What Indicators for Cluster Policies in the 21st Century?

Paper prepared for

Blue Sky II 2006
What Indicators for Science, Technology and Innovation Policies in the 21st Century?

Ottawa, September 2006

Charles H. Davis, Ryerson University

David Arthurs, Hickling Arthurs Low (HAL)

Erin Cassidy, National Research Council

David Wolfe, University of Toronto

August 25, 2006

FINAL

1 Introduction

Interest in innovation clusters has emerged from the recognition that competitive advantage derives not just from firm-based resources and capabilities, but also from resources and capabilities that are located in the firm's geographically proximate business environment. Geographical proximity can produce significant positive effects on rates of new firm formation and firm productivity, innovation, profitability, and growth.[1] According to some researchers, "most industries exhibit clustering behaviour" (Krugman 1994) and clustering "is so pervasive that it appears to be a central feature of advanced industrial economies" (Porter 1990). Clustering is indeed pervasive in Canada.[2]

The pursuit of the benefits of clustering has resulted in considerable activity in the development of public policy concerning innovation clusters. The practical impact of the cluster concept accelerated with the adoption of 'cluster theory' within public policy beginning in the early 1990s when the notion was embraced by practitioners in the public, private, and academic sectors. Governments at all levels have adopted the concept as a tool for promoting national and regional competitiveness, innovation, and growth (OECD, 1999, 2002), as cluster development promised an answer to the challenges created by increased international competition and the growing importance of innovation in the knowledge economy.

The OECD advocates a cluster approach to innovation on the grounds that "clusters are engines of innovation, and represent a *manageable* system for governments to implement the NIS [National Innovation System] Framework by complementing horizontal policies with more targeted and customised policies" (OECD, 2002; emphasis added). However, it is premature to consider clusters as *manageable*. In 1989, when cluster concepts were gaining traction in economic development circles, Thompson noted that prevailing theories of technology-based development were unable to distinguish between necessary and sufficient conditions for development, or between fixed and manipulable features, "both of which are important considerations for planners and policymakers" (Thompson, 1989). Although an enormous literature on clusters has appeared in the past two decades, knowledge of clusters is still highly fragmented, very descriptive, mainly qualitative, and inconclusive on several key points.

Nonetheless, a number of commonly accepted characteristics of clusters have emerged:

- Firms are linked through traded and untraded relationships with each other,
- Interlinked firms are geographically proximate[3], and

---

1 It must also be acknowledged that there can be negative effects of clustering, including congestion, inflated costs, and the risk of overspecialization making a region susceptible to shocks in a particular industry. For discussions of the effects of clustering on firm performance see Aharonson, Feldman, and Baum, 2004; Baptista and Swann, 1998; Beaudry and Breschi, 2003; Beaudry and Swann, 2001; Boschma, 2005; Fritsch, 2002; Gordon and McCann, 2005; Lublinski, 2003; Martin and Sunley, 2003; Palazuelos, 2005; and Pouder and St. John, 1996.

2 See, for example, Wolfe and Lucas, 2005 and 2004, and Wolfe, 2003.

3 The meaning of "geographic proximity" is a contested issue in cluster research and policy, and opinions vary as to whether proximate means within 'driving distance', a city, a province/state, or even a nation. Martin and

- Clusters encompass a mix of public and private organizations, such as research institutions, suppliers, and providers of business services, which provide specialized skills and infrastructure of value to the cluster.

However, the rush to employ cluster ideas has run ahead of many conceptual, theoretical, and empirical issues (Martin and Sunley, 2003). A basic problem in cluster research and practice is the semantic ambiguity of the cluster concept. Reviews of cluster research literature repeatedly point out that the concept is too packed with divergent or contradictory meanings to be coherent.[4] Furthermore, many alternative concepts, such as regional systems of innovation, innovative milieu, learning regions, growth poles, industrial districts, development blocks, technology platforms, and triple helixes, are available with which to conceptualize geographically circumscribed local innovation-intensive organizational environments.

There is now a need for a systematic understanding of the factors that contribute to the creation and development of clusters, and their inter-relationships over time, to improve economic and social development policy. The key challenge is thus to develop a framework and indicators that characterize the structural and functional features of innovation clusters, capturing linkages among firms and other innovation system actors, such as R&D institutions or educational institutions within some geographically bounded area, and measuring the progress of the cluster over time.

This paper explores the question of policy relevant indicators of innovation clusters, a particular case of the more general problem of how to produce meaningful and useful indicators for science, technology, and innovation (STI) policies. We begin by reviewing some of the challenges in defining innovation cluster indicators. We then propose a parsimonious, generic cluster framework comprised of six constructs and thirty-four variables, and summarize the process that has been used to study the initiatives of the National Research Council (NRC) that support cluster development in Canada. Finally, we discuss considerations for the application of policy relevant indicators.

2 The Challenge of Defining Innovation Cluster Indicators

Indicators are “measures of those variables that are to be included in a broadly policy-relevant system of public statistics” (MacRae, 1983: 5); meaningful indicators are statistics of “matters of public concern” (Innes, 1990). They are devices to make a domain of economic or social life visible for purposes of intervention (Power, 2004). In short, science, technology and innovation (STI) indicators are tools that are intended to contribute to public reason and the deployment of instrumental rational social action regarding the application of knowledge within the economy.

Sunley (2003) point out that there is no consensus regarding the geographical extension of cluster processes such as knowledge spillovers, social networks, and inter-firm linkages.

4 See, for example, Bekele and Jackson, 2006; Benneworth et al., 2003; Boschma, 2005; Malmberg, 2003; Malmberg and Power, 2005; Martin and Sunley, 2003.

Progress in the establishment and use of indicators of scientific and technological activities has been hampered by a number of challenges and weaknesses. Foremost among these is that the underlying theory and conceptual foundations have been flawed, resulting in “a disparate array of indicators and measures” (Geisler, 2005). For example, science indicators from the 1960s reflected prevailing beliefs in the “linear model of innovation” in which investments in R&D yield commercial benefits through an unspecified series of conversions (Godin, 2001).

The identification of policy relevant innovation cluster indicators faces other challenges as well. Although conventions exist for measuring and interpreting many STI variables that are relevant in cluster analysis (e.g., investment in R&D, innovation, S&T human resources, patents, technology balance of payments), such indicators are insufficient for innovation cluster measurement for a several reasons. First, they fail to capture basic features of clusters that are essential to understanding the state and performance of a cluster. For example, supply chain and forward market linkages, partnerships, knowledge sharing, social capital, and local sources of tacit knowledge are not reflected in these measures.

Second, many clusters cut across industrial sectors. Traditional statistical data, aggregated by industrial classifications such as NAICS (North American Industry Classification System) codes, are of little use for analysis of emerging areas such as nanotechnology, fuel cells, or nutraceuticals. Even when policy initiatives focus on existing technology areas (e.g. aluminum), data are usually not sufficiently refined to capture particular industrial categories (e.g. aluminum transformation).

Third, and critically for the purposes of providing cluster indicators, available STI statistics are usually aggregated at a regional or national level. It is difficult to identify economic activity that occurs at a sub-regional or cluster level. Statistical data at regional or metropolitan levels in a particular technology area are often subject to confidentiality rules that limit their availability.

Challenges also exist in applying cluster theory within policy. Policy making should be a rational and purposive exercise that relies on learning from ‘what works’ by mobilizing theory and observation in support of reflexive monitoring, evaluation, and dynamic social learning (Sanderson, 2002). However, accounts of early innovation policy environments offer scathing assessments of the actual knowledge base of policy. In regard to science and technology policy analysis in the U.S. in the early 1980s, Averch observed:

> “There seemed to be no canons or even craft rules giving guidance on what constituted reasonable and legitimate analysis and advice to decisionmakers … There were no standards for debate or argument. The most bizarre kinds of reasoning and the weakest kinds of evidence were offered in support of action recommendations.” (Averch, 1985: ix).

In the early 1980s, little theory except conventional neoclassical economics and the ‘linear model of innovation’ was available with which to frame innovation policy. The past two or three decades have seen the development of several theoretical frameworks that can be used to analyze and explain innovation from an economics perspective: industrial organization, transaction cost economics, positive agency theory, resource-based theory, new growth theory, and evolutionary economics (Galende, 2006). Cluster policy’s intellectual roots are in industrial organization theory via Michael Porter, with later additions from industrial location theory, regional economics, and evolutionary theory (Asheim, Cooke and Martin, 2006). Innovation policy, with its conceptalization of innovation as a cumulative process of interactive learning within systemic environments, is intellectually rooted in evolutionary economics.

The development of innovation theory and innovation policies during the past two decades has been a process of interactive co-evolutionary learning through the extensive take-up and development of evolutionary innovation systems concepts by national and international policy and program agencies (Mytelka and Smith, 2004). Interaction between theory and practice can continually improve innovation cluster theory (and associated indicators) and policy and management practices. The following sections outline the underlying framework and indicators for innovation clusters that NRC is using to understand and manage its cluster initiatives and policies.

3 NRC Cluster Framework and Indicators

NRC has launched a number of cluster initiatives intended to make their research institutes and programs drivers of technology clusters. NRC is implementing initiatives in twelve locations across Canada: ocean technologies in St. John's, e-business and IT in New Brunswick, life sciences in Halifax; nanotechnology in Edmonton; fuel cells and hydrogen in Vancouver; nutraceuticals and functional foods, and sustainable urban infrastructure in Saskatchewan; biomedical technologies in Manitoba; aluminum transformation in the Saguenay; and photonics in Ottawa. These initiatives are in direct response to the federal government's policies for innovation, commercialization and economic development. NRC is implementing initiatives in twelve locations across Canada.

As a result, NRC requires indicators to monitor the progress of its initiatives, to support reporting requirements to the federal government, to assist in program planning and management of current and future initiatives, and to aid in communications with stakeholders within the clusters, the provinces, and the federal government.

Over the course of a number of studies,[5] a framework, indicators, and a process to analyze the effects of NRC's involvement in technology clusters has been developed and implemented for six of its cluster initiatives.

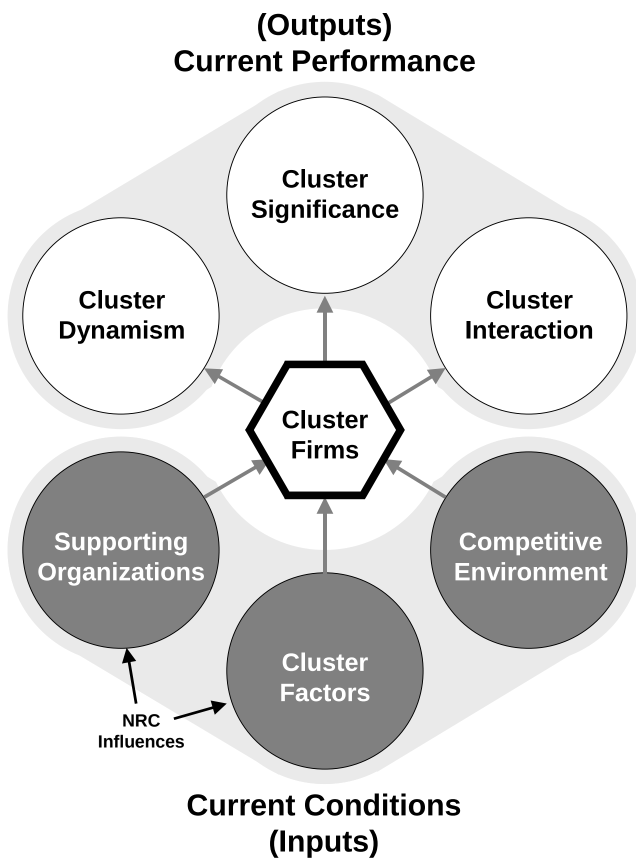
The weakness in the underlying theory supporting innovation indicators noted above holds true for the measurement of innovation clusters. While many different methods and techniques for analyzing clusters have been proposed in the literature (see for example, Padmore and Gibson 1998), no standardized approach has emerged, and numerous challenges have been identified. For example, the most widely known cluster model, Porter's Diamond, overlooks the capabilities of firms in the cluster, lacks measures of outcomes, and contains variables that are only broadly defined (Davies and Ellis 2000, Martin and Sunley 2003).

[5] See Hickling Arthurs Low, 2005, 2006a, 2006b; and Cassidy et al., 2005.

Since an underlying conceptual framework is necessary to structure cluster indicators, and as the existing frameworks were found wanting, a new cluster framework has been developed for NRC that derives from, but moves significantly beyond, the previous work of Porter; builds on the findings of the Innovation Systems Research Network[6] concerning clusters in the Canadian context; and is tailored to NRC needs.

The framework is illustrated in Figure 1. It has two parts, Current Conditions and Current Performance. Current Conditions consists of three constructs that measure the cluster's supporting organizations (including NRC), the competitive environment of customers and competitors, and the factors in the environment of the cluster that influence all of these actors (e.g. availability of HQP, business climate, etc.).

Figure 1: NRC Cluster Framework



Current Performance consists of three constructs that measure the cluster's significance in terms of a critical mass of core firms, the breadth of responsibilities, and reach of firms; interactions within the cluster and with the rest of the world; and its dynamism in terms of innovativeness and growth. The performance of the cluster as a whole is dependent on the success of the individual firms and moderated by the cluster factors, supporting organizations, and customers

6 The Innovation Systems Research Network (ISRN) is a group of Canadian researchers funded by federal research granting councils and NRC to research and disseminate results on Canada's diverse regional systems of innovation and develop policy responses for the various levels of government.

and competitors. There is a temporal disconnect between Conditions and Performance in that current conditions impact future performance, and current performance is the result of past conditions.

The current conditions portion of the framework is similar to the Porter Diamond. 'Supporting Organizations' in the framework is analogous to Porter's 'Related and Supporting Industries', although government-supplied services have also been included. 'Competitive Environment' in the framework is analogous to the combination of Porter's 'Firm Structure, Strategy, and Rivalry' and 'Demand Conditions'. These have been combined since local rivalry and local demanding customers have been found to be much less important in Canadian clusters compared to U.S. clusters, which are typically larger and more self-sufficient. 'Cluster Factors' is synonymous with 'Factor Conditions' in the Porter Diamond. The major improvement in the framework over the Porter Diamond is the addition of the suite of 'Current Performance Indicators' that will enable cause (conditions) and effect (performance) to be determined once a time series of data has been collected for a variety of clusters.

The framework is operationalized by breaking cluster conditions and cluster performance into a hierarchy of constructs, sub-constructs, and indicators. However, due to the lack of established conventions for cluster indicators and the challenges related to collecting supporting data as outlined above, purpose-specific indicators and data sources are required. These were developed for NRC by drawing on the broad range of characteristics considered important to clustering in the literature, and on the experience of ISRN in studying Canadian clusters. The resulting hierarchy of constructs, sub-constructs, and indicators is shown in Table 1.

Not all indicators are equally important to the conditions or performance of a cluster. Again, based on the literature the experience of ISRN, and the implementation of this process in six of the 12 NRC clusters, the relative importance of each indicator is shown in the table.

These indicators, by themselves, provide only a partial view of a cluster. As noted by Diez (2001), many of the benefits of clustering, such as the creation of local resources of tacit knowledge and social capital, and the promotion of collective learning, are intangible and therefore difficult to quantify. As a result, the cluster analysis process described below includes in-depth interviews and stakeholder meetings in order to more fully understand the state of the cluster.

The cluster measurement process used by NRC includes both the measurement of the quantitative indicators listed above, and methods to gather qualitative information and engage cluster stakeholders. The process has eight components:

1. Review of documents and the literature concerning the state of the cluster.
2. Definition of the scope of the cluster.
3. Identification of stakeholders.
4. Introductory cluster meeting to explain the process and validate the cluster scope and stakeholder list.
5. Telephone or face-to-face interviews with key cluster stakeholders to gain qualitative insight into the dynamics of the cluster.

6. Telephone or web survey of firms to acquire quantitative data on cluster conditions and performance.
7. Analysis of the data.
8. Final cluster meeting to communicate and validate the findings.

Table 1: NRC Cluster Constructs and Indicators

Concepts	Constructs	Sub-Constructs	Indicators	Relative Importance
Current Conditions	Factors	Human Resources	Access to qualified personnel	High
			Local sourcing of personnel	Medium
		Transportation	Quality of local transportation	Low
			Quality of distant transportation	Medium
		Business Climate	Quality of local lifestyle	Low
			Relative costs	Medium
			Relative regulations and barriers	Low
	Supporting Organizations	Innovation and Firm Support	Contribution of NRC	Medium
			Contribution of other research organizations	Medium
		Community Support	Government policies and programs	Medium
			Community support organizations	Low
			Community champions	Low
		Suppliers	Local availability of materials and equipment	Medium
			Local availability of business services	Medium
			Local availability of capital	High
	Competitive Environment	Local Activity	Distance of competitors	Low
			Distance of customers	Medium
		Firm Capabilities	Business development capabilities	High
			Product development capabilities	High
Current Performance	Significance	Critical Mass	Number of cluster firms	High
			Number of spin-off firms	Medium
			Size of cluster firms	Medium
		Responsibility	Firm structure	Low
			Firm responsibilities	Low
		Reach	Export orientation	High
	Interaction	Identity	Internal awareness	Medium
			External recognition	High
		Linkages	Local involvement	Medium
			Internal linkages	High
	Dynamism	Innovation	R&D spending	Low
			Relative innovativeness	Medium
			New product revenue	Low
		Growth	Number of new firms	High
			Firm growth	High

The process of measuring the indicators is, however, not the end of the story. To have value, the indicators must be properly interpreted and applied. Considerations for the application of innovation cluster indicators are examined in the next section.

4 Application of Policy Relevant Indicators

The application of policy relevant indicators for clusters depends on a number of considerations. First, is there a rationale for policy intervention? Second, what is the scope for intervention? Third, how will the collection and use of indicators fit into broader government processes? Fourth, how do the needs and uses of indicators change with the objectives of the cluster intervention? Each of these questions will be considered in turn, using NRC as an example.

4.1 Rationale for policy intervention

The rationale for government involvement in innovation is usually explained in terms of market failure and system failure. Market failure refers to situations in which price mechanisms do not take externalities into account. Underinvestment in knowledge production due to uncertainties and problems of appropriability is the classical justification for public subsidy of R&D, for example – the primary role of NRC institutes. Frequently, innovation cluster policies are justified in terms of market failure (OECD, 1999). In this perspective, cluster policies aim to produce public goods that the market cannot provide – networks, coordination, local services, and strategic development of links in the local value chain, for example (Martin and Sunley, 2003: 24). Depending on whether other suitable groups exist within a cluster, NRC may take a leadership or participatory role in providing such cluster facilitation.

More recently however, the rationale for government intervention in innovation has been conceptualized in terms of system failure. System failure refers to deficiencies in the rules or infrastructure that underpin interactive behavior, and in the actors that interact with other actors in the innovation system. The four major kinds of system failures are infrastructure failure, institutional failure, network failure, and capability failure (Woolthuis, Lankhuizen, and Gilsing, 2005). A system failure perspective on government involvement in innovation is particularly useful for cluster policies. Because of their cost and complexity, systemic instruments are developed and deployed much more feasibly at the cluster level than at higher geographic levels. For example, NRC institutes often provide incubators and business development support at the local level.

4.2 Scope of intervention

Typically the organizational ecology of innovation clusters encompasses a wide range of heterogenous actors, including players in the public, private and not-for-profit sectors, in addition to a core group of firms. The cluster approach thus implies complex governance (coordination) mechanisms – mixtures of markets, firms, alliances, associations, public-private organizations, and public organizations, with no a priori structurally superior solution (De Langen, 2003). In each cluster, NRC must determine what needs to be done, and what its role should be.

At the cluster level, NRC, in collaboration with other stakeholders, can use the framework and indicators for the foresight, strategic planning, and performance measurement functions of cluster governance, serving as a support for social knowledge management activities (Gertler and Wolfe, 2004). Social knowledgement management activities enhance communication between actors within a system, coordinating and generating commitment to action. Critical to the success of regional foresight and strategic planning exercises is the ability to involve key agents of change and sources of knowledge that can formulate a strategic vision for the region and generate the intelligence needed to chart a new direction to the future. The engagement of key actors and the recruitment of collaborative and entrepreneurial leaders at the local and regional level are essential for a positive outcome to these exercises. Key aspects of successful social knowledge management exercises are knowledge flows and system-wide learning. Knowledge of other actors' strategies and positioning vis-à-vis a given issue (e.g. through foresight or strategic planning) can reduce uncertainties, thereby enhancing a system's innovative capacity.

Internally, NRC's framework and indicators help to confirm which aspects of cluster performance NRC should influence (e.g., critical mass, linkages, or innovation), the ways that NRC can influence these (e.g., HQP, innovation support, community support), and where it needs to work with other cluster stakeholders to achieve change. An important lesson from cluster studies is the limited influence than any one stakeholder, including NRC, can have on cluster conditions.

4.3 The fit with broader government processes

As with the application of any policy relevant STI indicators, NRC's process of cluster analysis is situated within the broader government process of budget priorities and funding allocation, and within NRC's own planning and performance management framework. This includes the following recursive steps:

- Measurement – NRC, in cooperation with other cluster stakeholders, establishes an operational definition of the scope and extent of the cluster. The current conditions and performance of the cluster are then measured. These measurements are performed at regular intervals in order to track the conditions and performance of the cluster over time. As the cluster evolves, its focus may also change – in reaction to external forces, a cluster may re-invent itself; sub-clusters may form and acquire their own identity; or sub-clusters may become redundant and coalesce. The evolutionary nature of clusters presents a challenge in efforts to measure the progress of a cluster since it may transform itself into something quite different in the future.

- Strategic Decision Making – Using the cluster indicators, a gap is defined that NRC can most appropriately fill. NRC identifies stakeholders it can engage with to stimulate cluster development and funding is secured to implement an initiative.

- Implementation – NRC establishes R&D infrastructure, undertakes R&D, supports firms in developing their innovation capacity, and engages cluster stakeholders to develop and implement a strategic plan.

- Evaluation – Using a variety of methodologies, including cluster measurement studies, NRC evaluates the performance of the initiative against intended outcomes and ongoing relevance, and makes recommendations to improve future performance.

- Renewal – Based on an understanding of the cluster that is supported by cluster indicators, NRC engages the community to collectively determine the appropriate future course of action, to determine stakeholder roles in the context of the cluster's stage of development, to mobilize resources and to develop an action plan to move forward. It is expected that as a cluster develops and becomes sustainable, private sector champions will emerge and assume leadership of the cluster.

4.4 Responding to changing objectives

A significant segment of policy work, including that being done at NRC, recognizes that cluster development is a long-term process. The cluster life cycle adopted by NRC is shown in Figure 2, and consists of four stages: latent, developing, established, and transformational.[7] The stages are defined as follows:

- Latent – A region has a number of firms and other actors that begin to cooperate around a core activity and realize common opportunities through their linkages. Indicators for a latent cluster will include low critical mass, low identity, and low linkages.

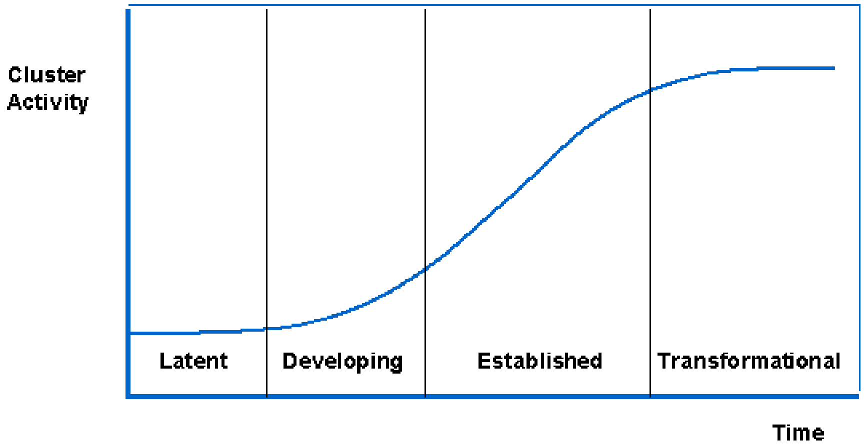
- Developing – As new actors in the same or related activities emerge or are attracted to the region, new linkages develop. Formal or informal institutes for collaboration may appear, as may a label and common promotional activities for the region. Indicators for a developing cluster will include developing linkages and high innovation.

- Established – A certain critical mass is reached. Relations outside of the cluster are strengthened. There is an internal dynamic of new firm creation through start-ups, joint ventures, and spin-offs. Indicators for an established cluster will include high critical mass, high identity, high linkages, and high innovation.

- 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. Depending on the state of transformation, indicators may be mixed.

7 This lifecycle was adapted from the general model proposed by Andersson et al. 2004 during an NRC/Statistics Canada workshop held in December 2004.

Figure 2: Cluster Life Cycle



Cluster policies will depend on the maturity of the cluster and its innovation system. For example, early stage clusters might focus on firm capabilities, the availability of capital, and access to qualified people. As clusters mature, indicators related to infrastructure, suppliers, and supporing organizations grow in importance.

The evolution of a cluster will also be driven by external shocks. For example, as the cluster grows, the emergence of new firms may alter the strategic alliances driving the cluster's R&D activities, or may require new strategies to meet the increased demand for skilled labour. The rise of foreign competitors or competing technologies may require an internal restructuring to increase efficiencies or a new investment in R&D capabilities. This dynamism causes the cluster's structure to change over time. A cluster framework and its indicators must account for the continually evolving characteristics of the cluster to remain relevant to policymakers.

5 Discussion and Conclusions

NRC has developed a conceptual framework and indictators to meet the challenges of innovation theory and cluster measurement as outlined earlier. The framework articulates a suite of indicators of cluster development. It includes indicators of the features of clusters that NRC can influence through the services that it provides, and the pathways that such influence can take. It also highlights the aspects of clusters that are beyond NRC's purview, but of relevance to other cluster players.

In the indicator planning process we assessed existing data sources. Few provided suitable indicators to support cluster development initiatives. Therefore indicators had to be developed and measured for each cluster. The process was initially driven by policy relevance for measuring success, reporting on results, and facilitating decision making by NRC in its cluster strategy going forward. Additional areas of relevance have been identified for Institute planning and cluster strategic planning processes involving stakeolders. Lessons learned so far regarding the the framework and indicators include:

- First, interaction between theory and practice can continually improve cluster theory (and associated indicators) and policy and management practices.
- Second, cluster policymakers and managers must understand innovation pathways and cluster dynamics.
- Third, policy relevant cluster indicators can support social knowledge management activities in a cluster environment that features a diversity of policy stakeholders with varied interests and information requirements. No one organization can make a cluster work, and establishing the mechanisms for cluster governance is a challenging task.
- Fourth, all cluster players should support the production of accurate and up-to-date indicators of a particular cluster, with support from senior levels of government.

Bibliography

Aharonson, Barak S., Joel A.C. Baum, and Maryann P.Feldman, 2004. "Industrial Clustering and the Returns to Inventive Activity: Canadian Biotechnology Firms, 1991-2000." Danish Research Unit for Industrial Dynamics [DRUID] Working Paper No 04-03.

Andersson, Thomas, Sylvia Schwaag Serger, Jens Sorvik, and Emily Wise Hansson, 2004. The Cluster Policies Whitebook. International Organisation for Knowledge Economy and Enterprise Development, Malmo.

Asheim, Bjorn, Phil Cooke and Ron Martin, 2006. "The Rise of the Cluster Concept in Regional Analysis Policy: A Critical Assessment," in B. Asheim, P. Cooke and R. Martin, eds., Clusters and Regional Development: Critical Reflections and Explorations. London: Routledge.

Averch, Harvey A., 1985. Averch, H.A., A Strategic Analysis of Science and Technology Policy. Baltimore: The Johns Hopkins University Press.

Baptista, Rui, and G.M. Peter Swann, 1998. "Do Firms in Clusters Innovate More?" Research Policy 27, 525-540.

Beaudry, Catherine, and Peter Swann, 2001. Growth in Industrial Clusters: a Birds-Eye View of the United Kingdom," SIEPR Discussion paper 00-38, Standford University.

Beaudry, Catherine, and Stefano Breschi, 2003. "Are Firms in Clusters Really More Innovative?" Economics of Innovation and New Technology 12: 325-342.

Bekele, Gashawbeza W. and Randall W. Jackson, 2006. Theoretical Perspectives on Industry Clusters. Research Paper 2006-5, Regional Research Institute, West Virginia University.

Benneworth, Paul, Mike Danson, Phil Raines, and Geoff Whittam, 2003. "Confusing Clusters? Making Sense of the Cluster Approach in Theory and Practice," European Planning Studies 11(5), 511-520.

Boschma, Ron, 2005. "Proximity and Innovation: a Critical Assessment," Regional Studies 39(1), 61-74.

Cassidy, Erin, Charles H. Davis, David Arthurs, and David A. Wolfe, 2005. "Measuring the National Research Council's Cluster Initiatives," Proceedings of 'Beyond Clusters: Current Practices and Future Strategies," Ballarat, Australia, June.

Davies, Howard, and Paul Ellis, 2000. "Porter's Competitive Advantage of Nations: Time for the Final Judgment?" Journal of Management Studies 37(8), 1189-1213.

De Langen, Peter W., 2003. The Performance of Seaport Clusters. Ph.D. disseration, Erasmus University, Rotterdam.

Diez, Maria Angeles, 2001. "The Evaluation of Regional Innovation and Cluster Policies: Towards a Participatory Approach," European Planning Studies 9(7), 907-923.

Fritsch, Michael, 2002. "Measuring the Quality of Regional Innovation Systems," International Regional Science Review 25(1), 86-101.

Galende, Jesus, 2006. "Analysis of Technological Innovation From Business Economics and Management," Technovation 26(3), 300-311.

Geisler, Eliezer, 2005. "The Measurement of Scientific Activity: Research in Linking the Philosophy of Science and Metrics of Science and Technology Outputs," Scientometrics 62(2), 269-284.

Gertler, Meric, and David A. Wolfe, 2004. "Local Social Knowledge Management: Community Actors, Institutions, and Multi-level Governance in Regional Foresight Exercises," Futures 36, 45-65.

Godin, Benoit, 2001. "Tradition and Innovation: the Historical Contingency of R&D Statistical Classifications," Institut national de la recherche scientifique, Montreal: Project on the History and Sociology of S&T Statistics, Working Paper no. 11.

Gordon Ian R., and Philip McCann, 2005. "Innovation, Agglomeration and Regional Development," Journal of Economic Geography 5, 523-543.

Hickling Arthurs Low (2005) "Baseline Study of the NRC Technology Cluster Initiatives", prepared for the National Research Council, November.

Hickling Arthurs Low (2006a) "The Evaluation of Technology Cluster Initiatives", prepared for the National Research Council, January

Hickling Arthurs Low (2006b) "Cluster Studies for NRC Technology Cluster Initiatives", prepared for the National Research Council, August.

Innes, Judith Eleanor, 1990. Knowledge and Public Policy: the Search for Meaningful Indicators. New Brunswick, N.J.: Transaction.

Krugman, Paul, 1994. "Location and Competition: Notes on Economic Geography," chapter 16 in R. Rumelt, D. Schendel and D. Teece, eds., Fundamental Issues in Strategy. Boston: Harvard Business School Press.

Lublinski, Alf Erko, 2003. "Does Geographic Proximity Matter? Evidence from Clustered and Non Clustered Aeronautics Firms in Germany," Regional Studies 37(5), 453-467.

MacRae, Duncan Jr., 1985. Policy Indicators: Links between Social Science and Public Debate. University of North Carolina Press, Chapel Hill & London, 1985.

Malmberg, Anders, 2003. "Beyond the Cluster - Local Milieus and Global Connections," in J. Peck and H.W.-C. Yeung (Eds.), Remaking the Global Economy: Economic-Geographical Perspectives. Sage, London, pp. 145-159.

Malmberg, Anders, and Dominic Power (2005). "How do (Firms in) Clusters Create Knowledge? Industry and Innovation 12(4), 409-431.

Martin, Ron, and Peter Sunley, 2003. "Deconstructing Clusters: Chaotic Concept or Policy Panacea?" Journal of Economic Geography 3(1), 5-35.

Mytelka, Lynn K., and Keith Smith, 2004. "Policy Learning and Innovation Theory: an Interactive and Co-evolving Process," Research Policy 31, 1467-1479.

OECD, 1999. Boosting Innovation: the Cluster Approach. Paris, Organisation for Economic Cooperation and Development.

OECD, 2002. Dynamising National Systems of Innovation. Paris, Organisation for Econmic Co-operation and Development.

Padmore, Tim, and Hervey Gibson, H., 1998. "Modeling systems of innovation, Part II, A framework for industrial cluster analysis in regions," Research Policy 26, 625–641.

Palazuelos, Manuel, 2005. "Clusters: Myth or Realistic Ambition for Policy-Makers?" Local Economy 20(2), 131-140.

Porter, Michael E., 1990. The Competitive Advantage of Nations. New York : The Free Press.

Porter, Michael E., 1998. "Clusters and Competition: New Agendas for Companies, Governments, and Institutions," in On Competition. Cambridge, MA: Harvard Business Review Books.

Pouder, Richard W., and Caron H. St John, 1996. "Hot Spots and Blind Spots: Geographical Clusters of Firms and Innovation.' Academy of Management Review 21, 1192–1225.

Power, Michael, 2004. "Counting, Control, and Calculation: Reflections on Measuring and Calculation," Human Relations 57(6), 765-783.

Sanderson, Ian, 2002. "Evaluation, Policy Learning and Evidence-Based Policy Making," Public Administration 80(1), 1-22.

Thompson, C., 1989. "High-technology Theories and Public Policy," Environment and Planning C: Government and Policy 7, 121-152.

Wolfe, David A . and Matthew Lucas (Eds.), 2005. Global Networks and Local Linkages: The Paradox of Cluster Development in an Open Economy. Montreal and Kingston: McGill-Queens' University Press.

Wolfe, David A. and Matthew Lucas (Eds.), 2004. Clusters in a Cold Climate: Innovation Dynamics in a Diverse Economy. Montreal and Kingston: McGill-Queens' University Press.

Wolfe, David A., ed. 2003. Clusters Old and New: the Transition to a Knowledge Economy in Canada's Regions. Montréal: McGill- Queen's University Press.

Woolthuis, Rosalinde Klein, Maureen Lankhuizen and Victor Gilsing, 2005. "A System Failure Framework for Innovation Policy Design," Technovation 25, 609-619