The biotechnology cluster in Vancouver

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Abstract

In order to examine the functioning of regional innovation systems, it is necessary to look at the building blocks of these systems, technology-based clusters. There is a strong biotechnology cluster in Vancouver - eighty-eight firms, according to BC Biotech (2002) - yet there is no major manufacturing facility. The Vancouver cluster is unlike other biotech clusters in that its output is solely intellectual property. This ongoing study not only examines the usual structure of a cluster (sources of innovation, barriers to innovation) but also will focus on the issue of intellectual environment, and seek to determine whether a strong cluster can be built without the presence of a large, globally-competitive, manufacturer.

Introduction

The ability to innovate is one of the most powerful sources of competitive advantage in modern economies. The ability to acquire, adapt and advance knowledge determines how well businesses and countries innovate and, in turn, how well they compete locally and globally. Knowledge is a unique commodity in that while it can be created, it cannot be destroyed. It can be transferred, but the source retains all of the knowledge it transfers to the recipient. Knowledge can flow from one institution to another, either through transfers of people, or through financial transactions that permit the acquisition of knowledge.

Technology-based clusters are emerging in regions that have achieved critical mass in the knowledge economy. These clusters are anchored by strong research universities, industrial laboratories and entrepreneurial companies, with human capital and infrastructure to match. Collectively these clusters form regional and national systems of innovation. This paper will apply experience in looking at a specific cluster (biotechnology) within a regional system of innovation in a federation to looking at how a cluster in one regional system of innovation may differ from a similar cluster in other regions.

The literature on national innovation systems (NIS) is quite recent. The first author to introduce the concept was Christopher Freeman in a case study of Japan, in 1987. Lundvall (1992) developed the concept from a more theoretical and conceptual point of view, using Denmark as an example. Since then the systems of innovation approach has shifting from solely a national perspective to one including regional or local systems. Are NIS unique systems, or are they simply agglomerations of RIS? Is an NIS greater than the sum of its component RIS? This focus on spatial aspects has two major advantages; on the one hand, it recognizes that innovation is a *social process* and is shaped by persons and institutions that share a common language, rules, norms and culture (i.e. common modes of communication). On the other hand, innovation is also a *geographic process***,** taking into account that technological capabilities are grounded on regional communities that share a common knowledge base.

For federations, the national system of innovation is more complex than that of a centrally-administered nation, since there are often provincial/state level institutions and actors that parallel national level institutions and actors, with some policies or powers under provincial control, and others under federal control. Canada is one of the few true economic and social (as well as political) federations in the world. In the OECD, only Australia, the US and Germany come close to the unique structure and socio-economic features that exist in Canada. Thus, unlike most nations in the OECD, and other parts of the industrialized world, the Canadian national system of innovation is different. A key element of the Canadian federation is the allocation of most economic powers to the national government and the assignment of social responsibilities - particularly health and education – to the provinces.

Holbrook and Wolfe (2000) have argued that, at least in the case of Canada, in order to understand the NIS, one must first understand the RIS. Is the Canadian NIS the sum of a number of RIS, whether based on economic regions or provincial boundaries? In the Canadian context this summation is distorted by the wide variation in sizes of the regional systems – national level data (and the ensuing analyses) of the Canadian system of innovation are heavily biased by the economic activities occurring in the two major industrialized provinces, Ontario and Quebec. In most developed nations innovation, science and technology policies are formulated by the central government, yet most innovation activities take place locally. Thus nation-wide innovation policies may not affect each region equally, and could conceivably be counterproductive in some instances.

The recently published OECD territorial review on Canada recommends a new regional policy approach, taking into account that Canada is becoming less a resource-based economy requiring the:

"*valorization of potential competitive advantages with regard to industrial production and services, and the removal of bottlenecks (weak cluster integration, valorization of natural resources, etc.) preventing further development. Given their often local and regional nature, this strategy should result in attaching a more important role to the territorial policies*" (OECD, 2002).

Turning to empirical studies regarding RIS, there are many case studies from the perspective of economic geography. In particular, there are studies that establish different typologies of RIS and clusters, with the intention to make explicit the differences that may be found within a country, and the complexities of the study of RIS and clusters. Longhi (1998) has argued that there are preconditions for the development of a regional system of innovation which include: a) a coherent set of territorial relationships among all economic actors, b) a specific culture, and c) a shared representation system, implying a strong consensus and integration among them.

A useful model was developed by Cooke (1998) who established two key dimensions to analyze RIS: the S&T (research) governance infrastructure and business innovation superstructure. The governance infrastructure dimension – initially developed for technology transfer purposes- establishes three main types of RIS: grassroots, network and dirigiste. It is clear that governance structure for Cooke it is not political governance as it is normally/usually understood. The initiation of the RIS is the key feature, which then affects funding, the type of research (applied, basic, near to the market, etc.), technology specialization and the forms and degrees of coordination. Grassroots are locally organized, network RIS are multilevel organized and dirigiste are the product of central government policies. The business innovation dimension gives us the posture of the firms in the regional economy, both towards each other and the outside world, as well as in relations with producers as with consumers in the market place. Firms can range from those with local influence to multinationals.

Cooke establishes two key dimensions to analyze RIS: the governance infrastructure and business innovation superstructure. Cooke uses the governance infrastructure dimension to classify modes of technology transfer. The business innovation dimension gives the posture of the firms in the regional economy, both towards each other and the outside world, as well as in relations with producers as with consumers in the market place.

Table 1: SOME EXAMPLES OF REGIONAL INNOVATION SYSTEMS[1]

Governance structure/ Business innovation dimension	***Grassroots***	***Network***	***Dirigiste***
Localist	Tuscany (northern Italian industrial districts)	Tampere (Denmark)	Tohoku (Japan)
Interactive	Catalonia *Saskatchewan* *Manitoba*	Baden-Wurtemberg *British Columbia* *Alberta*	Québec
Globalized	Ontario California	North Rhine–Westphalia	Singapore Midi-Pyrenées

Source: Cooke, 1998, regions in italics are added by the author

[1] These cases are studied in Braczyk, Cooke and Heidenreich (1998).

Going a step forward, one needs to distinguish between an RIS and an industrial cluster of the type defined by Porter, among others. How much innovation and what type of innovation should exist in a cluster for it to be considered a viable element of an RIS? Several possibilities exist:

- Clusters are geographic concentrations of interconnected companies and institutions in a particular field (Porter, 1998).

- A cluster is a geographically bounded concentrations of interdependent businesses (Rosenfeld, 1997, cited by Asheim and Isaksen, 2001)

- Clusters are regarded as places where close inter-firm communication, and social-cultural structures and institutional environment may stimulate socially and territorially embedded collective learning and continuous innovation (Asheim and Isaksen, 2001).

The British Columbia Biotech Cluster Study

There are a number of biotech clusters in Canada, seven of which are being studied by the ISRN project. The long-term objective is to compare these clusters within the NIS and seek out regional differences that can provide useful information about the RIS. For the purposes of this study, we started with a definition of a cluster based on Porter's model, but modified as described in the overall ISRN program description[2].

Wolfe and Gertler (2003) have proposed the existence of at least two types of industrial cluster in Canada Type I, "regionally embedded and anchored", and type II "entrepôt". In a type I cluster, "the local knowledge/science base represents a major generator of new, unique knowledge assets". In a type II cluster "much of the knowledge required for innovation and production is simply acquired through straightforward market transactions. Table 2 shows the clusters and a first approximation as to their typology. In the cases of the three smaller clusters, it is difficult to determine typology. They are shown here as "undifferentiated". It may well be that at some point they will grow to a point that they become either a type I or a type II cluster. Less likely, but still a possibility, is that type II clusters eventually grow to be type I . The ISRN research should help to determine this.

[2] Two key differences are a) the cluster does not have to be globally competitive, but nationally competitive, and b) public sector institutions can (and do) play major roles in the formation and sustainability of the cluster.

Table 2: Typology of Biotech Clusters in Canada

Cluster	Type	Size (in stars")*	Geographic boundaries	Economic boundaries
Montreal	I	70	++	++
Toronto	I	47	-	++
Vancouver	I	80	++	++
Saskatoon	II	22	Wide area	+
Ottawa	undifferentiated	6	+	+
London	undifferentiated	5	-	- -
Halifax	undifferentiated	n/a	++	+

* see Queenton and Niosi (2003)

Not all of these studies have been completed at this time; this paper highlights the biotech cluster in the province of British Columbia. The definition of "biotechnology" is that used by the OECD (see appendix "A"). It should be noted this definition excludes medical devices based on biotechnological processes. The initial work was based on firms and institutions based in Vancouver - in later years the hypothesis that the cluster extends to firms on Vancouver Island will be tested, and it is not clear that this can be taken for granted. For practical reasons, as well as for the geographic concentration usually associated with industrial clusters, this study does not extend to other parts of British Columbia.

The institutions and enterprises making up the cluster for our study are taken from a "snapshot' taken in early 2002 based on information from the National Research Council (NRC) and BC Biotech.[3] There are approximately forty privately owned firms, ten venture capitalists, nine government organization, two non-profit organizations, and three research institutes. Thirty-two private firms belong to the pharmaceutical cluster and eight to the medical device cluster. This number is constantly changing: BC Biotech (2002) has stated there are 91 biotech firms in BC in 2002 with 88 of them being in the Vancouver/Lower Vancouver Island area.

The Biotech "Vibe" in Vancouver

Biotech research institutes in Vancouver are, understandably, located near the three main post-secondary institutions: University of British Columbia (UBC), Simon Fraser University (SFU), and the British Columbia Institute of Technology. Government agencies are located on or near the UBC campus.

[3] BC Biotech (2003) stated there are eighty-eight firms in Vancouver and the southern part of Vancouver Island

The private component of the biotech sector in Vancouver consists of young and small firms. The oldest (and "model") is Quadra Logic Technology (QLT) founded in 1981, which is the largest privately owned biotech firm in Vancouver. Since 1995, 19 biotech firms have been spun off from UBC, and 7 from SFU; of these 26, 19 or 73% are still in existence. Figure 1 shows the growth of the BC biotech cluster start-up firms by year of start-up and stage of development.

The firms are located in five very narrowly defined neighbourhoods – the UBC campus, the Vancouver General Hospital, and the Burnaby/New Westminster industrial area. All but one of the venture capitalists are located in the financial district, in downtown Vancouver. An interesting observation is that the firms often "trade up" from one lab facility to the next, by taking over larger premises and releasing their old space to newer, and thus smaller firms. At the same time many of the specialized facilities built to incubate biotech companies (often in public institutions, and built with public money) are now empty as they are often too expensive for start-up companies.

Insert Figure 1

BC Biotech - The voice of BC's Biotechnology Industry

BC Biotech is a non-government, not-for-profit industry driven association. Representing over 90% of BC biotech's community across all sectors, BC Biotech is an effective voice on a range of issues that affect the industry, from influencing public policy to stimulating investor interest. It gives its members access to the information, resources and assistance they need to make their ventures a success. BC Biotech keeps its members informed about the current state of the biotechnology industry in BC around the world. Through its events, seminars, and educational opportunities, BC Biotech facilitates networking, partnering opportunities, and growth for its members and for BC's biotechnology industry.

Barriers to Innovation

In discussing barriers to innovation, respondents reported difficulty finding and retaining qualified employees. There is substantial competition with US and Eastern Canada due to economic disadvantages in Vancouver - primarily high personal income taxes and housing costs – these are somewhat offset by the cultural and climatic conditions of the area. As some respondents noted:

-"N*eed some kind of incentive to attract employees, something we can work with other than scenery - like tax free stock options…"*
-*"No incentive to finance biotech in Canada"*
-*"Best thing government could do is leave us alone".*
-*" Let us do business without interfering"*
-*"Lack of experienced management, upper level"*

Observers of the biotech cluster (such as government officials) argued the lack of industrial experience in Vancouver is due to the relative youth of biotech cluster. The lack of highly qualified and experienced management is a problem, not only in Vancouver, but across Canada. Apart from a lack of senior management personnel, there is a lack of expertise in the regulatory/drug development area. Respondents have reported the existence of "prowling" head hunters but inter-firm movement by technical personnel is relatively low. When asked what could be done to overcome these barriers, responses included:

-*"Tax breaks! Like Quebec!".*
- *"Tax credits (or tax holidays) for upper level management to be attracted to work here"*
-*"Finance – more grants (no pay back)"*
-*"Need to increase science coming out of universities. Not enough commercially minded scientists."*

It was argued that it is difficult to attract upper level personnel to Vancouver because of its relatively remote location on the North American continent. There are not enough big companies, and potential executives feel that there is not enough scope for mobility among biotech enterprises[4]. Additionally individuals perceive that BC and Canada are high-tax locations and that Canadian salaries are not competitive with US salaries: however once recruited to Vancouver they are less likely to leave.[5]

Sources of Innovation

Respondents, when asked about sources of innovation noted that there is now a constant progression of trained PhD students from UBC labs contributes to talent in BC. According to one: "*it's a trickle down effect better than in '92".* Innovation is helped by the close proximity of firms to university labs - "*opportunities from UBC, SFU and the University of Victoria where tech comes from university and genome centres."* . The biotechnology cluster appears to have grown from knowledge "spillovers" coming out of the universities (Goldfarb and Henrekson 2003).

There is strong, friendly and collegiate biotech community in Vancouver, even though there are no business relations between these companies. Many companies affirm that they are not "part of network of related firms in the region", since they each believe they work in a specific niche, developing a particular technology/product, whose market is not local companies but global pharma companies. It seems that there are two biotech

[4] As noted by Richard Florida (2000), people often move not for the job that is being offered to them, but for the job opportunities presented by moving to the new location.

[5] The social benefits conferred by the higher taxes in Canada system, such as health care, and the relative advantage in purchasing power of the Canadian dollar erase the perceived differential.. Also from a firm's point of view costs per researcher are lower: R&D expenditures per researcher (in US$ in 1999, as reported by the OECD) are $112,000 per researcher in Canada, $168,000 in France, $148,000 in Germany $135,000 in the UK and $160,000 in the US.

specialities in Vancouver, based on the OECD definition and the categories it provides to classify the industry: DNA-genomics, and proteins and molecules (especially proteomics, and peptides sequencing and synthesis). There is a strong network of biotech innovators: the BC Biotech Association provides networking opportunities for its members: 80% of those interviewed mentioned the importance of the BC Biotech Association.

The situation appears to be similar for service companies and contract research organizations. Often they were established originally to support the development of the local cluster, but their actual customers are all around the world, especially US companies, not Vancouver's firms.

BC Biotech appears to be the glue that keeps these companies together, and the networking events are more for social purposes, to know the community (for newcomers), and key for consultants and lawyers for making contacts. (see Figure 2). While BC Biotech is the glue, the driving forces are the research programs at UBC and the existence of venture capital and angel investors. Arguably there is little horizontal integration, but even less vertical integration, as in the Porter model of clusters.

What anchors firms in Vancouver? Lifestyle, 'social and historical' roots in the city? A connection to UBC seems to be a common anchor for many of the companies. Many of them started at similar times and went through similar challenges—having other individuals to interact with who have had similar experiences has created a shared bond between some of the firms. Firms rarely compete with each other for local talent. They are able to attract talent to the city - aided by the weather, scenery and lifestyle of the city - but out-migration of talent does not appear to be a problem. Firms appear to be sufficiently specialized that there is little movement among firms by the technical specialists, thus creating a horizontal group of firms, each more or less at the same level of relationship to their sources of IP and at the same level of relationship to their other inputs (capital, services) and their eventual clients/customers.

As a side experiment we searched websites for the biographies of the senior officers of most of the biotech firms in Vancouver. A majority of the websites listed the degrees, and the institutions which awarded them, for their senior people. While this experiment was not rigorous, 30 out of 44 sites examined listed the degrees for at least some of their key people. 45% of these people had degrees from Canada, with 27% coming from BC. About 30% had their highest degree from a US institution. One senior official of a biotech firm in Vancouver told us most of their recruiting was done outside BC, and that if they could get their senior people to stay in Vancouver for two years, then they had little worry of them leaving. The first two years were critical; this manager emphasized the need for some sort of special tax treatment for new hires, particularly those from the US, to ease the transition from the US tax system to the Canadian system.

Another important element in BC is the existence of a strong venture capital market; the number of angel investors in BC with deep pockets was mentioned by several interviewees as being a unique feature of this cluster Venture capitalists stated:

- *“There are lots of venture capitalists in BC but not enough science”*
- *“The environment of the biotech cluster in Vancouver is similar to that in the mining industry in Vancouver when the Vancouver Stock Exchange was still operating.”*
- *“Vancouver is used to high risk with unpredictable outcomes. There are a lot of angel investors because of this dynamic”*

An analogy serves to illustrate the cluster: consider a garden in Vancouver (with the backdrop of mountains and sea!). The soil is the university environment, predominantly UBC. The seeds of ideas germinate in the soil there, watered by funding from the federal granting councils. The plants grow fertilized by funding from venture capitalists. There is some cross-pollination from BCBiotech and more water from federal R&D support to companies (IRAP funding and R&D tax credits). Few of the flowers live long enough to mature and go to seed, and generate new plants – most are picked while they are still blooming and are carried off by passers-by, large multinational pharma companies, who want to have the flowers in their homes[6].

Observations and Analysis

Over the past decade there has been a stream of new companies being spun off from one or other of the research facilities. 1991 was an exception, which possibly coincided with the sharp downturn in the stock market. This trend stopped two years ago – again perhaps because of the downturn in the stock market and the parallel decline of dot-com companies. But this may not be the only reason - one respondent said:

“*There are a lot of genetic disease spin offs that are making good money but there isn't enough science coming out of UBC so there is currently a slow decline of spin off companies.”*

As seen in Figure 1, the rate of biotech start-ups over the past decade has varied widely. There are no obvious reasons for this time variance – from 1992 until 2001 the stock market’s appetite for initial placement offerings (IPOs) was insatiable. What causes the flow of intellectual property from the universities (particularly UBC) to vary so greatly? Are the sudden changes spin offs due to market conditions, or to other factors? It is probable that the decline of spin-off companies from UBC since the mid 90s can be attributed to:

- Not enough money to support new companies (high-tech bubble burst).
- Saturation of the market: there are too many one-product/technology companies.
- Venture capitalists concentrating their money in already existing companies, trying to keep them alive.

Companies spun off from university research labs appear to be a particularly effective means of technology transfer out of universities (Rogers, et.al, 2003). Since 1995 SFU

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[6] I am indebted to Monica Salazar for developing this analogy. It is left to the reader to determine the nature of the weeds and other pests usually found in my garden!

and UBC have together spun off 81 companies, of which 51 (63%) are still in existence. Of the 81, 26 were in the bio tech area and of these 19 (73%) are still in existence (Clayman and Holbrook, 2003). In this admittedly limited sample, biotech firms were a much larger than expected subset of the spin-offs and were more likely to succeed.

The importance of these spin-offs in the cluster leads to another question – is one explanatory factor of the observed difference in spin-off formation between the two major universities – UBC and SFU? UBC has a medical school, and SFU does not, which, for this sector is a major element as a driver and user of innovations. This division is emphasized by the tight concentrations of UBC spin-off firms around two UBC locations – its main campus and the main teaching hospital. This feature is hardly surprising, but what is interesting is the much wider dispersion of the (admittedly fewer) SFU spin-offs. But the perhaps this is due to their radically different intellectual property policies? UBC retains all rights to discoveries made in its labs, granting only a non-exclusive licence to the discoverer, while SFU gives all intellectual property rights to the discoverer in its labs. In the case of SFU, the University Industry Liaison Office (UILO) acts only as a broker if the individual so desires.

Could UILOs have done better trying to merge individual initiatives and make stronger companies with more than one product in the pipeline? This appears to be a disadvantage for the growth of the companies and the cluster[7]. Of course, part of the problem is that each scientist wants his own company[8]. Possibly firms are spun off too early in the stage of technological development. They can have promising technology/products, but it is difficult to survive in the long term, needing ongoing injection of financial resources without producing results and revenues.

As noted above, there is also the interesting question as to whether Victoria is part of Vancouver's biotechnology cluster? No matter what method of transportation is used, it takes over two hours to travel from one city centre to the other (other than by scheduled helicopter service). Two hours is often taken as the outer boundary for travel time across the geographic area of a cluster. While some argue that information technologies permit the creation of virtual clusters, there are those who argue that innovation is primarily a matter of interpersonal communication (as for example, Antonelli, 2000). Accepting this argument, it is clear that electronic means of communication (even Internet video) have not yet reached the level of acceptance where they can replace physical meetings.

What is clear is that there are many region-specific factors supporting the success of the biotech cluster in Vancouver. Vancouver has world-class university research facilities, but no large, multinational, private sector enterprise. This may have region-specific results in terms of the creation and development of start-up firms. These firms are not dominated (or discouraged) by the presence of a large player in the local cluster, nor are they fed "scraps" of intellectual property from projects that a larger firm might not wish to follow up. Vancouver has always been home to a highly entrepreneurial, risk-taking, financial community, originally established to exploit investment opportunities in the

[7] mentioned by several interviewees, especially consultants and venture capitalists
[8] purposely "his", since there almost no female entrepreneurs apart from Julia Levy of QLT

resources sector – mainly mining, but the resource sector has been all but taken over by large multinational firms. There is an observed abundance of entrepreneurial, risk-taking managerial and financial talent, and like the technical specialists these individuals have elected to transfer their entrepreneurial and intermediary skills to a new sector, rather than move elsewhere. Also, the chartered banks, which do play a role in generating capital for the industry, have S&T investment officers with independent decision-making authority in Vancouver, unlike other regional centres such as Halifax. This itself may be an important factor, and illustrates that national innovation policy should also focus on the established financial services sector, rather than simply assuming that all capital needs will be met through independent venture capitalists.

How then does the Vancouver cluster sustain itself, and remain competitive at the national level, if not globally? The answer seems to lie in the nature of the outputs of the firms – often they never manufacture and market a product, but rather sell the intellectual property (including regulatory approvals and licences) to larger multinational firms for manufacture elsewhere. The Vancouver entrepreneurial environment seems particularly favourable to the creation of firms, and it is the firms themselves (or their major assets, usually intellectual property) that is the final product of the cluster.

By comparison, preliminary results suggest the other two large centers of bio-tech activity in Canada, Montreal (Quebec) and Toronto (Ontario) have quite different characteristics, a result predicted by Table 2. Montreal is home to manufacturing and research facilities of several large multinational firms, induced, in part by the active promotion of Quebec as a research hub by the provincial government, through the use of preferential R&D tax credits. Toronto also has a large bio-tech manufacturing sector, but these for the most part are generic drug manufacturers, who manufacture and market pharmaceuticals and other bio-tech based products whose patents have expired or whose properties are already well known. What all three have in common is a large, world-class university research community, a cosmopolitan community which provides support for all cultures and lifestyles and good transportation links.

Conclusions

This study is a work in progress, which will be extended to include the characteristics of other clusters being studied by other investigators, both those studying the biotech sector in other cities in Canada and other industrial clusters in Vancouver and elsewhere. The commonalities and differences noted above may be specific to this industrial sector. But what is clear is that these similarities and differences do have to be understood, and applied to other centres in Canada. Governments, both federal and provincial, may wish to establish biotech clusters elsewhere in Canada, to make use of local sources of highly skilled labour, raw materials or manufacturing capabilities. But simply wanting to have a biotech cluster establish itself, or survive in the long run without massive, ongoing injections of financial resources into such communities is not enough. There are necessary and sufficient conditions for the establishment of any industrial cluster in a community, and these conditions probably differ from one industrial sector to another.

The major policy issue that underlies this investigation is: what are the necessary and sufficient conditions that support the formation of a biotech cluster in Canada? Are the necessary or sufficient conditions region specific?

What are the necessary (common) features: university, labs, government agencies, private firms, human capital? What are the sufficient conditions (conditions for continued existence)? According to Porter it must include at least one private firm with a global reach. We propose a new test - can the cluster survive the catastrophic loss of a node/actor, such as the closing or transfer of a major industrial facility. Can a cluster survive without certain nodes, whether they be public sector or private sector nodes?

The results suggest that innovation policy must not only focus on public investment in science and technology but also on issues such as venture capital financing, human capital development and the factors that influence the quality of life in a city[9].

The data to date suggest that there is indeed a viable biotech cluster in the Lower Mainland region of BC. There is a strong public sector institution (UBC) at the centre of the cluster, supported by smaller, more specialized, research institutes funded by both the federal and provincial governments. There is a continuous stream of highly qualified researchers coming through the post-secondary education pipeline into the cluster. There are a number of viable enterprises, with sufficiently diverse interests and markets that if one enterprise fails, the viability of the cluster is not immediately put in question[10]. The cluster is constantly evolving, changing as the technology evolves, constantly seeking new market niches.

Unlike the classical definition of a cluster, this cluster is not based on the manufacture and marketing of specific, physical products, but rather on the development of intellectual property. The intellectual property is often first created in one of the public sector institutions, before it is transferred to the private sector through the licencing of the base technologies to a start-up company. Indeed, one can think of the public sector as acting as a catalyst for the creation of spin-offs.[11] These companies develop the intellectual property and bring it to the level where it is ready for production. At this point the BC strategy is to sell its intellectual property, or the company as a whole, to an established biotech manufacturer (big pharma) in some other region.

This process does not fit the traditional cluster model constructed by Michael Porter. The Porter model has two features which narrows the scope of the concept to a large

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[9] The reader should review several of the papers by Richard Florida on this subject; his results, which were based on research in the USA, have been replicated for Canada by Gertler et. al. and can be found at <<www.competeprosper.ca>>

[10] This is a feature of the horizontal nature of the cluster – the firms are not inter-dependent, and act in different technology/market niches.

[11] The Canadian R&D tax credit program is also a major public sector support mechanism, but it is not region-specific, although some provinces "sweeten" the benefits in order to try to attract R&D enterprises. The tax credit/cash rebate provisions of this program also set in place a significant barrier to small privately-controlled firms who are considering the transition to publicly traded status.

manufacturing-based economy with domestically-based multinational companies. Porter's model defines a cluster to be a vertically-integrated agglomeration of enterprises that have a strong domestic market and a significant competitive advantage in the global market. Given that the BC economy is in a transition from a resource-based economy to a knowledge-based service economy, this model may be the successful model for this specific set of economic circumstances.

"*It is recognized that all user-producer (or customer-supplier) relations constituting inter-firms networks must, by definition, involve some degree of vertical integration. Therefore, horizontal is used to describe networks based on other kinds of relations – including, for example, cooperation between rivals or informal know-how trading. This usage, has generated a basic distinction between 'trade' networks with strong vertical aspect and 'knowledge' networks with a strong horizontal aspect*" (Edquist and Hommen, 1999: 73).

In general the BC biotech sector does not manufacture commercial products – its product, if there is one, is intellectual property itself. As a corollary, the cluster is not a vertically-integrated agglomeration, but a loose horizontal association of enterprises who do not compete for market share. We have found this "knowledge network" model to be a viable one. Given that the BC economy is in a transition from a resource-based economy to a knowledge-based service economy, this model may be the successful model for this specific set of economic circumstances.

The rise of contract research organizations (CROs) is a case in point. Canada is a good place for a corporation to carry out research – professional salaries are on average lower than in the US, and there is a favourable tax regime for corporate R&D at both the federal and provincial level. The CROs have few local customers; they make use of the existence of the Vancouver biotech cluster to develop their capabilities and export their knowledge-based services.

Suh (2002), in his description of emerging patterns of innovation networks in Korea linked the emergence of "new technology based firms", mainly small and medium sized enterprises (SMEs), to the economic upheavals of 1997, when the traditional Korean economic system, founded on the *chaebols* was shattered. It is tempting to link the emergence of a regional cluster based on SMEs to the disruption, in a Schumpeterian sense, of the existing economic order in a region, leading to the creation of conditions where radically new enterprises can flourish. This is certainly true for BC – the severe contraction of the resource-based economy in BC due to depressed world commodity prices, trade disputes with the US, natural disasters (forest fires) and high labour wage rates in BC has certainly provided an economic disruption, at the regional level, equivalent to the Asian financial crisis of 1997.

There are several high wage-rate, high educational attainment economies based on resource extraction. These economies are constantly being threatened by competition from lower wage rate (and usually lower educational attainment) resource-based economies. It is tempting to suggest that it is possible for an economy to evolve from being a resource-based economy to a knowledge service-based economy without having to pass through the intermediate stage of being an industrialized manufacturing-based economy. The BC biotech cluster offers, at least, a potential blueprint for this type of transition. Study of this example may well give policymakers insight into the conditions that they may wish to replicate in other jurisdictions and for other industrial clusters. Size does matter – there are probably critical factors, below which cluster activity will not ignite and be self-sustaining, such as population, regional domestic product, access to human resources from outside the region, transportation and communications infrastructure.

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12 See www.utoronto.ca/isrn

13 This document as well as others presented at this conference can be downloaded from: www.business.auc.dk/druid

14 This document as well as all working papers presented at the annual conferences of the Innovation Systems Research Network -ISRN, can be downloaded from: www.utoronto.ca/isrn

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Appendix "A"

OECD biotechnology definition (provisional)

Summary of the Second Ad Hoc Meeting on Biotechnology Statistics

The second ad hoc biotechnology statistics meeting, set up under the aegis of the National Experts on Science and Technology Indicators (NESTI) group, was held in Paris 3-4 May 2001. Nineteen Member countries as well as the European Commission and BIAC participated: in total 35 Delegates and six members of the Secretariat.

This was the second ad hoc meeting; the first was held in March of 2000. Five new countries were represented this year: Iceland, Ireland, Italy, Germany and Norway. Key issues addressed at this meeting included the establishment of a statistical definition of biotechnology, the presentation of a statistical compendium on existing national statistics and a review of alternative methodological approaches taken by countries to measure this activity.

Main Outcome

A provisional single definition and a list based definition of biotechnology were adopted. At the first ad hoc meeting it was agreed that both a single definition -- based on a set of words along the lines used in many countries-- and a list based definition -- based on a list of biotechnology processes/technologies-- were needed. These two different definitions would be useful for statistical data collection.

At the first ad hoc meeting a small working group was established to try and >reach an agreement on a single and a list based definition. This group, in >conjunction with the Secretariat of the Working Party on Biotechnology, developed both a single and list based definition. Both were then circulated to the different groups for comment, revised, and the resulting definitions were presented at the second ad hoc meeting. Debate on this issue led to an agreement on the definitions of biotechnology listed below.

The provisional single definition of biotechnology is as follows:

"*The application of S&T to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services*."

The list based definition is based on the following five categories:

1. DNA (the coding): genomics, pharmaco-genetics, gene probes, DNA sequencing/synthesis/amplification, genetic engineering.
2. Proteins and molecules (the functional blocks): protein/peptide sequencing/synthesis, lipid/protein engineering, proteomics, hormones, and growth factors, cell receptors/signalling/pheromones.

3. Cell and tissue culture and engineering: cell/tissue culture, tissue engineering, hybridisation, cellular fusion, vaccine/immune stimulants, embryo manipulation.
4. Process biotechnologies: Bioreactors, fermentation, bioprocessing, bioleaching, bio-pulping, bio-bleaching, biodesulphurization, bioremediation, and biofiltration.
5. Sub-cellular organisms: gene therapy, viral vectors.

The initial function of the single definition was to serve as a reference for simple data collections. However it is preferable to include the list based definition, or its main headings, in the guidelines as well, to help respondents fill in the survey and to ensure that the data collected are internationally comparable.