in this volume are part of the continuing set of case studies generated by this project. The overriding goal of the project is to analyze how the formation and growth of these clusters contributes to local economic growth and innovative capacity. Underlying this objective is a set of more fundamental conceptual questions: How do local assets and relationships between economic actors enable firms, in any industry, to become more innovative? Under what circumstances does “the local” matter, and how important are local sources of knowledge and locally generated institutions (public and private) in strengthening the innovative capabilities of firms and industries? What is the relative importance of *non-local* actors, relationships, and flows of knowledge in shaping the development trajectories of localized innovation and growth? The project combines both quantitative and qualitative methodologies to study 26 cases across Canada. Our methodology allows for systematic comparisons between these case studies, which — again, in contrast to most of the existing work in this field — include metropolitan and non-metropolitan locations, as well as more and less knowledge-intensive industries. It combines a strong analytical approach with a more policy-oriented component, and overcomes the tendency in previous policy work to rely on cluster models imported from other countries that may not reflect the Canadian reality. A key aim of the study is to formulate cluster-based policy prescriptions that are appropriate for the distinctive circumstances confronting Canada’s regional economies.

## CLUSTER THEORY

The conceptual foundations of cluster or agglomeration studies are found in a diverse group of theories: Marshallian theory, location theory, transaction-cost and institutional theory, international business theory, regional studies, and strategic management (Belussi 2004; Newlands 2003; Benneworth and Henry 2004). Differences in emphasis and method by different disciplines (especially regional science, economics, and geography) make it difficult to synthesize and integrate the diverse strands of this literature. The question of how to understand localization economies is unsettled. Major groups of theories attempt

to explain agglomerative behaviour in terms of transaction costs, trust and untraded interdependencies among firms, collective learning, and institutional or evolutionary economies involving economies of scale, path dependence, or network formation.

One major approach, following in the tradition of Marshall, places greater emphasis on the influence of agglomeration economies and supply-side externalities. This approach views clusters as the product of traditional agglomeration economies, where firms co-located in the cluster benefit from the easier access to, and reduced costs of, certain collective resources, such as a specialized infrastructure or access to a local labour market for specialized skills. The concentration of critical factors of production in specific regions reinforces the effects of increasing returns in the region. An external economy is a spillover effect in which the activity of one agent has an intentional or unintentional effect on another. (The focus is on positive externalities, although negative ones exist also.) Marshall (1920) identified the three principal sources of external economies: input-sharing, labour market pooling, and knowledge spillovers. Input-sharing occurs when firms share a local supplier industry that emerges to service downstream customers. Labour-market pooling occurs when human capital with special skills is available in a particular location (labour markets are traditionally considered to be geographically sticky). Knowledge spillovers occur when “the secrets of industry are in the air” and diffusion of tacit knowledge takes place through deliberate or unanticipated pathways; Marshall uses the example of workers learning to use new technologies.

The second view emphasizes the role of knowledge and learning processes in sustaining clusters, often on the basis of local flows of spatially sticky tacit knowledge. This second approach also emphasizes that knowledge flows in clusters are not necessarily restricted to the local level — dynamic clusters usually develop strong connections to other clusters through the international sharing of knowledge (Bathelt, Malmberg and Maskell 2004). This draws attention to the need to understand how local clusters are situated within an international hierarchy, in those cases where the local knowledge base provides one element in a more complex set of knowledge flows. This perspective highlights the ways in which the benefits derived from externalities in the form of knowledge spillovers are tied to ensembles of related capabilities. From this perspective, the economic advantages conferred by the institutional infrastructure of the region are a vital element in the “supply architecture” for learning and innovation.

This perspective has inspired a great deal of research. Knowledge spillovers, in particular, are believed to be an important mechanism of learning and innovation within clusters. However, it is clear that many business-location decisions are determined not by Marshallian external economies but by access to natural factors of production such as energy, or by access to essential infrastructure such as transportation facilities. Moreover, agglomeration economies are also driven by urbanization economies — benefits that the firm realizes from locating in economically larger or more industrially diverse environments. Some industries producing “general purpose technologies,” such as information and communication technologies (ICTs), will especially benefit from urbanization economies because of access to diverse local customers.

### THE CLUSTER LIFE-CYCLE

Research in Canada to date has confirmed that firms do cluster in specific geographic areas and that by doing so achieve greater competitive advantage. These results have been documented in a number of academic papers and books (Wolfe 2003; Wolfe and Lucas 2004). These studies also underline the importance of the presence and participation of public sector institutions, both public sector laboratories and university facilities. Furthermore, the studies suggest that there may be one set of environmental conditions that support the creation of a cluster; while a different set of conditions may be required for the ongoing development of a cluster and the competitive advantages the cluster confers upon its constituent enterprises. The detailed study of individual clusters is important for improving our understanding of the stages of cluster development and the most appropriate form of policy intervention suited to each stage. Much of the academic work is driven by the need for a systematic understanding of the factors that contribute to the creation and development of clusters, and their inter-relationships for the very real objective of improving economic and social development.

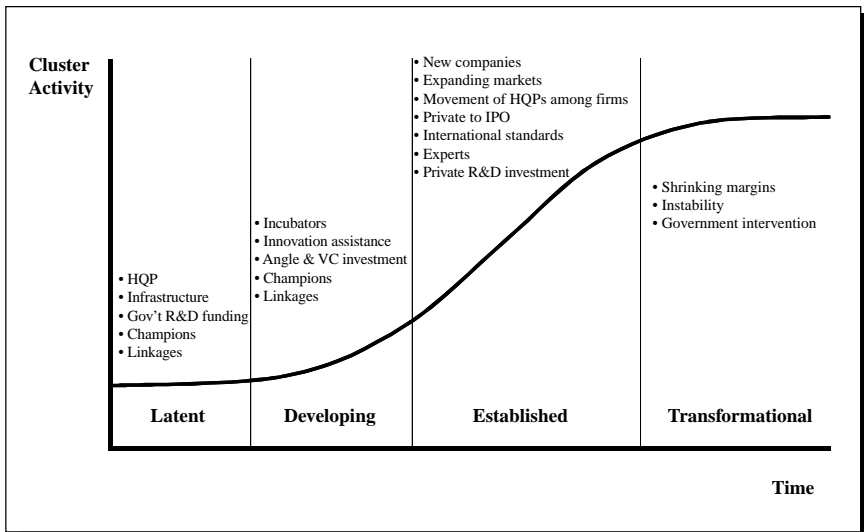
Through the ISRN case studies, we have identified a life-cycle model of cluster development and transformation that includes the following stages (adapted from Andersson *et al.* 2004):

- *Latent*: the presence of a strong research infrastructure or the growth of a thick labour market endowed with specific skill sets creates the

preconditions for cluster formation. The region has a number of firms and other actors that begin to cooperate around a core activity and realize common opportunities through their linkages.

- *Developing*: an outbreak of entrepreneurial activity, often as spinoffs from the lead or anchor firm or from public research institutes, stimulates the development of the cluster. As new actors in the same or related activities emerge or are attracted to the region, stronger linkages develop among the key players in the cluster. Formal or informal institutes for collaboration may appear, as may a label and common promotional activities for the region.
- *Established*: a certain critical mass of firms and supporting institutions is established. Relations both inside and outside the cluster are strengthened. There is a self-sustaining dynamic of new firm creation through start-ups, joint ventures, and spinoffs.
- *Transformational*: clusters change with their markets, technologies, and processes. In order to survive, the cluster must avoid stagnation and decay. Transformation may be through changes in the products and methods, or into new clusters focused on other activities.

FIGURE 1  
Cluster Life-Cycle



The cluster life-cycle model traces the stages of development through which many clusters progress. The majority of the ISRN case studies lie within the developing or established stages of the model, although a number have clearly gone through the transformational stage in recent years. The life-cycle is important because it reminds analysts that clusters at different stages of maturity involve different sets of actors and supporting institutions along with different degrees of integration and cohesion. They also require various sets of policy supports to move to the next stage along the graph.

### CLUSTER TYPOLOGY

The cluster literature also suffers from a tendency to subject all clusters to the same analytical frame of reference regardless of the degree to which they conform to the cluster model along a number of different dimensions. This tendency to impose a “one size fits all” approach conceals some critical distinctions between individual clusters and can lead to poorly tailored and ill-suited cluster policies. A recent comparative study of a broad cross-section of clusters, both in Canada and internationally, has suggested a number of important criteria that can be used to develop a typology of different clusters. The following analysis presents a preliminary attempt to formulate one such typology.

The key challenge in developing any typology is to select the key categories for organizing the typology along both the horizontal and vertical axes. The proposed ISRN typology organizes clusters along two key dimensions: knowledge dynamics along the vertical axis and industrial structure and cluster linkages along the horizontal one. The categories arranged along the knowledge-dimension axis build on work done by several of our collaborators. Following on work by Asheim and Gertler (2005), we distinguish between the nature of the innovation process within industries depending on the nature of their specific knowledge base. To their two original knowledge bases, analytical and synthetic, we add a third, hybrid, reflecting the specific nature of key parts of the Canadian economy. These distinctions refer to knowledge bases that draw upon different combinations of codified and tacit knowledge, different mechanisms for sharing or transferring knowledge among key actors in the cluster, different requirements for skills and qualifications, and finally, different research and institutional structures required to support the knowledge base in the cluster.



The synthetic knowledge base applies to industrial contexts where the innovation process involves the application of existing sources of knowledge or new combinations of knowledge. This often occurs in response to the necessity of finding technical solutions to specific problems that emerge out of the interaction between clients and suppliers. Greater reliance is placed on applied product development than on pure research. Tacit knowledge-sharing among firms along the supply chain or between engineers in different firms within the cluster can constitute an important source of innovation. University-industry linkages play an important role in these clusters, but their contribution more frequently takes the form of applied problem-solving than basic research, and both the university and college or technical education system are viewed as important sources for talent and recruitment. Tacit knowledge tends to play a greater role than in other types of economic activity, due to the fact that a key source of synthetic knowledge is the concrete experience gained in solving concrete problems encountered in the workplace — the classic case of learning through doing, using and interacting described in much of the innovation literature. Compared to the synthetic type of knowledge, concrete production skills and craft play a much greater role in the production process. Consequently, firms in these clusters tend to recruit more from polytechnic or professional schools or rely upon on-the-job training.

In contrast, an analytical knowledge base refers to industrial settings that rely upon scientific knowledge and where the production process draws upon sources of knowledge that make extensive use of cognitive and rational models. Prime examples of industrial clusters that rely upon this type of knowledge base are found in information technology and biotechnology. Both basic and applied research, as well as more formal development of products and processes, constitutes the central activities of this type of knowledge production. While firms in these clusters need their own research and development (R&D) departments to interpret and select from the vast sources of codified knowledge available to them, they tend to draw upon research results from the higher education system or national laboratories as a source for potential innovations or product modifications. University-industry linkages are an essential part of the knowledge transfer for clusters that rely upon this type of knowledge base. It follows that formal or codified sources of knowledge play a greater role in these settings. This does not, however, mean that tacit knowledge is irrelevant, as detailed studies of the geography of innovation confirm that

analytical knowledge flows are highly “sticky” and the outputs of research institutes and universities are often applied by firms in close geographic proximity to the research centre.

The third category, resource-based knowledge represents a hybrid category, reflecting the greater importance of resource industries within the Canadian context and the combination of both analytic and synthetic knowledge bases in generating new products and processes in these industries. The knowledge setting of this category applies to clusters where the primary source of input is a raw material or agricultural product. Increasingly, most forms of cultivation, as well as resource extraction, draw upon scientific and analytic knowledge bases; but at the same time, they tend to involve a higher degree of skill or craft in the production process. While firms in the agricultural, forestry, mining, and energy sectors may all depend upon a scientific knowledge base, their primary focus involves the extraction or transformation of natural resource products.

The categories arranged along the horizontal axis are derived from detailed analysis of the ISRN’s 26 cluster-case studies across the country, as well as the systematic comparison between the cases. This in-depth case-study research has revealed a number of critical factors about the clusters. A key variable concerns the extent to which the cluster is locally embedded or strongly coupled with a continental or global supply chain for production. Some of the most widely cited literature in the field maintains that a strong local market and strong local competition are two essential elements for the development of internationally competitive clusters. In contrast, the ISRN research findings lean overwhelmingly in the opposite direction. Many of our case studies indicate that in the most successful Canadian clusters, the markets served are continental or international, that local customers constitute a relatively small proportion of the firm’s total market, and that firms’ most sophisticated and demanding markets are not local.

Similarly, there is a strong emphasis within the international cluster literature on the importance of a strong local supply base. Once again, our research has produced novel results. While certain key inputs are predominantly local (see below), relatively few regions can rely exclusively on their local knowledge base to develop, design, and produce innovative products. Indeed, our evidence suggests that firms in successful clusters are more likely to be deeply imbedded in continental and global knowledge networks and production

systems. While the local cluster may excel in the production of key aspects of knowledge, or in certain parts of the value or production chain, local firms rely upon relations with partners and suppliers in other clusters, maintained through global networks, to generate and produce innovative products. Clusters where these conditions predominate are labelled part of a global supply chain. In previous contributions we had tentatively identified this category as the *entrepôt* model.

Secondly, we identify a number of clusters where a strong lead anchor firm either plays a critical role in anchoring the cluster, as the source of many of the initial spinoffs that stimulated the development of the cluster, or in serving as the beacon for future technology directions for the cluster. While not all firms in the local cluster may have direct buyer/supplier relations with the anchor firm, they usually acknowledge its critical leadership role and rely upon both its technological leadership and business strategy as a virtual “foresight exercise” to chart future directions for the firm. The failure of the lead firm or firms, or their inability to weather a transformative challenge, such as that constituted by the emergence of a disruptive technology, a shift in key market conditions or a significant downturn in the business cycle, may catapult the cluster from the established phase of the cluster life-cycle into a transformational situation. While the future of the entire cluster does not necessarily depend on the response of the lead firm to this critical challenge, the outcome will have major implications for the future direction of the cluster. The Ottawa telecom, photonics, and southern Ontario steel clusters all appear to be in such a transformational situation at the present time.

The third category involves cases where the membership of the cluster is composed of relatively small, independent firms, many of which may operate by subcontracting with individual agents, as frequently is the case in the film or multimedia clusters. It may also arise in cases where the cluster has emerged through a process of vertical disintegration, where more traditional integrated firms have spun out specialized functions into separate firms and these have populated a newly emerging cluster, as appears to be the case with our Sudbury mining supply and services cluster.

We have made a preliminary attempt to populate this typology with the 26 individual case studies currently being examined in the ISRN’s national cluster study.

FIGURE 2  
Cluster Typology

<i>Knowledge Dimensions</i>	<i>Industrial Structure and Cluster Linkages</i>		
	<b>Lead/Anchor Firm</b>	<b>Global Supply Chain</b>	<b>Local Value Chain</b>
<b>Synthetic</b>	Ontario Steel	Montreal Aerospace  Waterloo Auto-parts	Sudbury Mining S&S  Windsor Auto-parts/ Tool, Die, and Mould
<b>Analytic</b>	NB – IT  Ottawa Photonics and Telecom  Calgary, Vancouver Wireless	Waterloo ICT  Mtl, Tor, Van, Hal Biotech	CB-IT  Mtl, Tor, Van Multimedia  Quebec Photonics  Ottawa Biotech
<b>Hybrid</b>		Saskatoon Biotech	Ontario/BC Wine  BC Wood  Ontario Food

### BOOK OUTLINE

This volume presents eight of ISRN’s more recent case studies. It describes clusters in regions as diverse as Toronto, Sudbury, and the Okanagan Valley and in industries as varied as biotechnology, tool, die and mould-making, and mining services. These case studies are at various stages of maturity and exhibit significant variation in institutional dynamics and knowledge and resource flows. Some common themes are evident, including the importance of global markets, public training and research infrastructure, immigration of skilled labour, and civic engagement. While our case studies exhibit these factors to varying degrees, the inflow of knowledge, resources, labour, and finance, and

the presence of public sector institutions, as both central and supporting actors, are important to all. As noted in previous ISRN publications, Canadian clusters often exhibit a strong external orientation, both in terms of markets and factor inputs and a heavy reliance on public sector training, research, and networking activities. Canadian clusters consciously operate within global networks and frequently rely on public/private partnerships to strengthen their innovation capacity.

The authors are consistent in their detailed attention to the historical factors that launched each cluster and shaped its subsequent evolution. It is evident that a cluster's early mix of public/private actors and internal/external linkages influences its future growth trajectory. The assertion that history matters as much as geography is particularly directed to policy-makers attempting to help clusters adjust to recent internal and external shocks. The authors argue that to be effective, policies need to consider historically rooted institutional dynamics and regional culture.

A number of chapters extend on this theme by examining methodological challenges to identifying and evaluating clusters. They illustrate the problems of statistical definitions that overlook clusters that cross industrial sectors such as multimedia, biotechnology, and mining supply and services and suggest new mechanisms for capturing statistically invisible synergies. Some also attempt to translate the qualitative data obtained from extensive interviews into quantitative measures of cluster vitality. This analysis builds on rich qualitative descriptions of industry linkages and knowledge flows, a richness that is evident across all case studies.

We begin with Lowe and Gertler's description of Toronto's diverse life-sciences industry. They describe the region as one of North America's leading centres for "biomedical research and commercial activity" and note that it contains a diverse range of organizations, including dedicated biotechnology firms, drug and device distributors and manufacturers, related suppliers and professional service firms, contract research organizations, universities, hospitals, and biomedical research centres. The cluster falls within the global supply chain/analytic knowledge category of our typology. Most of the firms in this industry are closely tied into a global network of suppliers and customers and they rely heavily on access to global sources of codified knowledge. The diversity and size of the local economy and the strength of the local research infrastructure have helped to foster these connections.

The authors link Toronto's institutional diversity to its decentralized governance structure as well as a long history of "diffused and indirect" government involvement that emphasized individual policy initiatives rather than a coherent, region-wide plan. This has resulted in Toronto having a very different pattern of institutional linkages from more centralized biotechnology regions, such as Montreal. Though Toronto's governance system has not previously been explored in depth, policymakers have often praised Montreal's system as a "well-coordinated" and efficient model that could be applied in other regions. Lowe and Gertler argue that Toronto's governance history has helped to create a diverse and dynamic industry that may be more resilient to market shocks than its Montreal counterpart. The authors advise policymakers to work within a region's existing institutional culture and not to take lessons learned in one region and blindly apply them to another.

The next chapter shifts our attention to Saskatoon's agriculture-biotechnology cluster, a much smaller, less diverse, and more centralized cluster that is nevertheless equally connected to global supply-chain relations and analytic knowledge base. Phillips *et al.* build on their earlier descriptions of the cluster (Phillips 2002; Ryan and Phillips 2003) to explore the use of quantitative measures to gauge the cluster's vitality. The authors translate their interview data into a set of quantitative measures of innovation and linkage density and centrality to provide concrete and easily comparable indicators of cluster strength. Based on their previous analysis of cluster dynamics, the authors analyze the density of cluster linkages between eight core actors and 90 other cluster organizations and then analyze the centrality of those actors to internal knowledge and resource flows. The results reinforce the author's earlier findings that the cluster is anchored by public research and networking institutions that attract firms to the region by facilitating access to local and global knowledge sources.

Hickman and Padmore's description of the Okanagan wine-making industry shifts our focus from analytic to synthetic knowledge and from a global to local supply chain. The industry is comprised mainly of small to medium family-owned enterprises that are highly connected. A dense network of internal linkages enables the firms to effectively share locally acquired knowledge despite a history of "idiosyncratic, individual, and incremental innovation." Although the authors note that the industry is not yet competitive, they observe a steady evolution in that direction since the industry reoriented itself from low- to high-quality wine. This shift was influenced by external factors, especially trade agreements such as the General Agreement on Tariffs and Trade

and the North American Free Trade Agreement, and by the federal government's support for the planting of new grape stock. Here is an example in which a cluster's early weaknesses are corrected by focused national policy intervention, local associational initiatives, and an inflow of skilled labour.

Despite the high degree of networking within the cluster, the authors argue that there is now a need for new learning strategies and a deepening of institutional capacity. Although knowledge flows within the cluster take place primarily through labour mobility, the authors note the increasing contributions of the public research and training institutions and an increasing reliance on research conducted outside the region. Observing that nascent attempts to support research and development and training in the industry are beginning to strengthen the local knowledge base, the authors strongly recommend that policymakers continue to support these activities. This evolution suggests that while the cluster's institutional linkages remain primarily local, its innovative capacity increasingly relies on a hybrid of synthetic and analytic knowledge.

The growing importance of public support is also recognized in Holmes, Rutherford and Fitzgibbon's story of the tool, die, and mould (TDM) industry in the Windsor-Essex region in southwestern Ontario. Often overlooked, TDM is characterized by small, highly specialized firms privately owned by self-made entrepreneurs with little formal education, but strong skilled technical backgrounds. The industry provides high-skill, high-wage jobs that are critical to the competitiveness of the region's broader manufacturing base; and much of the production is exported outside the immediate region. As in the Okanagan, the immigration of skilled labour and the gradual improvement of local training capacity were important early factors in the industry. Like wine-making, TDM has long been considered more of an art than a science and innovation has depended upon flows of synthetic knowledge, largely facilitated through labour mobility.

The release of skilled labour into the market through the collapse of the region's first large firm was a key early event, a characteristic common to a number of ISRN case studies. New firm start-up and labour movement has been facilitated by the largely informal social and familial networks that predominate in the region, and are a cultural legacy of early immigration patterns. This legacy has also resulted in a high level of cooperation between firms, which frequently share equipment, knowledge, and skills. Despite the industry's strengths, the authors identify a number of present challenges that may threaten the industry's continued viability. TDM is in a state of flux, both in

terms of its economic relationship with its key customer, the automotive parts industry, and because of a gradual shift from craft production based on a local synthetic knowledge base to computer automated production that is increasingly dependent upon analytic knowledge from outside the region. Reduced demand, technological change, and overcapacity in the automotive industry have resulted in the off-loading of costs down the value chain that now threaten the viability of small TDM firms, increasing their vulnerability to foreign competition. This cluster is a good example of a mature cluster that may soon undergo a significant transformation. The authors argue that the TDM industry is a crucial part of the Windsor-Essex region's competitive advantage and that policymakers need to help the industry adapt if it is to thrive.

Another cluster that has been largely overlooked until recently is Sudbury's mining supply and service industry. David Robinson charts the gradual coming to consciousness of the industry and describes how this recognition helped the cluster strengthen its innovation and networking capacity. This story highlights the importance of seeing beyond statistical categories and argues for the importance of recognizing and building on existing regional strengths. As in the previous two case studies, investments in public research, training, and networking infrastructure followed a flourish of entrepreneurial activities and occurred late in the cluster's development. The key event in the cluster's history was the outsourcing of supply and service activities by the region's two large mining firms. This released skilled labour into the region and resulted in a proliferation of small service-oriented firms. Key knowledge flows were long tied to local mining experience, but as the industry began to export beyond the region, it was challenged to increase its innovative capacity. Synthetic knowledge remains the foundation for this industry, however, and public institutions have played an important role in increasing local skills even as the cluster attempts to connect with a global supply chain.

Multimedia is another industry that is difficult to capture statistically because it crosses multiple sectors and because freelancers comprise a considerable part of its labour force. In their chapter, Britton and Legare build on previous work (2004) to examine the evolution of the economic and institutional interdependencies that influenced patterns of spatial concentration in the industry and the importance of local supply chains. This concentration reflects the region's high number of Canadian corporate head offices and advertising agencies, and its large share of the nation's film and television industry. The authors also investigate the public commitments and policy choices



that influenced this pattern and conclude that the nature of the multimedia industry makes it difficult to realize significant internal scale economics and encourages firms to pursue external returns from clustering. The synthetic knowledge base resides in the skilled labour force that moves easily through the industry.

The role of anchor firms in the development of a cluster and the challenge to cluster survival when those firms disappear is the central theme of the description of Vancouver's wireless industry by Langford, Wood and Jacobson. The cluster was originally anchored by three large firms responsible for much of the recruitment and training of labour in the region. The authors note that these firms "provided insight into a bigger world," and promoted a more "risk-tolerant entrepreneurial culture." The cluster is now dealing with the loss of these firms and the resulting loss of institutional infrastructure. One of the largest threats was the loss of linkages into the global marketplace, which also served as conduits through which analytic knowledge was transferred back into the region.

Since innovation is a core activity in the wireless industry, the authors argue that such analytic knowledge flows are crucial to the sustained innovativeness of the cluster. While they argue that local competitive advantage lies mainly in the diffusion of non-codified knowledge within a skilled labour market, they note that the bulk of analytic knowledge upon which wireless technology is based is imported into the region from around the world. The market and supply-chain linkages for wireless technology are also global. A strong local public research capacity helps the region sustain the ability to absorb this knowledge and maintain an ample supply of skilled labour.

In our final chapter, Nelles, Bramwell and Wolfe's describe the emergence of Waterloo's ICT industry, an industry that exports most of its products and imports much of its knowledge. Despite this external orientation the authors emphasize the importance of regional culture in directing the cluster's evolution. They link the industry's present mix of highly innovative small and medium-sized firms with an economic model favoured by nineteenth-century German immigrants. A number of parallels exist with earlier chapters, including the importance of informal social networks in sustaining a long history of civic engagement, the importance of a strong and diverse economy in providing a diverse customer base for the new industry, and the strong interaction between various actors in the local economy. These themes are evident in the long history of civic engagement by leaders in Waterloo's advanced manufacturing industries, an engagement that led to the creation of the University of Waterloo. The

university is a central actor in the cluster, and the early decision to focus on engineering education and research, and to establish a cooperative education program, have helped to sustain close ties between the university and local industry. The university's early decision to create a permissive intellectual property regime that left intellectual property in the hands of local researchers is also credited with much of the region's early success at creating and sustaining spinoff firms from the local knowledge base. The cluster's external linkages are facilitated by a robust internal knowledge infrastructure.

### CONCLUSION AND POLICY IMPLICATIONS

As the ISRN research project enters its fifth and final year, the major intellectual contributions are already becoming clear. We summarize the most important of these below. As noted above, our findings tend to contradict the overwhelming emphasis in the cluster literature on the predominance of local factors. Concerning the relationship between local and global forces in the development of clusters, our findings indicate that in many of the most successful clusters, the most important markets served and the most demanding customers or end-users are continental or international. Similarly, with respect to the role of the local supply base, our research has produced rather novel results. While certain key inputs are predominantly local, relatively few regions can rely exclusively on their local knowledge base to develop, design, and produce innovative products. Indeed, our evidence suggests that firms in successful clusters are more likely to be deeply imbedded in continental and global knowledge networks and production systems. As noted above, the local firms in many of our clusters rely upon relations with partners and suppliers in other clusters, maintained through global networks, to generate and produce innovative products.

That said, certain characteristics and properties of local innovation systems remain critically important to the competitive success of firms in a wide range of industries. Despite the importance of non-local markets, knowledge flows, and (in some cases) supply bases, our research confirms that the local dynamics of social interaction between members of the cluster are crucial. These intra-cluster relationships promote the local circulation of knowledge, underpinning the learning processes that enable firms to succeed at innovation. Our work documents the nature and significance of these knowledge flows, and the various forms they take. The local participants in these social learning systems include firms, institutions of education and research, venture capital-

ists, producer associations, and specialized government research labs. In this way, the case studies document a balance between local and non-local relationships and knowledge flows: in other words, the dynamic tension between the local “buzz” described above and global “pipelines” that circulate knowledge among clusters.

Furthermore, while our analysis thus far has been conducted largely at the level of the individual cluster, the case studies suggest that the most successful clusters have profited from the development of strong social networks at the community level and the emergence of dedicated, community-based organizations. These entities link leaders in the individual clusters to a broader cross-section of the community. They appear to be supported by new institutions of civic governance that identify problems impeding the growth of the cluster and help mobilize support across the community for proposed solutions. We have found some evidence to suggest that size is a critical variable in the success of civic engagement, with some of the larger, urban centres encountering greater difficulty in achieving effective degrees of mobilization.

Another finding of fundamental importance, relating to the role of local assets in the innovation process, concerns the relationship between research infrastructure and cluster emergence and evolution. The international literature on the most celebrated clusters identifies research infrastructure, especially postsecondary educational institutions, as the essential ingredient for cluster formation. Significantly, and to the contrary, our research indicates that, with a few notable exceptions, research infrastructure plays a *supporting, not a causal*, role in the growth of clusters in Canada. In some significant instances, the local development of advanced educational and research programs clearly *follows* the emergence of a dynamic local cluster, rather than precedes it. In most cases, the presence of a strong research infrastructure constitutes a local antecedent that lays the groundwork for the emergence of a cluster. This research infrastructure also contributes to the presence of a “thick” labour market in the local economy, which serves as a magnet for firms in search of highly skilled labour. It may also attract firms to a city-region in the expectation of tapping into the knowledge base that exists. However, the strong research infrastructure and a thick labour market are underlying conditions that extend beyond the boundaries of individual clusters.

One of the most consistent findings from our work concerns the role of local labour markets and talent. If there is one type of input that is overwhelmingly local, it is highly skilled labour. It is clear that the depth and breadth of

the local labour market is the key ingredient defining a cluster's ability to support knowledge-intensive production. It is also the factor that is most amenable to public policy influence. However, our work suggests that the creation of a talented labour pool in turn depends on many different factors, including not only the strength of local postsecondary education and specialized training institutions, but also a set of "quality of place" characteristics that determine a region's ability to retain well-educated labour and attract it from elsewhere. However, this finding has also revealed a potential downside to the talent factor: not all locations in the country will be equally successful in the pursuit of this objective. Some of our cases have encountered significant obstacles in developing a deep labour market, despite persistent efforts.

The implications of our research findings for the formulation of "cluster-friendly" public policies are also becoming increasingly clear. While it is commonplace to state that governments cannot create clusters by fiat or direct policy intervention, our understanding of the evolutionary and path-dependent character of cluster genesis makes it clear that government policies play a critical role at many different stages of cluster formation and the cluster life cycle. It is important to be clear about the most valuable initiatives at the individual stages of cluster development. The critical insight that the evolutionary perspective affords is that multiple locational outcomes are possible in the early stage of cluster formation. This potential makes it difficult, if not impossible for regional policymakers to target the development of specific clusters. Conversely, the importance of local antecedents for cluster development means that policy, across multiple levels of governance, can contribute to the accumulation of key assets in a specific location. As Feldman, Francis and Bercovitz (2005) and Swann and Prevezer (1998) demonstrate, these chance events that act as triggers for cluster formation or the "entrepreneurial spark" occur within a specific historical and geographic context. Frequently, it is public sector agencies that are critical in establishing the local antecedents that define this context. The public sector encompasses federal, state or provincial, and local governments; as well as public research institutes like Canada's National Research Council or the US government laboratories or institutions of higher education (although this would include leading private universities in the US). In some instances, private sector research laboratories or contract research organizations can also lay the groundwork for the emergence of clusters, with strong support from public sector funding. While the ultimate impact of these policy interventions cannot be fully anticipated at the outset, over the long term, those

policy interventions that strengthen the research and institutional infrastructure of a region or locality have the greatest potential to act as attractors for a cluster of firms.

When it comes to increasing entrepreneurial activity, the role of policy intervention is far less clear. As some of the cases discussed above illustrate, government policy played a critical role in stimulating the genesis of the cluster, but often in a completely inadvertent manner. In these instances, governments were pursuing policies designed to achieve other goals, but the consequences of the policy triggered the kind of chance occurrence that path dependency describes. Government policy at the third stage of cluster formation and development is much more varied and is often tailored to meet the needs of the specific region and locality in which the cluster is located. A key element of cluster development at this stage is the emergence of second- and third-generation start-up firms. Also, government policies to sustain the entrepreneurial drive are vitally important. These can include a broad range of government policies to support upgrading the innovative capacities of firms and promote the rapid diffusion of technologies, networks to foster greater interaction among the emerging small and medium-sized enterprises, as well as providing much needed mentoring programs for newly minted entrepreneurs. Often local high technology industry associations emerge with support from local and regional government agencies to play this role. A key barrier that a rapidly growing cluster often runs up against is an adequate supply of the critical skills needed to feed the growing firms. This is a policy area where local universities and colleges have played a crucial role, often with the backing of state and provincial governments, in expanding training and research programs in the areas of most crucial need. The formation of angel networks and the attraction of venture capital into the locality can also be supported by appropriate government policies (Feldman, Francis and Bercovitz 2005; Porter *et al.* 2001).

The central lesson here is that the path dependencies for cluster creation are highly variable, and that the chance events that provide the trigger for cluster formation can come from many sources. Public sector involvement can affect cluster trajectories in a variety of ways, though the impacts are often unpredictable and even, in some instances, unintended. Whether intentional or inadvertent, one of the most effective public policies for seeding cluster development is a sound investment in building the research infrastructure and educated labour base in a region. The establishment of a strong local talent pool of highly skilled and knowledgeable workers both feeds the growth of the

local firms in the cluster as increasing returns begin to take hold, and attracts outside firms to invest in the cluster to gain access to the “local buzz.”

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