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Summary. This paper surveys some of the current methodologies employed to analyse cluster development, as well as some of the key themes emerging from both the analytical and prescriptive literature noted above. It uses this survey as the context in which to present a synthesis of the initial findings of the current national study of industrial clusters in Canada, conducted by the Innovation Systems Research Network. The national study comprises 26 cases which aim to identify the presence of significant concentrations of firms in the local economy and to understand the process by which these regional-industrial concentrations of economic activity are managing the transition to more knowledge-intensive forms of production. The central questions in each case are: What role do local institutions and actors play in fostering this transition? How important is interaction with non-local actors in this process? How dependent are local firms on unique local knowledge assets and what is the relative importance of local versus non-local knowledge flows between economic actors? How did each local industrial concentration evolve over time to reach its present state and what key events and decisions shaped its path? And, finally, to what extent do these processes, relationships and local capabilities constitute a true cluster? Ultimately, what are the key relationships, linkages and processes that ground the cluster in its existing location?

1. Introduction

Interest in cluster development has exploded in recent years across North America, Europe and newly industrialised countries. This interest has been prompted, in part, by fascination with the success of Silicon Valley at reinventing itself through successive waves of new technology; and, in part, by the efforts of other regions to emulate the Silicon Valley model. A growing number of clusters around the globe, from Scotland to Bangalore and from Singapore to Israel, claim direct lineage to the original model in northern California (Miller and Coté 1987; Bresnahan *et al.*, 2001; Rosenberg, 2002). The perceived success of Silicon Valley, and the claims by other regions to have replicated its formula for success, have stimulated a widespread interest by policy analysts and consultants eager to assist national, regional and local governments in growing their own clusters. This fascination with using the leading success stories as a model for the development of new clusters has vastly outstripped our current understanding of the key factors or elements that support the growth of clusters. It is not even clear whether there is a unique paradigm for cluster development that cuts across the diverse array of regions and industrial sectors currently attempting to apply the concept as the key to their economic development strategy.

The relevant body of literature has applied the cluster concept in two different, and sometimes contradictory, ways: first, as a

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functionally defined group of firms and supporting institutions that produce and market goods and services from a group of related industries that are concentrated in a specific geographical locale; secondly, as an overarching framework to guide policy-makers in the design of initiatives to promote that development. The underlying rationale for the first concept is to generate analytical results that can provide insights into the forces that contribute effectively to cluster development and thus provide guidance to local and regional policy-makers in crafting their development strategies. The more applied practitioners who work with the second approach often draw upon the results of the first in drafting policy guidelines, but in a rather limited way. Too often their interpretation of the more analytical cluster studies amounts to little more than the elaboration of lists of the 'critical factors' for cluster development derived from individual studies of the most successful cases. These lists provide relatively little in the way of effective guidance for policy-makers trying to apply the lessons learned to their local economy—which may be based on different economic sectors and facing radically different economic prospects. Frequently, the two strands of research, the empirical and the prescriptive, tend to work at cross-purposes, with the policy goals sometimes predetermining the analysis, rather than the other way around. A key challenge for those interested in applying the concept of clusters from either perspective is to respond to the concerns raised by Martin and Sunley (2003) that academic analysts are being seduced by the lure of the 'cluster brand' at the expense of serious analysis of whether the presence or absence of clusters actually contributes to sustained economic development in local and regional economies.

This paper reports on the initial findings of a broad comparative study of cluster development across a wide range of industrial sectors and virtually all regions of the Canadian economy, conducted by members of the Innovation Systems Research Network.[1] It presents an overview of some of the key conceptual issues in cluster analysis that are emerging from both the analytical and prescriptive literature noted above and uses that overview as the context for exploring initial findings emerging from the ISRN study. The national study is comprised of 26 cases, which aim to identify the presence of significant concentrations of firms in the local economy and understand the process by which these regional-industrial concentrations of economic activity are managing the transition to more knowledge-intensive forms of production. The study's design is unique in terms of the large number and breadth of cases being studied using a common methodological framework and approach. One of the challenges for cluster analysis is to accommodate the diverse array of industrial sectors and geographical locales in which clusters are found. The danger is that generalising from a limited number of case studies in specific sectors, such as information technology, or specific regions, such as high-growth areas of the leading industrial economies, may lead to inappropriate policy conclusions for the broad cross-section of regions and sectors to which they are applied. The key questions posed in each of our cases are

(1) What role do local institutions and actors play in fostering this transition to more innovative, knowledge-intensive production?
(2) How important is interaction with non-local actors in this process?
(3) How dependent are local firms on unique local knowledge assets, and what is the relative importance of local versus non-local knowledge flows between economic actors?
(4) How did each local industrial concentration evolve over time to reach its present state, and what key events and decisions shaped its path?
(5) And, finally, to what extent do these processes, relationships and local capabilities constitute a true cluster? What

are the key relationships, linkages and processes that ground the cluster in its existing location?

The initial results are surprising in that they contradict some of the most commonly accepted arguments in the literature. It is also clear that the national and regional contexts in which these cases have evolved are of great importance in shaping their specific evolutionary trajectories. In particular, the open nature and smaller size of the Canadian economy relative to that of the US appear to explain the apparently distinctive and divergent characteristics of Canadian clusters (or putative clusters). These findings provide a strong note of caution for policy-makers seeking a generic or 'cookie cutter' approach to clusters as the prescription for the economic development challenges they face.

2. Emerging Themes in the Cluster Literature

While the cluster literature is expanding rapidly and becoming ever more diverse, a number of broad themes pre-occupy cluster analysts. In particular, three stand out. The first is the issue of path dependence: how do cluster dynamics become established and can they be seeded, particularly through the action of public-sector agencies? Despite the ever-increasing base of empirical case studies available, there remains a striking lack of consensus over how clusters are started and to what extent their emergence can be set in motion by conscious design or policy interventions. One approach in the literature adopts an historical perspective to unearth the origins and evolution of specific clusters. According to Malmberg and Maskell (2002), these historiographic studies attribute the emergence of the cluster to some natural or social factor endemic to a particular location that triggers or stimulates a certain kind of activity by a local entrepreneur. Once the initial activity is launched, its expansion is sustained by the emulation effect as other firms spin off from the anchor firm or engage in related activities. Equally important is the attraction, or embeddedness, of firms to the region in which they originate and the infrequency of relocation—in other words, the force of inertia.

As straightforward as this analysis may appear, many such accounts have difficulty dating the precise origins of individual clusters and identifying the critical or initial founding event. In the case of the most celebrated cluster, Silicon Valley, no such consensus on its origins exists. The common launch event for many is the decision by William Shockley to move to California and establish his semiconductor company in 1956 and the subsequent decision by seven of his key employees to leave to establish Fairchild Semiconductor, which became the source of most of the major semiconductor firms in the Valley. Other accounts date the origins of the Valley from the decision by David Packard and William Hewlett to found their company in a garage in Palo Alto in 1939. Yet Timothy Sturgeon (cited in Kenney, 2000b, pp. 3–4) argues that the real roots of the cluster should be dated as far back as the formation of the Federal Telegraph Company in 1909 with the ensuing spin-offs laying the basis for the Valley's early electronics industry. The critical issue is how to draw policy lessons on the formation of clusters when their precise origins are so difficult to ascertain. And where, in particular, does policy fit into a seemingly random or serendipitous process?

The second key theme concerns the nature of knowledge and learning in clusters. Within economic geography, clusters have generally been perceived in one of two ways. The first approach, dating back to the work of Alfred Marshall, 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 specialised infrastructure or access to a local labour market for specialised skills (Porter 1998). The second view emphasises the role of knowledge and learning processes in sustaining clusters, often on the basis of local flows of spatially sticky tacit knowl-

edge. This second approach also emphasises 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 *et al.*, 2002). 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.

The final theme concerns the scales of analysis. While much of the cluster literature focuses predominantly on the influence of local factors on cluster development, there is growing recognition that clusters are embedded in a broader institutional matrix at the regional, national and even supranational levels. The central question involves the nature of the relationship between the local cluster and other analytical frames of reference, such as national or regional innovation systems. If we accept that clusters should be defined primarily in local terms, then the issue of how they fit into broader institutional frameworks must be addressed. In the eyes of some, clusters can be defined in relatively self-contained terms, with little attention paid to the role that higher levels of spatial analysis contribute to the success of local clusters. Given the parallel interest in the concept of innovation systems—at the national, regional and sectoral levels—it is not surprising that some analysts have attempted to specify the nature of the linkages and the relative contributions made by the different spatial levels to economic competitiveness. There is an emerging interest in the need to understand how clusters are inserted into these broader scales of analysis and how the latter both support and constrain the trajectories for growth and development within the cluster.

2.1 Path Dependency and the Creation of Clusters

According to Michael Porter, clusters are seeded in a variety of ways; however, their growth can only be facilitated by building upon existing resources. They cannot be started just anywhere from scratch. The key assets that determine the viability of a cluster are firm-based. Of particular importance is the emergence of a lead or anchor firm for the cluster. Whole clusters can develop out of the formation of one or two critical firms that feed the growth of numerous smaller ones. It is the emergence of these core or anchor firms that is so difficult to predict, yet so central to the history of many leading clusters. Examples of the role played by this kind of anchor firm are found in the case of Medtronic in Minneapolis, MCI and AOL in Washington, DC, (or, as we shall discuss below, NovAtel in Calgary). In other instances, the presence of major anchor firms in a local cluster can act as a magnet, attracting both allies and rivals to the region to monitor the activities of the dominant firm. This is the case with San Diego, where Nokia, Ericsson and Motorola all established their CDMA wireless research efforts to benefit from Qualcomm's leadership in the field (Porter *et al.*, 2001). Other analysts emphasise the role played by highly skilled labour, or a unique mix of skill assets, in seeding the cluster. Either way, the process also requires a long time to take root.

This does not mean that the public sector has no role to play in catalysing cluster development. The public sector—broadly defined—encompasses federal, state/provincial/regional and local governments, as well as public research institutes like Canada's National Research Council and institutions of higher education. The impact of public-sector interventions on cluster development can be positive or negative, as well as intentional or inadvertent in character. One emerging hypothesis suggests that the public interventions that seem to have the most effect in seeding the growth of a cluster are ones that contribute to the development of the asset-base of skilled knowledge workers.

The catalytic role of the federal laboratories in the origin of knowledge-intensive clusters is central in Feldman's (2001) account of the emergence of the current telecommunications clusters in the Washing-

ton–Baltimore corridor. Feldman's analysis emphasises the importance of entrepreneurship in driving the development of that cluster. She traces the roots of this entrepreneurial drive to the massive wave of downsizing and outsourcing that occurred in the US federal government in the late 1970s and 1980s. As a result of this process, employment conditions in the federal public service became less secure and future prospects deteriorated. In the same period, public-sector pay scales began to lag significantly behind those for executives in the private sector. An increased emphasis on outsourcing by the federal government provided a further inducement for prospective entrepreneurs to leave the government and start firms to supply goods and services back to their former employer. Other policy initiatives launched in the early 1980s facilitated the licensing and transfer of technology from federal laboratories and provided further support for innovation in small businesses.

> Enterprising scientists licensed technology out of their own university or government research labs to start new companies and chose to locate the new companies near their existing homes (Feldman, 2001, p. 878).

Although cluster creation was clearly not the principal objective in the policy decisions she cites, the inadvertent role played by public policy in the formation of the cluster cannot be overlooked. The lesson here is that the evolutionary paths for cluster creation are highly variable. Public-sector decisions can affect cluster trajectories in a variety of ways, although the impacts are often unpredictable and often unintended. While this growing consensus in the literature on the origins of clusters and the nature of evolutionary paths explains the presence of significant agglomerations of firms in specific locales, it does not fully account for the benefits that firms derive from cluster membership nor whether firms located in the cluster are more innovative or economically competitive than those found in more dispersed locations.

2.2 Knowledge and Spillovers in Clusters

The benefits of clustering and the potential advantages that firms derive from cluster membership are addressed in a second theme found in the literature—the role of knowledge and spillovers in clusters. One stream of literature stresses that the key advantages are derived from the agglomeration economies afforded by the cluster. These agglomeration economies arise primarily from the ready access to a collective set of resources available to firms co-locating in the same region or locale. This perspective is adopted in the work of Michael Porter, although he embellishes the benefits attributed to traditional agglomeration economies by setting out the competitive advantages derived from the effects of his 'diamond'. Porter stresses that the location of a firm within the cluster contributes to enhanced productivity, higher wages and greater innovativeness by providing access more easily and/or cheaply to specialised inputs, including components, machinery, business services and personnel, as opposed to the alternative, which may involve vertical integration or obtaining the needed inputs from more remote locations. Sourcing the required inputs from within the cluster also facilitates communication with key suppliers in the sense that repeated interactions with local supply firms in the value chain creates the kind of trust conditions and the potential for conducting repeated transactions on the basis of tacit, as well as more codified, forms of knowledge. Clusters offer distinct advantages to firms in terms of the availability of specialised and experienced personnel. The cluster itself can act as a magnet drawing skilled labour to it. Conversely, the location of specialised training and educational institutions in the region provides a steady supply of highly qualified labour to the firms in the cluster (Porter, 1998).

While not diminishing the importance of these agglomeration economies, another stream of literature suggests that the underlying dimension that confers competitive advantages on the firms located in the cluster is

shared access to a distinctive local knowledge-base. The central argument in this stream is that the joint production and transmission of new knowledge occur most effectively among economic actors located close to each other. Proximity to critical sources of knowledge, whether they are found in public or private research institutions or grounded in the core competencies of lead or anchor firms, facilitates the process of acquiring new technical knowledge, especially when the relevant knowledge is located at the research frontier or involves a largely tacit dimension. Knowledge of this nature is transmitted most effectively through interpersonal contacts and the interfirm mobility of skilled workers. However, Breschi and Malerba (2001) argue that this approach overestimates the benefits of physical proximity alone. They argue that sheer proximity is not sufficient to account for local knowledge spillovers. In their view, the body of research on local knowledge spillovers overlooks the broader set of factors and conditions that support the effective transfer of knowledge in clusters.

> A key feature of successful high-technology clusters is related to the high level of embeddedness of local firms in a very thick network of knowledge sharing, which is supported by close social interactions and by institutions building trust and encouraging informal relations among actors (Breschi and Malerba, 2001, p. 819).

In other words, the degree to which firms can tap into a common knowledge-base at the local level depends on more than just spatial proximity, cultural affinity or corporate culture. In this sense, there is a strong interdependence between the economic structure and social institutions that comprise the cluster. The institutional context of the cluster defines how things are done within it and how learning transpires. As Gertler has argued, it is a function of institutional proximity—the common norms, conventions, values and routines that arise from commonly experienced frameworks of institutions existing within a regional setting (Gertler, 2003, p. 91).

It is also critical to differentiate between different kinds of knowledge spillovers. Much of the literature on knowledge spillovers and, in particular, the role of tacit knowledge, presumes that the knowledge being shared is highly technical in nature and results largely from the transfer of research results between regionally embedded research institutes and private firms. However, technical research results are only one element of the kinds of knowledge flows that contribute to the competitive dynamics of a successful cluster. One of the most important sources of knowledge flows is the knowledge embodied in highly qualified personnel which flows directly from research institutes to private firms in the form of graduates and also moves between firms in the form of mobile labour. There is a strong suggestion in the literature that the recombining of talent in new constellations through labour mobility and the spinning-off of new start-up firms is one of the most important sources of innovation in dynamic clusters (Saxenian, 1994; Brown and Duguid, 2000). A third form of knowledge flows involves entrepreneurial skills. This is often one of the least well documented, but most critical, elements of successful clusters. Closely related to this is knowledge about external market conditions. For small and medium-sized enterprises, an essential piece of knowledge they must acquire to grow and expand concerns the competitive conditions in external markets and which ones constitute the most suitable targets for expansion. Entrepreneurial skill and market information can be transmitted through the cluster via a variety of mechanisms—some formal and some informal—but one of the most important is frequent peer-to-peer mentoring and knowledge sharing that is organised through local civic associations. The dynamic role played by civic associations in facilitating this form of knowledge flow underlines the importance of the local and regional institutional structures once again. The final dimension of knowledge sharing crucial for the success of the cluster is the kind of infrastructural knowledge resources found in the specialised legal,

accounting and financial firms that are essential to the success of individual firms in the cluster. These kinds of services often provide vital support to the individual firms in the cluster.

In an attempt to elaborate further the role that knowledge plays in sustaining clusters, Maskell (2001) has proposed a knowledge-based theory of the cluster. He suggests that the primary reason for the emergence of clusters is the enhanced knowledge creation that occurs along two complementary dimensions: horizontal and vertical. Along the horizontal dimension, clusters reduce the cost of co-ordinating dispersed sources of knowledge and overcoming the problems of asymmetrical access to information for different firms producing similar goods and competing with one another. The advantages of proximity arise from continuous observation, comparison and monitoring what local rival firms are doing, which act as a spur to innovation as firms race to keep up with or get ahead of their rivals. The vertical dimension of the cluster consists of those firms that are complementary and interlinked through a network of supplier, service and customer relations. Once a specialised cluster develops, local firms increase their demand for specialised services and supplies. Furthermore, once the cluster has emerged, it acts as a magnet drawing in additional firms whose activities require access to the existing knowledge-base or complement it in some significant respect (Maskell, 2001, p. 937). In critical respects, this knowledge-based conception of the cluster takes for granted key aspects of the Porter diamond, in its assumption that firms co-located in the cluster tend to be rivals in the same product markets or part of a locally based supply chain, and that close monitoring of competitors or tight buyer–supplier interaction are key elements that tie the firm to the cluster. While these conditions may hold for the most developed clusters in their respective industrial or product segments, there is growing evidence (see following sections of this paper) to suggest that they do not apply universally to all clusters—especially those in more specialised niches or at an earlier stage of cluster development.

If this is the case, then it opens up a new line of inquiry about the relationship between the global and the local, and complicates considerably the question we posed at the outset: just what is it that ties the group of firms to a specific location? A knowledge-based theory of the cluster must recognise that relatively few clusters are completely self-sufficient in terms of the knowledge-base they draw upon. As the innovation process changes to involve the development of ever more complex technologies, the production of these technologies requires the support of sophisticated organisational networks that provide key elements or components of the overall technology (Kash and Rycroft, 2000). While some elements of these complex technologies may be co-located in an individual cluster, increasingly the components of these networks are situated across a wide array of locations. This suggests that the knowledge flows that feed innovation in a cluster are often both local and global. Bathelt *et al.* (2002) maintain that successful clusters are those that are effective at building and managing a variety of channels for accessing relevant knowledge from around the globe. However, the skills required when dealing with the local environment are substantially different from the ones needed to generate the inflow and make the best use of codified knowledge produced elsewhere, and these different tasks must be managed by the cluster. They maintain that an accurate model of the knowledge-based cluster must account for both dimensions of these knowledge flows.

Bathelt *et al.* refer to these two kinds of knowledge flows as 'local buzz' and 'global pipelines' respectively. Following Storper and Venables (2003), 'buzz' arises from the fact of physical co-presence. It incorporates both the broad general conditions that exist when it is possible to glean knowledge from intentional face-to-face contacts, as well as the more diffuse forms of knowledge acquisition that arise from chance or accidental meetings and the mere fact of being in the

same location. Buzz is the force that facilitates the circulation of information in a local economy or community and it is also the mechanism that supports the functioning of networks in the community. In this context, it is almost impossible to avoid acquiring information about other firms in the cluster and their activities through the myriad number of contact points that exist. Pipelines, on the other hand, refer to channels of communication used in distant interaction, between firms in clusters and sources of knowledge located at a distance. Important knowledge flows are generated through network pipelines. The effectiveness of these pipelines depends on the quality of trust that exists between the firms in the different nodes involved. The advantages of global pipelines derive from the integration of firms located in multiple selection environments, each of which is open to different technical potentialities. Access by firms to these global pipelines can feed local interpretations and the usage of knowledge that contibuted to the emergence of successful firms and clusters elsewhere. Firms need access to both local buzz and the knowledge acquired through international pipelines. The ability of firms to access such global pipelines and to identify both the location of external knowledge and its potential value depends very much on the internal organisation of the firm, in other words, its 'absorptive capacity'. The same can be said of local and regional clusters (Bathelt *et al.*, 2002).

However, the precise mix of the global and local knowledge flows present in individual clusters must of necessity be indeterminate. There is increasing evidence to suggest that, even in the most advanced clusters, a growing proportion of the knowledge-base is not exclusively local. The most recent work on Silicon Valley suggests that the production involved in local clusters is part of a complex production chain that is connected into global production networks. The most dynamic of multinational corporations and a larger proportion of emerging small and medium-sized enterprises are embedded in a variety of specialised clusters around the globe. Both types of firms use their presence in the local clusters to access specialised bodies of knowledge created by the local research institutions or tap into a specialised skill-set or unique technical knowledge developed by cluster-based firms. However, rarely are the local knowledge-bases of these clusters, or the production activities of the firms embedded in them, completely self-contained. Rather, according to Sturgeon (2003, p. 200), "what gets worked out in the clusters is exactly the codification schemes that are required to create and manage spatially dispersed but tightly integrated production systems". A greater proportion of the production of complex technologies in sectors ranging from information technology to automotive assembly occurs in these modular production networks with activities dispersed across a wide range of global locations. What take place in the clusters of the more industrialised economies are the core interactions between lead firms and key suppliers that resist easy codification, such as design, development of prototypes and determining the validity of manufacturing processes. The production of high-value-added or low-volume products also takes place in these locations. He implies that there is a geographical hierarchy of clusters within specific industrial sectors, with Silicon Valley acting as the key location for standard-setting activity in information technology (Sturgeon, 2003, p. 220).

A marked pattern of stronger global (vs local) relations emerges even more clearly in a recent study of opto-electronics clusters in six locations. This study found that extraregional commercial linkages are more important than localised ones due to the highly diversified nature of the end-user markets and the complexity of the technologies involved in assembling an end-product for the market. The individual clusters in each of the six case-study regions are dominated by a dominant local actor: either a strong research centre or a lead firm that serves as a catalyst to bring together the firms in the cluster. However, due to the nature of the technologies involved and the intrafirm and interfirm

dynamics, there is little local co-operation and few traded relationships among firms within the individual clusters. What the firms in the clusters do share is their common linkage to the leading institution or firm and their common interest in stimulating and maintaining the critical supply of highly skilled labour (Hendry *et al.*, 2000, pp. 140–141).

2.3 Placing Clusters in a Broader Context

The complex role of both local and non–local knowledge sources in the dynamics of even the most advanced clusters draws our attention to the relationship between the local dimensions of the cluster and the other levels of governance within which they are embedded. If, as we have argued above, institutions are the hidden glue that holds clusters together, the implicit question is whether the institutional structures relevant to cluster dynamics are exclusively those found at the local level. A number of studies have recently focused on the relationship between the concept of the cluster and others used to analyse the innovative capacity of regional and national economies, principally the innovation systems approach. Bunnell and Coe argue for a shift in focus away from forms of analysis that privilege one particular spatial scale as the basis for analysing and understanding the nature of innovation towards those that emphasise the relationships that exist between and across different spatial scales. They adopt the concept of 'nested scales' from Swyngedouw, but suggest that this should not be conceived in a hierarchical or deterministic sense, but rather as involving effects that can move in multiple directions across the scales (Bunnell and Coe, 2001, p. 570).

Thus clusters can be seen as nested within, and impacted by, other spatial scales of analysis, including regional and national innovation systems, as well as the kind of global relationships and forces implied by the 'pipelines' discussed above, each of which adds an important dimension to the process of knowledge creation and diffusion that occurs within the cluster. Various elements of each of these spatial levels of analysis may have significance for the innovation process. For instance, the national innovation system, as analysed by Nelson (1993) or Lundvall (1992), may play a preponderant role in establishing the broad framework for research and innovation policies, in providing a national system of research organisations, in establishing the rules of corporate governance that influence firm behaviour, in setting the rules of operation for the financial system that determine the availability of different sources of financing and time-horizons for new and established firms and, finally, for setting the broad framework for the industrial relations, employment and training systems that influence job paths, interfirm mobility and skill levels for the labour force. Levels of regional specialisation as encompassed in the concept of regional innovation systems developed by Cooke and others play an important role in affecting cluster performance through the provision of the regional/state/provincial research infrastructure, specialised training systems, the broad education system, policies for physical infrastructure and the investment attraction dimensions (Cooke *et al.*, 1997; Cooke, 1998). At the local level, varying degrees of civic associationalism, particularly the business–higher education link, influence cluster development. The local level can also play an important role in the provision of infrastructure such as roads and communication links, as well as in the governance of the primary and secondary education system.

The case of Silicon Valley clearly illustrates the way in which these differing scales of governance impact on the performance of local clusters. The cluster exists within the distinctive features of the US system of innovation—with its unique system of laws, regulations and conventions governing the operation of capital markets, forms of corporate governance, research and development and other relevant factors. A number of these features are central to the story of Silicon Valley's growth and development, including the highly decentralised nature of the post-

secondary education system with complementary and interlocking roles for both the federal and state governments. Changes introduced in the 1970s and 1980s in capital gains tax rates and the tax treatment of stock options, as well as the rules governing investments in venture capital by pension funds, stimulated the growth of the venture capital industry, a critical factor for the development of the ICT cluster. The federal government played a central role as the initial customer for many of the early products of the cluster. It was also the primary funder for much of the critical research and development that has underpinned the growth of these clusters (Rowen 2000). Thus the concept of 'nested scales' of analysis deepens our understanding of the multiple factors that influence the development trajectory of a cluster and, ultimately, its economic performance. From a policy perspective, it also draws attention to the role that higher levels of government play in creating the conditions that support cluster development (Porter *et al.*, 2001).

3. Methodological Approaches to Cluster Studies

One of the key challenges in attempting to draw a consistent set of conclusions from the rapidly expanding opus of cluster studies is the diverse array of methodological approaches used in the studies. The first approach employs a diverse set of statistical-analytical tools, of differing sophistication, to measure the degree of clustering found in local and regional economies. A second approach involves the conduct of case studies of individual clusters or several clusters on a comparative basis. These case studies can involve a wide range of clusters all located within one country or a select group of similar clusters located across different countries. The intent is to use a standard framework to compare the individual cases or benchmark them against the presumed leader or role model for the clusters. Another approach focuses on the analysis of public policies and strategies explicitly designed to promote the establishment and/or growth of individual clusters or sets of clusters. This latter approach is frequently undertaken for a regional or municipal development authority with the goal of benchmarking the relative performance of the region's clusters and providing policy prescriptions for improving their competitive success. This last category usually includes some combination of both quantitative and case-study methodologies.

3.1 Statistical Approaches to Cluster Analysis

One of the most common techniques employed by analysts to identify the presence of clusters within a specific geographical locale is the use of the employment location quotient, which is a ratio of employment shares for a particular industry: the regional industry's share of total regional employment over the national industry's share of total national employment. A quotient greater than one identifies those industries that may constitute the components of local clusters, since it indicates a higher degree of specialisation in the industry regionally than exists at the national level. This is usually interpreted to reflect the degree of competitive advantage enjoyed by the industry locally, relative to its status elsewhere in the country.

A more sophisticated version of this method of analysis is found in the growth–share matrix used by some analysts to provide a maximum amount of information about the relative strength of a local cluster. The growth–share matrix combines three specific measures of local industrial strength in one diagram: the absolute size of the sector in the region, measured in terms of employment; the average annual regional growth rate in employment for the sector, and its location quotient. The representation of the growth–share matrix in graphical form provides a powerful visual medium for depicting the relative economic strengths of a regional or local economy. The use of the growth–share matrix also provides an easy way to benchmark local and regional econ-

omies against other localities where the analysis has previously been done and is useful for highlighting the relative strengths and competitive challenges facing a region (Information Design Associates and ICF Kaiser International, 1997, pp. 41–45). One critique of this methodology is that location quotients are largely an industry–based technique derived from traditional statistical categories such as Standard Industrial Classifications (SIC) and, consequently, offer little insight into the interdependencies between sectors that ought to characterise dynamic local clusters. Ultimately, they are only useful if employed in association with other methods that provide some degree of information on industrial interdependence (Bergman and Feser, 1999, ch. 3).

A more sophisticated version of this technique is represented in the ambitious undertaking by Michael Porter through the Institute for Strategy and Competitiveness at the Harvard Business School. The Institute's Cluster Mapping Project uses statistical techniques to profile the performance of regional economies in the US over time, with a special focus on clusters. Economic profiles of the 50 US states and the District of Columbia were prepared for the National Governors Association Initiative "State Leadership in the Global Economy" using this approach. The detailed profiles of each state provide analyses of major concentrations of employment for both traded and untraded clusters. The Cluster Mapping Project uses information drawn from the County Business Patterns data on employment, establishments and wages by four-digit SIC codes, plus patent data on location of inventor, to identify the core clusters in a region using the correlation of industry employment within geographical areas. The dominant clusters in a region are identified using a location quotient analysis to identify those that are relatively more concentrated based on the region's total employment. Applying this methodology, the Cluster Mapping Project has identified 41 types of clusters in US economy, differentiated between traded, resource-driven and locally oriented clusters (Porter *et al.*, 2001, pp. 18–28; Porter, 2003).

Despite the apparent sophistication of these techniques, they are not without their critics. First, the empirical approaches to cluster identification tend to overlook the nature of cluster life cycles. Clusters frequently go through specific stages of development and the identification of the stage of development for an individual cluster is very important to an analysis of the cluster dynamics. Empirical methodologies that focus exclusively on a statistical snapshot of the cluster at a specific point tend to ignore an analysis of its trajectory of development (Breschi and Malerba, 2001). Empirical analyses that incorporate the rate of growth of employment in the cluster can partially compensate for this shortcoming, but failure to account for this factor means that two clusters on a radically different development path may appear to be quite similar in a statistical snapshot at one point. More generally, their value is limited by the fact that they fail to capture the critical contribution made by soft factors, such as trust and social capital, as well as the organisational dynamics of the cluster. Thus, they only hint at the role played by non-market-based processes, or untraded interdependencies (Storper, 1997).

3.2 Case Studies

Many analysts reject the argument that clusters can only be adequately studied by using statistically oriented methods. They argue instead that the growth and innovation dynamics of clusters can only be properly captured by using qualitative research techniques, especially in-depth interviews with a broad cross-section of cluster participants or ethnographic accounts of the cluster's evolution from leading members. The most common approach in this category is the intensive case study of an individual cluster—the most studied being Silicon Valley. The original model was Saxenian's (1994) case study of Silicon Valley undertaken in the early 1990s and the comparison she provided with Route 128 in Massachusetts. Saxenian drew upon

the growing body of literature on the dynamics of regional network-based industrial systems to highlight the similarities and the differences between the two regions. Firms in network systems compete in global markets and collaborate with distant customers and suppliers, but their most strategic relationships are often local because of the critical importance of face-to-face communication for rapid product development. The variable that determines the relative performance of firms in different regionally based networks is the nature of its industrial system, which includes three important dimensions—the indigenous mix of institutions and culture in the region; the structure of the industrial system; and the internal organisation or industrial culture that prevails in firms in the region (Saxenian 1994, pp. 5–7).

Saxenian's study of Silicon Valley and the insights it affords have been complemented by two recent volumes edited by Kenney (2000a) and Lee *et al*. (2000). Both provide a series of studies that enrich our understanding of the historical trajectory of Silicon Valley's development, its institutional underpinnings and its operating dynamics. The papers in these volumes trace some of the critical junctures in the history of the Valley and, especially, the central role played by key anchor firms in stimulating the growth of related firms at different stages in the Valley's evolution. The influence of forces at different spatial scales is also highlighted, in particular the key support mechanisms provided by the federal government, including defence procurement and critical funding for pre-commercial research. The nature of entrepreneurship, interfirm relationships and the role of knowledge flows in the Valley are also covered.

Although these analyses offer competing explanations of the underlying dynamics that have sustained the growth of the Valley's firms through successive waves of technological innovation, their authors agree that its dynamism can be attributed to the nature of its 'ecosystem' which involves the continuous creation of a multitude of diverse, specialised firms and support organisations that constantly interact with each another to accelerate the innovation process. Saxenian and a number of colleagues have also completed a broad comparative case study of a number of emerging regions attempting to emulate Silicon Valley. The regions covered in this study include Ireland, India, Cambridge in the UK, Israel, Scandinavia, Taiwan and northern Virginia within the US. The key factor driving the growth of these clusters is the ready supply of skilled human capital that attracts managerial talent and entrepreneurs into the cluster. Public policy can support this tendency in a number of ways, but these authors are highly critical of attempts to jumpstart clusters or make top–down or directive efforts to promote them (Bresnahan *et al.*, 2001).

Other notable projects employing a case-study approach include the five detailed studies undertaken by Michael Porter for the US Council on Competitiveness. The Council's Clusters of Competitiveness Initiative examined five regions in the US: Atlanta, Pittsburgh, the Research Triangle, San Diego and Wichita, selected to provide a diverse sample based on size, geography, economic maturity and relative degree of economic success. The case studies used a variety of research methodologies to obtain data on the five regions, including data from the Cluster Mapping Project described above, a set of regional surveys designed and conducted specifically for the Initiative and in-depth interviews with business and government leaders in each region. The study identified a set of factors that contribute to the evolution of regional economies. Successful regions leverage their unique mix of assets to build specialised clusters. They do not try to pick winners, but build on their existing assets to create unique economic strengths that offer competitive advantages to firms based in the region. Building strong regional economies is not an overnight phenomenon. It takes decades of effort to develop existing assets, create new ones, link firms to this regional asset-base and attract inward investment to the cluster. Finally, they conclude that col-

laborative institutions play a critical role in building regional economies by facilitating the flow of information, ideas and resources among firms and supporting institutions (Porter *et al.*, 2001, pp. x–xiii).

It is apparent from the preceding review that the case-study approach can yield important insights into the nature and dynamics of regional industry clusters and the sources of their success. The most effective case studies transcend the limitations of the purely statistical approach to shed new light on the underlying social and institutional dynamics that create the extrafirm dimensions of the cluster's strength. The limitation of these studies, however, is that it may be difficult to compare findings across individual cases if they have not been derived within a common study framework. While the best of them illuminate the relative strengths of a particular cluster, the lack of comparability limits our appreciation of why certain clusters succeed to a greater extent than others. The comparative study by Bresnahan *et al.* and Michael Porter's work for the Council on Competitiveness, which introduced a degree of comparability into the case studies, take an important step in overcoming this limitation. They provide a useful model for other studies in the design of their own research methodologies.

4. Cluster Evolution in Canada: What Have We Learned So Far?

The ISRN's national study of cluster development employs a range of empirical methods to document and understand the emergence and evolution of local clusters in different regions of Canada. It has been designed to allow us to examine—whenever possible—the same type of industry in two or more different regions in Canada. At the same time, we are also studying multiple industrial cases in the same region. Each case is being examined using a common research methodology, based primarily on in-depth interviews with key cluster participants, although supplemented by statistical analysis at the regional and national levels (Gertler and Levitte, 2003; Amara *et al.*, 2003). Each case study addresses a common set of features including

(1) the size and composition of the actual or potential cluster;
(2) the history of the cluster's evolution, including key events (intentional and accidental);
(3) the nature of relationships between firms, and between firms and the research infrastructure;
(4) the geographical structure of these relationships;
(5) the role of finance capital (especially angel investors and venture capitalists);
(6) the role of local associative behaviour; and
(7) other forces contributing to (or inhibiting) the growth of the cluster.

In this way, we hope to discern intrasectoral commonalities, as well as differences in experience that may have arisen due to regional influences and histories.

The selection of industries covered reflects the breadth and structure of the Canadian economy, resisting the temptation to focus solely on a narrow list of 'new economy' cases. The cases range from highly knowledge-intensive activities such as biotechnology, photonics and wireless equipment, telecommunication equipment and aerospace, to more traditional sectors such as steel, automotive parts, specialty food and beverages, and wood products. The cases are distributed across both metropolitan and non-metropolitan regions, reflecting the unique geography of Canada's national economy.[2] We are employing a common research framework and interview guide to analyse all 26 cases. Each case study is based on in-depth, semi-structured interviews with a range of stakeholders drawn from 5 different groups, with the total number of interviews conducted ranging from a minimum of 50 to more than 100, depending on the size and complexity of each case. Specific interview guides have been developed for each of these stakeholder groups:

(1) 'Lead' (large, technologically dynamic, export-oriented), smaller and mid-sized firms, including suppliers.
(2) Industry associations, chambers of commerce, local political leaders and 'civic entrepreneurs'.
(3) Government agencies (federal, provincial, local).
(4) Universities, colleges and other institutions for research and training (including offices of technology transfer/commercialisation as well as relevant departments and individual researchers).
(5) Financial sector (venture capitalists, banks, other).

The first wave of case studies commenced in mid 2001, with most research projects slated to last three years. Two sets of preliminary results have been presented at annual meetings of the ISRN held in May 2002 and 2003, and the first set are available in published form (Wolfe, 2003). What follows is a description of some key indicators of cluster dynamics and properties, and a discussion of common themes emerging across many of the case studies.

4.1 Key Cluster Indicators: How Do We Know a Cluster When We See One?

In contrast to many pre-existing studies of clusters, we have been careful to treat the existence of a local cluster as a hypothesis to be verified through investigation, instead of an *a priori* assumption. Given this orientation, we need some systematic methodology for discriminating between the *bona fide* cases and the imposters. The research completed thus far, and the theoretical and conceptual literature from which we draw our inspiration, have led us to emphasise *flows* and *dynamics* over stocks and static measures of innovativeness. They also point quite clearly to the centrality of knowledge and learning processes, both embodied and otherwise. At this stage, the analysis focuses on four categories of indicators: inflows, outflows, local social dynamics and historical path dynamics.

Inflows. One clear way to confirm the existence of unique, distinctive local knowledge-based assets is by tracking three different forms of inflow. Capital inflows, in the form of venture capital investments, foreign direct investments, or mergers and acquisitions, indicate that investors have identified the local presence of local knowledge assets and capabilities. This seems to have been the case in Ottawa's information technology sector, where Cisco (US) and Alcatel (France) both acquired local firms during the 1990s to partake of the optical and telecommunications expertise embedded in the region through the presence of Nortel and JDS Fitel (now JDS Uniphase) (Chamberlin and de la Mothe 2003). More recently, non-local venture capitalists have continued to invest aggressively in Ottawa firms with high growth potential throughout the post-2000 downturn in both the telecom and photonics sectors. The same phenomenon is evident in the case of Calgary's wireless industry, where Intel has invested directly in new R&D capacity (Langford *et al.*, 2003).

Inflows of people are, in our view, an especially robust indicator of local dynamism. It is now increasingly well established that highly educated, talented labour flows to those places that have a 'buzz' about them—the places where the most interesting work in the field is currently being done. One way to track this is through the inflow of 'star scientists' or by tracking the in-migration of tomorrow's potential stars (post-docs). The recent analysis of this geography in the context of the Canadian biosciences demonstrates that centres such as Vancouver, Montreal and Toronto have exerted a powerful attractive force. Moreover, those firms that have developed working relationships with such stars have experienced significantly higher employment growth between 1997 and 2002 (Queenton and Niosi, 2003).

Another approach, promoted by Florida and colleagues (Florida, 2002; Gertler *et al.*, 2002), utilises a more broadly defined measure of 'talent' and has documented its strong geographical attraction to the presence of

other creative people and activities locally. Of course, in-bound talented labour represents knowledge in its embodied form flowing into the region. Hence, such flows act to reinforce and further accentuate the knowledge assets already assembled in a particular region. In Canada, cities such as Toronto, Vancouver, Montreal and Calgary stand out as leading centres for the attraction and retention of highly educated and creative workers. One should also be able to track knowledge inflows directly, in their disembodied form. This would be monitored through licensing of intellectual property produced elsewhere, or through local citation of externally generated patents, as is suggested in the case study of the Saskatoon biotech cluster (Ryan and Phillips, 2003).

Outflows. Dynamic, innovative clusters of economic activity should also be discernible by the things that flow outward to the rest of the world. Of course, Porter's own methodology for identifying clusters starts with this point, by attempting to document locally produced goods and services that are traded on world markets. But a more complete analysis would need to go beyond these relatively tangible flows, to consider some important but intangible outflows. Foremost among these would be outflows of knowledge, as monitored through various formal modes of intellectual property transfer (such as licensing or patent citations). We would argue that this kind of activity provides perhaps the best indicator of wider recognition of the unique capabilities and knowledge assets of a region. As noted below, emerging evidence from our biotechnology case studies confirms that dynamic firms in Canadian clusters are indeed the origin point for knowledge outflows to commercial partners in the US, Europe and Asia (Gertler and Levitte, 2003).

Local social dynamics. This is the starting-point for most of the literature in economic geography and related fields over the past 15–20 years. This literature has tended to focus on local social dynamics almost to the complete exclusion of all else, including the important non-local flows discussed above. Relevant here, of course, is evidence of co-operation and network-based behaviour, particularly those forms that promote the circulation of knowledge locally. But, as Malmberg and Maskell (2002) point out, competition is as much a part of the story as is collaboration. The dense local clustering of competing firms provides a vitally important opportunity for mutual monitoring and observation, itself a crucial form of knowledge flow. Our case studies are beginning to document the circulation of labour and entrepreneurs between local firms (or other organisations such as research institutes) through the collection of information on career histories, spin-off activity and the process of new firm formation. As noted below, the case-study evidence to date suggests that informal monitoring of other firms' activities as well as learning through the circulation of labour among firms are relatively more important sources of knowledge flows than formal collaborations among the local firms or dense networks of buyer–supplier relationships. Other key markers of local social dynamics include the presence of community-level institutions for associative governance (public, private and hybrid). Such institutions have the potential to promote social interaction and reflexive behaviour leading to successful adaptation and resilience in the face of competitive challenges from abroad. And as Maskell and Malmberg (1999) have argued, because of the path-dependent nature of such local institutions, they are usually quite difficult to replicate, making them a key component of the region's distinctive and unique asset-base.

Historical path dependencies. Following on from the previous point, perhaps the most discerning test of 'true' cluster dynamics is one that assesses the alleged cluster's resilience and robustness over time, in the face of severe shocks and dislocations. How has the region fared under such circumstances? How effectively have its firms and institutions adapted and evolved in response to

such pressures for change? To what extent can firms take advantage of opportunities to learn from success (manifest in the form of successful spin-offs and demonstration effects from successful competitors and/or role models)? In an important respect, the post-2000 meltdown in the telecom and information technology sectors is providing an important laboratory for studying how individual clusters in city-regions such as Ottawa, Waterloo and Calgary respond to these 'external' shocks and the degree to which the 'extrafirm' institutional supports afforded by the location within a cluster serve to cushion the shock and facilitate both the adjustment strategy on the part of individual firms, as well as a broader process of firm collapse and regeneration within the cluster at large.

Related to this idea is another question: how is failure handled? In the most dynamic regions, failure is recognised as a learning opportunity, such that potential investors may see entrepreneurs who have experienced past failure as lower-risk prospects if they have learned valuable lessons in the process (Saxenian 1994; Best 2001). Similarly, the failure or downsizing of large, once-successful firms represents a potential opportunity for regional renewal, since highly educated and experienced knowledge assets are released back into the local economy. Our assertion is that successful clusters capitalise on such events by absorbing these valuable assets back into productive activity—for example, by facilitating and supporting the process of new firm formation. Less dynamic places will tend to squander such opportunities by permitting or encouraging out-migration. One case that we are following closely is that of Ottawa's telecom and photonics cluster. Local surveys indicate that close to 20 000 jobs have been shed by large firms such as Nortel and JDS Uniphase since the onset of the downturn. Nevertheless, the number of firms generated by the cluster has increased by 300. No one in the local economy expects all of these to survive and grow, but the rate of new firm formation as well as the continued inflow of venture capital during the downturn are compelling indicators of the cluster's vitality.

4.2 Case Studies in Canada: Common Themes and Emerging Findings

The interim findings of those cases in progress reveal both commonly shared experiences and unique local circumstances concerning the forces shaping each region's evolution over time. Our observations are structured around five dominant themes.

Learning. Learning has been found to be the key economic process unfolding in each of the cases. Learning is instrumental in enabling old industries to adapt to changing competitive conditions in the global economy, as well as new ones to become more successful innovators. The learning processes have been identified as present both within individual firms and across firm boundaries in the form of learning from other firms, research institutions, industrial associations and related institutional elements of the cluster. Moreover, we have uncovered instances of both local and non-local learning relationships across our range of case studies. However, one of the most notable findings to date has been that non-local learning relationships appear to be more significant than the existing literature would have us believe. Not surprisingly, given the openness and strong export orientation of much of the Canadian economy, many of the firms interviewed in our case studies indicate that their markets and competitors are overwhelmingly outside the region and the country. Thus far, this tendency appears to be especially marked in sectors such as ICT, biotechnology and aerospace. This suggests that at least two corners of Porter's famous diamond—sophisticated and demanding local customers and strong rivalry between local competitors—are not consistently present in the Canadian context. Also notable is the fact that there seems to be relatively little of the diverse specialisation that characterises the larger ICT clusters, such as Silicon Valley. However, location within the cluster does

serve as a spur to learning and innovation, as the local buzz within the clusters ensures that firms are well informed about what others are doing. As we shall discuss below, learning also seems to occur at the cluster-wide level through community-based organisations and both formal and informal processes of mentoring.

Labour. One of the most consistent findings thus far concerns the centrality of skilled labour as the single most important local asset. The local endowment of 'talent' in the labour force is emerging as a crucial determinant of regional-industrial success. This endowment is created and maintained by the retention and attraction of highly educated, potentially mobile workers who are drawn to thick, deep, opportunity-rich local labour markets. The emergence of a strong, concentrated talent pool in local and regional economies also serves as a key factor in launching individual clusters along the path to sustained growth and development. Critical mass appears to be important here: until this is achieved, local employers will fight a losing battle in attempting to retain or attract the skilled talent they need, particularly in the context of a highly competitive North American labour market for highly educated workers. Once this status is achieved, this sets in motion a positive, self-reinforcing circle through which regions with a critical mass of highly skilled workers in a particular sector are able to attract still more workers of this kind. The initial source of the local talent pool can be highly varied, with both government laboratories and local anchor firms playing a key role in developing the early talent base. Post-secondary educational institutions also play a central role in many of the health-based biotech clusters, but seem to be less critical for the initial launch of many of the other clusters. In many of the cases we are studying it appears that post-secondary institutions are followers, not leaders in key areas of technology. However, once industry has demonstrated leadership in the area and the cluster begins to grow, post-secondary institutions seem particularly adept at expanding their programmes and offering in the areas of strength required by the cluster. Their capacity to expand the local talent pool thus becomes critical in accelerating the pace of cluster development.

A fascinating case that demonstrates this effect most clearly is the information technology cluster in Waterloo, Ontario. The roots of this cluster are linked to the decision of a group of local business leaders to create a new university in the region in the late 1950s. Even more influential were the subsequent decisions to focus the core strengths of the university in the sciences, math and engineering and to establish what has become one of the most successful co-operative education programmes in North America. The founders of many of the firms that populate this cluster—including well-known success stories such as Research in Motion (RIM)—are graduates of the university and many started their firms with core technologies developed while they were at the university or through their practical experience in their co-operative terms (Wolfe, 2002).

Leadership. While one of the hallmarks of cluster-based development is its highly decentralised, socially organised network of relationships between local economic actors, the research thus far has highlighted the role that leadership can play in differentiating one firm (or one region) from another. Moreover, this is exercised at two different but equally important scales. First and foremost, the quality and nature of leadership within the firm are crucial in explaining the different strategic approaches taken by firms in the same industry and region, as well as their ultimate competitive success. Perhaps the most vivid example of this comes from the steel industry case study (Warrian and Mulhern, 2003), in which the very different paths taken by leading firms such as Stelco and Dofasco—both integrated steel producers operating from the City of Hamilton—have been strongly shaped by radically divergent attitudes towards co-operation with local research organisations. Dofasco has been far more aggressive than Stelco in pursuing rela-

tionships with local institutions of research and higher learning. Similarly, Bombardier, Canada's leading aerospace producer, has differentiated itself from the competition (and its home-base in Montreal from other aerospace-producing regions around the world) by its corporate strategy of buying assets (both tangible bricks and mortar as well as intangibles such as knowledge) and managing them skillfully, rather than by building them from scratch.

Leadership is also expressed at a social scale: at the level of the community. Here, our early findings point to the key role of 'civic entrepreneurs' in catalysing the development of new and emerging industries such as telecom equipment in Ottawa (Chamberlin and de la Mothe 2003), wireless equipment in Calgary (Langford *et al.*, 2003) or the emerging multimedia sector in Nova Scotia's Cape Breton Island (Johnstone and Haddow, 2003). These community leaders—who are more often than not from the private sector—help to animate local processes of strategic visioning, galvanise socially organised activities to upgrade the innovative capabilities of local firms and represent the common, collective interest of firms in the industry when required.

Legislation and labs: the role of public institutions and organisations. Our case studies also reveal the subtle but pervasive influence of institutional forces, exerted in a number of different ways and at a number of spatial scales. While private-sector initiative and ingenuity are of obvious importance, provincial and national institutional frameworks play a key role in shaping the trajectory of regional-industrial evolution by making certain kinds of strategic choices by firms easier, and others more difficult. They have also played a leading role in building the knowledge infrastructure in different regions of the country: universities, colleges, government labs and other research and technology-transfer organisations. Through the direct creation of crown corporations or government labs at both the federal and provincial levels, they help to produce critical knowledge-based assets for the region. Examples such as Alberta Government Telephone and its role in fostering the Calgary wireless industry through firms such as Novatel demonstrate vividly the potential influence of publicly funded entities in triggering the emergence of new industries and firms (Langford *et al.*, 2003). Similarly, the National Research Council labs in Ottawa, Montreal and Saskatoon have served as important attractors of private firm investment—in telecom, health-based biotechnology and agricultural biotechnology—as well as a generator of significant numbers of spin-off firms started up by former employees (Niosi and Bas, 2000, 2003). Finally, publicly funded agencies have been found to play crucial roles as '*animateurs*', working side-by-side with private and not-for-profit organisations at the local level to organise reflexive learning processes at the level of industries and communities.

However, not all of this public-sector influence is exerted through conscious decision-making. An illustration of the inadvertent role that public policy can play is provided by the case of the telecommunications equipment cluster in Ottawa, which traces its origins partly to the judicial decision in the US that forced the Western Electric Company to divest itself of its subsidiary, the Northern Electrical Manufacturing Company (now Nortel) in the late 1950s. Cut off from its sources of innovation and research, Northern Electric searched for a location to establish its own research facility. It eventually bought a substantial tract of land on the outskirts of Ottawa to be the home of Bell Northern Research, largely because it viewed the presence of the federal government's National Research Council labouratories and the Communications Research Centre as a substantial draw for the highly skilled research scientists and engineers it expected to populate its own facility. Many of the leading entrepreneurs in the Ottawa telecommunications and photonics cluster began their careers as researchers for BNR (Chamberlin and de la Mothe 2003). This case should caution us to avoid looking only for the direct effects of government policy on cluster development.

Location. While our work began from the premise that 'geography matters', we recognise the perils of presupposing the importance of place, rather than examining this proposition through systematic study. What is emerging from our cases is a more nuanced understanding of the importance of proximity to the creation and maintenance of learning dynamics for firms and industries. As already noted, the cases document a consistent tension between local and non-local relationships and knowledge flows—in other words, the dynamic tension that exists between local buzz and global pipelines. Moreover, they are leading us to appreciate the specificity of particular case-study circumstances, in which regional, national, sectoral and historical variation are significant. For example, the studies of Montreal's aerospace industry, Saskatoon's agri-biotech sector (Ryan and Phillips, 2003), Calgary's wireless industry (Langford, Wood *et al.*, 2003) and Hamilton's steel industry (Warrian and Mulhern, 2003) reveal that much of the knowledge-base required for innovation and production is acquired through relatively straightforward market transactions, often from non-local (even global) sources.

Perhaps the most vivid examples come from the life sciences, where firms in Canada's leading biotech clusters (such as Montreal, Toronto, Vancouver and Saskatoon) have strong non-local backward and forward linkages. Recent analysis of Statistics Canada's national survey of biotechnology firms (Gertler and Levitte, 2003) reveals the complex, dual geography of relationships in which successful firms are embedded. On the one hand, they tap into global knowledge markets by hiring highly qualified personnel from abroad. They also take advantage of other global flows of knowledge, through the use of scientific publications and databases, by licensing their intellectual property to foreign partners, or by licensing the intellectual property of foreign firms for their own use. When they develop collaborative relations with other firms, for both research and marketing purposes, these are both local and global in nature. On the other hand, they rely heavily on local sources of investment capital from private sources (angel investors, family and friends) and are highly likely to have spun off from another local company or research institution at some point in their past.

Nevertheless, there is still an important role to be played by local institutions and actors that enable local firms to exploit this knowledge effectively and combine it with other local assets and capabilities for success. While global knowledge flows are certainly important to the competitive success of local firms, the local knowledge/science-base represents a major generator of new, unique knowledge assets. Local universities and research institutes constitute an important part of this base as 'anchors' that generate highly skilled graduates, spin-off start-ups and new, publicly available knowledge (often developed interactively with other local partners outside the sphere of the university). In many cases, it appears that one or a few 'anchor' firms or 'lead' institutions play a critical role in these processes. Examples from our ongoing work include biotechnology in Montreal, telecom and photonics in Ottawa (Chamberlin and de la Mothe, 2003), steel in Hamilton, particularly as produced by Dofasco (Warrian and Mulhern, 2003) and the evolving information technology cluster in New Brunswick.[3]

5. Conclusion

It should be clear from the above discussion that the large and varied international literature on cluster emergence, evolution and policy offers much in the way of rich detail. At the same time, it suffers from an inconsistency of definitions and methodological approaches that compromises the value of the findings flowing from this work. It should be equally clear that the approach adopted in the ISRN project differs from most of the work performed under the rubric of 'cluster studies' in several important ways. First, much of the earlier work presumes the importance of 'the local' and then sets out to find indicators that confirm this. In contrast, our approach is

to treat the possible existence of cluster dynamics as an hypothesis to be investigated and either verified or rejected. For this reason, we continue to ask ourselves: when, or under what circumstances, does spatial proximity matter, and why? Secondly, our relatively large number of case studies across a broad spectrum of both mature and emerging industries, in large metropolitan regions as well as smaller urban centres, provides a solid basis for comparison and for the development of a more robust theory of cluster development. Thirdly, in stark contrast to the vast majority of work on clusters, the indicators we have fashioned for this project emphasise dynamic processes and change over comparative statics. Furthermore, drawing inspiration from recent conceptual work on knowledge-based theories of the firm, innovation processes and the cluster, we have favoured knowledge-based indicators of cluster dynamism and success. Fourthly, rather than adhering to a purely quantitative style of analysis, our view is that quantitative and qualitative analytics are mutually complementary and can render a far more complete story of local innovative dynamics than can quantitative measures alone. Finally, our overarching interest in innovation systems—both regional and national—has encouraged us to situate our analysis of cluster evolution within the broader institutional framework that shapes the behaviour and practices of firms. At the same time, our conceptual approach also emphasises the importance of firm-based and community-level agency (leadership), as well as the potential significance of serendipity, local historical accidents and path dependence. As a result, we are better positioned to highlight and understand the distinctive paths followed by individual cases.

The picture already emerging from our study departs substantially from the received wisdom—most notably concerning the alleged importance of a strong local customer-base and strong local competition in spurring the emergence and evolution of dynamic, knowledge-based clusters. Nor is it evident from our findings that direct, non-market interaction and knowledge sharing between local firms in the same industry are rampant. Our evidence suggests that, where such interaction occurs, it is indirect and mediated through civic associations and other local organisations. While this form of local learning is considerably more prevalent between firms and their local suppliers, not all inputs are locally sourced. In particular, it appears that a large component of the knowledge inputs to local production—at least in certain sectors—is drawn from well outside the region.

The findings reported in this paper represent the results to date from a substantial number of the cases in our study. The next stage of the analysis involves a systematic comparison of the results across similar cases in different regions and different cases in the same region. The goal of this analysis is to enrich not only our conceptual understanding of the process of cluster evolution, but also our insight into the role that public policy—at a range of geographical scales—might play in either promoting or discouraging this process. This nuanced understanding will hopefully provide a more effective guide for policy-makers across a range of geographical scales, as well as an appreciation of the intersecting impacts of both local and global factors on the process of cluster development.

Notes

1. The Innovation Systems Research Network is a cross-disciplinary, national network of researchers funded by the Social Sciences and Humanities Research Council of Canada, with additional support from other federal and provincial departments and agencies. In 2001 the ISRN launched a five-year study of industrial clusters across Canada. The authors are co-ordinators of this study. More details on the network, its members and the current cluster study can be found at the website: http://www.utoronto.ca/isrn.
2. The framework and milestones document which provides more detail on the research project, as well as the presentations from the 2003 meeting, can be found at: http://www.utoronto.ca/isrn/clusters.htm. The project is scheduled to conclude in 2005.

3. The New Brunswick cluster is of particular interest because of efforts by the provincial government to use the local telecommunications firm (NBTel) as the 'anchor' for an emerging ICT cluster and the recently adopted strategy by the federal government's National Research Council to accelerate the cluster's growth by locating a branch of its Institute for Information Technology in the provincial capital, Fredericton (Davis and Schaefer, 2003).

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