1 Introduction

The Canadian government has issued a number of declarations in recent years that it seeks to make Canada a world leader in life science research, development and commercialization. To that end, the federal government has produced a series of strategy and policy statements in support of science and technology, created a number of new institutions, and refocused a variety of existing science programs to nurture public and private investment in a wide range of projects in the life sciences, including the plant, animal and microbial kingdoms. Ultimately, the goal of this effort and these investments is to create new technologies, new products and new services that will generate economic activity, higher skilled and paid employment in Canada and a higher quality of life for Canadians.

Given the intensity of rhetoric and effort, it is worth asking a few basic questions about this strategy. This paper addresses four basic issues. First, is this focus on life sciences, often called the “knowledge” economy, appropriate for Canada? Second, what benefits (and costs) will the knowledge economy, and particularly the life science sector, generate? Third, how confident are we that Canadians will gain from such investments? Fourth, if the focus is appropriate, what is the best way of achieving the goals?

2 Is a focus on the life science knowledge economy appropriate in Canada?

Canada has been among the most prosperous and advanced economies in the world, ranking in the top tiers of the UN World Development Index and offering its citizens one of the top per-capita incomes of any nation. Much of our historical success has been credited to our capacity as a “hewer of wood and drawer of water.” As Innis (1956) has written, much of our economic history and current competitive position in world markets is fundamentally based on natural

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resources above, on and below the soil. In economic terms, our natural resource factor endowments have determined the nature of our modern economy. The succession of resources that could be exploited—beginning with the Portuguese, Spanish and French fisheries and proceeding through the fur trade, the wheat economy, the lumber industry and finishing with the exploitation of our mineral and energy resources—both have defined our national structure and provided the base for our prosperous life-style today.

The global knowledge explosion and extensive trade liberalization after the Second World War, however, challenged Canada’s comparative advantages in many of our traditional sectors. In the industrial economy, land, labor, and capital were the key assets for growth. Drucker (1994) has argued that “the basic economic resource—‘the means of production,’ to use the economist’s term—is no longer capital, or natural resources (the economist’s ‘land’), nor ‘labor.’ It is and will be knowledge.” It appears, as Grossman and Helpman (1991) argue, that comparative advantage is becoming endogenously generated and evolving over time. As the rate of innovation accelerates, the possibility of firms, sectors or areas losing existing, or gaining new comparative advantages, increases.

In the knowledge economy, the key asset is innovation—the ability to develop new ideas, products, and organizational structures by combining existing ideas, products and structures in new ways. Most advanced industrial economies, including Canada, have reoriented in the past few decades around technological change and innovation. Producers in all sectors of the economy, but particularly sectors facing new technological competition, have recognized that the long-term threat to their livelihoods is their ability to generate returns on land, labor and capital that are commensurate with returns in other sectors locally or globally. Ultimately, the Canadian resource sector must deliver productivity gains at least equal to other domestic sectors or mobile resources (skilled labor, capital and improved land) will be bid away.

While the technological imperative is not necessarily a new feature—waves of change involving machinery, chemicals and business processes have swept through the life science part of the economy in the past—the acceleration of science since 1985 has fundamentally altered the challenge. With the advent of new molecular techniques—genomics, gene isolation, transgenics, proteomics and other genetic engineering tools—the competition to keep ahead, or even abreast of others, is intensifying. While many recognize the imperative to invest heavily in the knowledge economy, the path to success is uncertain. In the first instance, most research efforts do not successfully deliver new, commercially attractive products, technologies or services. One rule of thumb many use is that only about 10% of efforts yield inventions that warrant patenting, of which only 10% are commercialized and only 10% of those are big winners. Hence, less than 0.1% of research makes a big impact on the economy and society.

Furthermore, there is ample evidence that new, transformative products, technologies and services exhibit significant evidence of imperfect structures and markets. While there is a wide disparity of scale and scope of research in different sectors and different regions around the world, there is no significant evidence that larger research programs are relatively more successful in
primary research than smaller centers. Research results exhibit some of the characteristics of lotteries, where there are big winners and lots of losers but you cannot win if you do not play. More importantly, however, there do appear to be significant economies of scale and scope when it comes to the development and commercialization of new products, technologies and services. In the first instance, all commercially successful products, services and technologies are protected through some package of intellectual property (often using a combination of trade secrets, patents, trademarks, regulatory barriers and contracts) and exploited in a way to recoup as much as possible of the capital invested in the research and development process. Thus, returns from such research tend to accrue first to the developers, then to early adapters and eventually to late adopters and consumers. For that reason alone, some governments are concerned about being developers and adapters and not simply adopters and customers.

Meanwhile, many of the functions needed to be successful in taking new ideas, reducing them to practice and getting them to markets appear to be linked to scale, experience and, increasingly, networks. In the past there was the view that large integrated companies, such as ConEdison and Hewitt Packard, were the optimal institutions for successful commercialization, with the result that products markets were relatively static and not overly competitive. Increasingly these functions are tending to be outsourced or shared within an industry, which leads to agglomeration of this activity in a relatively small number of well-defined regions, which have specific specialization in a range of applications. For example, Silicon Valley is the centre of computer programming and chip technology development, Boston Route 128 has had significant success with mainframe computers and biopharmaceuticals, Montreal is a hub for a range of bio-pharmaceuticals and Saskatoon has become the hub for global oilseeds biotechnology research. This level of concentration attracts the attention of governments, as they seek to become leaders in specific fields, using their investments in universities, public labs, infrastructure and joint ventures with private firms to attract new actors and lock-in to their jurisdictions existing actors and investments.

The confluence of these pressures has caught the attention of governments around the world. After about 1980, most governments retrenched from proactive industrial policy, preferring instead to accept the advice of economists to create the monetary, fiscal and regulatory environment conducive to long term growth. With the advent of new science, which has triggered a shift in traditional comparative advantages and emergence of new global competitors, all governments now are actively testing new policies, programs and initiatives in an effort to attract and lock-in as much of this new activity as possible. While the imperative has been recognized, and lots of activity has been forthcoming, it is not at all clear yet how effective this new, proactive approach has been, is, or will be.
3 What are the potential benefits and costs of knowledge-based, life science research?

Approximately 40% of the world’s market economy is now based upon biological products and processes (Gadbow and Richard, 1990). Although biological knowledge has been used in the economy for centuries\(^1\), since 1973 modern Mendelian plant breeding, in particular, has been increasingly influenced and driven by new molecular biology techniques. Knowledge and technologies flowing from innovations in the basic science of biology—usually categorized as ‘biotechnologies’—have had a profound influence on how that portion of the economy has developed and will continue to be important for the future development of the industry. Genomics research takes us to the next stage, enabling us, for the first time, to grasp the language of life and to understand, for example, the tiny genetic differences that determine the productivity of a plant, animal or microbe and, above all else, human vulnerability to diseases and stressors. Friesen (2000), Chairman of Genome Canada, has argued that “...[b]y fully understanding genes, we will be able to improve diagnosis of diseases, detect genetic predispositions for certain diseases and develop new medicines.” Perhaps more importantly for our nation, genomics research could also lead to new energy sources (biofuels), to disease, insect, drought and environmentally resistant crops, more nutritious products and, ultimately, healthier, more productive farm animals. Furthermore, this technology can be used to solve forensic mysteries and to save endangered species.

Ultimately these new technologies will lead to an array of new research efforts, new production methods, new products and new services, which will generate benefits in the research system, to producers of traditional and new products and, ultimately, to consumers. It is worthwhile to discuss how each may benefit. The conventional economic view is that yield-enhancing research ultimately benefits consumers more than producers because the expansion of supply lowers prices, which transfers many of the gains to consumers. Quality-enhancing innovations (such as GoldenRice, new therapeutics and novel foods), in contrast, tend to provide greater benefits to the production system because prices usually rise due to a trade-off between yield and quality and because consumers are often willing to pay more than before (Alston et al., 1998). Increasingly, however, the gains to both traditional producers and consumers need to be shared with inventors (who control unique intellectual property). The scale and distribution of the benefits, both among producers and consumers, and between countries, depends on the context for the inventions and the degree of competition in the input and output markets.

Moschini and Lapan (1997) developed a theoretical argument that with private use of IPRs and drastic inventions—that is, one that is absolutely superior to and ultimately replaces all existing technologies (such as a new crop variety that is resistant to all pathogens)—most of the benefits of new inventions would

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\(^1\)One of the oldest large-scale applications of biotechnology by industrial societies was the cleansing of wastewater through microbial degradation in the 19th century (OECD, 1999).
go to consumers. They argue that the innovator will need to price the tech-
ology lower to get producers to adopt the technology, which producers then
do, which causes the product output supply to expand and prices in output
markets to fall, ultimately shifting much of the benefit to consumers. But for
non-drastic inventions—that is, where the invention is better than most but
not absolutely superior to all existing technologies (such as human insulin or
Roundup Ready crops)—the main beneficiary is the inventor or holder of the
intellectual property rights. In this circumstance, the owner of the technology
will price their invention where users are almost indifferent between the existing
and new technologies, so that output consumed stays relatively constant and
product prices remain steady. As a result, the innovator captures most of the
benefits.

While economists generally accept these conclusions, governments and con-
sumers want to see evidence of the distribution of benefits and costs. So far,
most of the analyses concerning GM products and genomics have been par-
tial, mostly focused on agri-food technologies and products (e.g., Marra, 2001;
Kalaitzandonakes, 2003; Alston et al., 1998; Phillips, 2003). The applied studies
of yield enhancing inventions so far show that a significant portion of the bene-
fits go to consumers. Most analyses are similar, estimating that consumers gain
from 10% to 75% of the net benefits of technologies that make existing produc-
tion systems more competitive. The difficulty is that the gains come in almost
invisible increments, often amounting to a minor fraction of any purchase. As
such, while the overall consumer share of the benefit is large, it is usually over-
lowied or discounted in most advanced industrial economies. Moreover, this
benefit is shared wherever the good is sold and consumed, which means that for
many of these products a large share of the benefit accrues to importing coun-
tries around the world. There has been less comprehensive work on genomic
innovations targeted on health care, forestry and fishing. Most of that work has
been focused on issues such as the deleterious impact of private property rights
on uptake and use of specific medical advances (e.g., Myriad Genetics’ patented
BRACA 1 and 2 genes).

Although governments are interested in the theoretical distribution of ben-
efits among consumers and producers, they are particularly concerned about
capturing a share of the benefits in their jurisdiction. Recently, economists
have observed that in knowledge-based sectors, knowledge spillovers are often
locationally tied. Where this happens, there may be a possibility to create lo-
cal capacity that attracts research investments, which if successful may put a
jurisdiction on a higher growth path (Grossman and Helpman, 1991). Zucker
et al. (1998) concluded that local agglomerations of public sector and university
research ‘stars’ helps to create those conditions, attracting clusters of private sec-
tor activity around the core. Phillips and Kahachatourians (2001) and Phillips
(2003) documented that phenomena in the Canadian and global canola sector
in recent years. Given the unevenness of many research programs and the po-
tential for increasing returns to scale from R&D clustered in a few locales, those
countries that are able to attract corporate research programs often gain some
long-term economic development benefits. In the first instance, they can capture
a large share of the investment and jobs in development of a new technology or variety. More importantly, perhaps, they can also capture early adopter benefits if the research results are commercialized locally. Thus, public organizations have proactively used public money and their capacity to undertake long-term research to develop foundational, non-excludable innovations (from which the benefits are not expected to be privately appropriable) in order to provide a base for attracting private research, development and commercialization.

While much of the discussion about supporting innovation focuses on seeking and capturing benefits, new technologies inevitably have a downside. Although gross annual returns of biotechnology applications appear large, it is necessary to consider the costs of developing the innovations and any externalities of adopting the technology. A longitudinal assessment of the adoption of herbicide tolerant canola in Canada concluded that although the gross annual returns after introduction were large, the gross investment by the industry was only recovered in the seventh year of adoption and even then industry had not recouped the value of pre-existing chemical markets that were cannibalized by the new technology (Phillips, 2002). There are also possible externalities of introducing new GM varieties into a market. Losses caused by co-mingled supplies (e.g., in the organic or wheat markets) or, alternatively, the investments made to segregate supplies (GM free soybean and corn markets), must be included in any cost-benefit analysis of new products. As few of those costs are borne by innovators, there will be a continued public debate about how new GM products can be made to benefit society as a whole, and not simply corporate innovators. Finally, one must keep in mind, that once a product is extensively adopted, innovator returns are often reassigned to the home countries or regions of the innovators and their shareholders, which in the life science sector, are located almost exclusively in the US or European Union (EU).

4 Are Canadians receiving any benefits yet?

Canada would appear to be well positioned internationally in the life science field, as it ranks second behind the US in the number of biotechnology firms operating and accounts for almost 10% of the world’s biotechnology-related revenues (Genome Canada, 2004). These accomplishments suggest returns come in a number of ways.

At the product level, the evidence of net returns to Canada is mixed. Most of the analysis has focused on the key GM foods that have been commercialized in the past decade. Recent studies on Bacillus thurengensis (Bt) corn, Bt cotton, Roundup Ready soybeans and herbicide-tolerant canola show that gross returns can be variable, depending critically on weed pressures or insect infestation rates (if the infestation rates are low, returns will be low) (Carpenter and Gianessi, 2001). While some productivity gains have been observed, producers also lose due to lower market prices caused by increased productivity and supply. Some (e.g., Kalaitzandonakes, 2003) argue that the relatively low estimates of impacts may underestimate farmer returns as many of the reported benefits
(e.g., ease of use and reduced risk) have yet to be quantified. Regardless of the size of the benefits, the distribution among producers will not be equal, because farmers with different locations, farm structures and management capacity will gain differently. In the first instance, those producers who adopt the new technologies have a greater opportunity to gain. Studies have shown that early adopting producers tend to gain up to one-third to one-half of the benefits. Late adopters often neither gain nor lose, as any productivity gains are offset by lower prices, caused by greater supply. Non-adopters unambiguously lose, as they face lower prices without any compensating rise in productivity. Many of these non-adopters are smaller, less well capitalized farmers, often in depressed regions in developed or developing nations, which often raises concerns about the plight of farmers and rural agrarian regions of the world.

Canada’s share of the total returns is ultimately limited by its adoption of the technology and by its small market. Over the first 11 years of commercial cultivation, 21 GM crops were planted on more than 577 million hectares by more than 10 million producers around the world. Three main crops—soybeans, maize and canola—made up virtually all of the total acreage planted to GM crops in Canada over the period (cotton is the only other globally significant GM crop). While 22 countries have produced one or more transgenic crop, the USA, Argentina, Canada and China accounted for more than 90% of the acreage so far, with Canada accounting for about 5% of total acreage (while Canada accounts for almost all of the GM canola produced, it contributes relatively little to cultivation of GM corn, soybeans or cotton). As noted, our net returns are a function of the number of producers adopting and the rate of adopting. Similarly, we are limited by the number of consumers using the new products. Given that Canada has only about 3% of the world’s population (albeit a larger share of global purchasing power), our share of the consumer benefits is undoubtedly diluted by our size.

There is more evidence that we are capturing some of the benefits in our extensive life science research and commercialization industry across Canada. BIOTECanada (2001) reports that the industry is broken into seven different sectors: food processing (13%), bioinformatics (3%), aquaculture (3%), environment (9%), natural resources (3%), agriculture biotechnology (17%) and human health (52%). Statistics Canada’s (2001) survey of the biotechnology industry by province offers some insights (Table 1).

Recent research in the SSHRC-funded Innovation Systems Research Network has identified seven life science clusters in Canada, representing a wide range of size, scope, foci and histories, which on the evidence available appear to be growing faster than other parts of the economy (Table 2). While Montreal, Toronto/London, Ottawa and Vancouver are clearly leaders in absolute terms, Saskatchewan appears to have carved a smaller but profitable niche.

The Vancouver cluster, which focuses largely on biomedical biotechnology, is in essence a research community led by the University of British Columbia (UBC) at the core. The UBC (and to a much lesser extent SFU) is the home to almost 80 research stars who produce a wide array of intellectual property. While there have been some spin-offs from UBC (over two thirds which sur-
Table 1: Biotechnology in Canada, 2001

<table>
<thead>
<tr>
<th>Province (region)</th>
<th>No. of companies</th>
<th>Biotech revenues (millions)</th>
<th>R&amp;D investment (millions)</th>
<th>Employment in Biotech</th>
<th>Products in the pipeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic*</td>
<td>23</td>
<td>20</td>
<td>14</td>
<td>1,500</td>
<td>139</td>
</tr>
<tr>
<td>Quebec</td>
<td>130</td>
<td>1,500</td>
<td>349</td>
<td>31,054</td>
<td>11,072</td>
</tr>
<tr>
<td>Ontario</td>
<td>101</td>
<td>1,400</td>
<td>395</td>
<td>7,141</td>
<td>2,376</td>
</tr>
<tr>
<td>Manitoba</td>
<td>37</td>
<td>121</td>
<td>30</td>
<td>3,500</td>
<td>2,346</td>
</tr>
<tr>
<td>Saskatchewan</td>
<td>26</td>
<td>20</td>
<td>10</td>
<td>5,272</td>
<td>167</td>
</tr>
<tr>
<td>Alberta</td>
<td>40</td>
<td>122</td>
<td>118</td>
<td>719</td>
<td>131</td>
</tr>
<tr>
<td>British Columbia</td>
<td>91</td>
<td>414</td>
<td>420</td>
<td>15,049</td>
<td>1,789</td>
</tr>
<tr>
<td><strong>Total in Canada</strong></td>
<td>375</td>
<td>3,597</td>
<td>1,336</td>
<td>64,235</td>
<td>18,020</td>
</tr>
</tbody>
</table>

* Includes PEI, NS, NB and Nfld.
** Numbers do not equal due to multiple sources used.

...vived five years), the prime focus of the cluster is on developing IP rather than products.

The Saskatoon cluster is an almost pure agricultural-life science cluster, with a core focus on oilseed crops. While the university is the home to the largest number of researchers, many of the stars and much of the IP that is developed and used comes from the federal labs. The National Research Council Plant Biotechnology Institute, the host of many research collaborations, and the Agriculture and Agri-Food Canada research centre appear to share leadership with the local industry association—Ag-West Bio Inc. While the cluster is research focused, it has had significant success commercializing world-first GM plants, vaccines and inoculants. Recent public investment in the University, the Canadian Light Source Inc. and various genomics projects has the potential to change the direction of the cluster over coming years.

London, Ontario, has been identified as having an established biomedical devices competency which started in the 1970s. However, there is currently an ‘early stage’, emerging life science cluster (with a focus on biopharma applications). The research efforts under Innovation Systems Research Network (ISRN, www.utoronto.ca/isrn) have focused largely on how it is emerging. It is not yet clear whether London has, in fact, a distinct life science cluster or whether the London-based activity is merely a ‘cohort’ of the Toronto cluster.

The Toronto cluster is a two part cluster with one part dedicated to core life science activity and the other to biomedical devices technology. The region is anchored by the Medical and Related Sciences (MaRS) Discovery District while both the University of Toronto and the Health Network have been identified as primary knowledge generators. Preliminary observations suggest that although knowledge production is key in the region, there is not a substantial amount...
**Table 2:** Comparison of Canadian life science-based clusters

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Focus</th>
<th>Core actor(s)</th>
<th>Interviews conducted</th>
<th>Stars</th>
<th>Preliminary observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vancouver</td>
<td>life science</td>
<td>UBC</td>
<td>50+</td>
<td>80</td>
<td>• producer of IP, not products</td>
</tr>
<tr>
<td>Saskatoon</td>
<td>Agricultural biotechnology</td>
<td>NRC-PBI</td>
<td>60</td>
<td>45*</td>
<td>• research-based cluster</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• new investments in genomics, CLSI and U of S may change direction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• early stage life science cluster</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• unclear whether an independent cluster or merely part of Toronto cluster</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• transportation considered a weakness</td>
</tr>
<tr>
<td>London</td>
<td>life science / biomedical devices</td>
<td>UWO, Robarts Research Institute and Lawson Health Research Institute</td>
<td>40</td>
<td>5</td>
<td>• 40+ research institutes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• 18,000 people employed in life sciences</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• 15—20 spin-offs</td>
</tr>
<tr>
<td>Ottawa**</td>
<td>Biomedical and biotechnology</td>
<td>Gamma Dynacare (OLSTP)</td>
<td>100+</td>
<td>6</td>
<td>• 40+ research institutes</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>• 18,000 people employed in life sciences</td>
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<td>• 15—20 spin-offs</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• concentrated in Toronto at exploration stage; move to peripheral regions (i.e., Etobicoke) at exploitation stage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• limited network coherence</td>
</tr>
<tr>
<td>Montreal</td>
<td>Pharmaceutical and biotechnology</td>
<td>MaRS Centre, U of T and the Health Network</td>
<td>N/A</td>
<td>47</td>
<td>• provincial government leads in terms of progressive policies</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• 15 spin-offs from the University of Montreal</td>
</tr>
<tr>
<td>Halifax</td>
<td>Pharma, health, nutraceuticals, IT and biomedical</td>
<td>none</td>
<td>40 min.</td>
<td></td>
<td>• mixed bag of firms/ little product focus</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• not clearly a cluster</td>
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<td></td>
<td></td>
<td></td>
<td>• weak networks</td>
</tr>
</tbody>
</table>

*Niosi and Dalpe (2003) calculated the number of stars. This number includes stars from across all three Prairie provinces. Note: Star breeders are not included in this figure which has significant implications for the Saskatoon based cluster. One would assume that this number would be considerably larger if breeders were included.


of intellectual property that is protected or exploited. There is a core concentration of companies situated downtown as well as a concentration of skilled workers in peripheral regions, making the cluster the fourth largest biomedical centre in North America. It has also been suggested that Toronto, however, has a profile problem when it comes to life science because it lacks any large, successful locally-generated firms that could serve as a ‘branding’ mechanism for the region. While the U of T has a significant number of stars, it has historically been considered unsuccessful in facilitating spin-offs. This has been attributed to the lack of recognition of commercial potential of knowledge in the life science sector. Some survey respondents report that the region is risk averse in terms of investment in life sciences—there is a large pool of investment resources in the region but there is a noted lack of expertise in terms of financing life sciences.

While there appears to be a large number of research institutes in Ottawa and a large number of people employed in the life sciences (by one estimate 18,000), Ottawa’s identifiable life science cluster is quite small. As of 2002, there were only 47 actors (30 small biotech firms, 6 government labs, 1 connected university and 10 service/support organizations). The cluster employed approximately 650 individuals at that time and some reports suggest it has declined with recent relocations of activity to Montreal. Only two of the Ottawa-based firms had actually generated patents by 2002 and the University of Ottawa had only a few stars and limited success with patents (11 as of 2002). While there appear to be many spin-offs, there is limited evidence that they will be sustainable.

Both the Statistics Canada (2001) and ISRN² data suggest Montreal has the largest identifiable life science cluster in Canada. Like Toronto, Montreal appears to have a two part regional focus—in this case large pharmaceutical and small biotechnology firms. Niosi and Dalpe (2003) identified 351 actors in Montreal (130 human health, 26 human nutrition, 12 agricultural biotechnology and 7 environmental firms; 171 service and supporting enterprises; 1 government lab and 4 related universities). As of 2002, 29 firms in Montreal had 234 locally-invented patented technologies. Eighty-nine percent of those were owned by the eight largest firms. This represents a huge growth in the region from 1999, when only 14 firms had 66 patents in total. Montreal benefits significantly from provincial programming and national research labs.

Based on evidence available to date, Halifax does not have a cluster based on the traditional definition of the concept. The region consists of a ‘mixed bag’ of firms with little or no market focus. Actors are not focused on any specific technology or product application. Rather some actors are involved in the health sector (devices, pharmaceuticals, information technology and nutraceuticals) while others work on horticulture, environmental applications and food quality. Most firms were established in the 1990s or later and there is currently no obvious anchor firm or organization. Firm-based strategies so far appear to be focused on solvency and expansion rather than collective action or interaction. Thus, actors in the region are loosely connected. There are two main trade associations within the region but so far the community remains a group of

²www.utoronto.ca/isrn
loosely connected actors. In contrast to most other clusters, there has been little or no investment in infrastructure in the past few decades (some report that the most recent major investment was the Tupper building in 1968).

Attempting to compare and contrast these seven clusters in any quantitative or qualitative way is extremely challenging. There are significant differences in terms of size (Montreal vs. Saskatoon), market focus (core biotech in Vancouver versus medical devices in Toronto), and cohesion. Although life science based industries have certain cognate “deeper science” similarities, they differ in terms of industrial organization. Irrespective of how we measure them, however, the sheer size of the life science sector and its visible presence in seven urban centers whets the appetite of economic developers and policymakers across Canada.

5 How can Canada optimize the anticipated benefits of genomics?

While Canada has had some success accelerating its life science capacity—in 2003 Canada stood sixth in the world in terms of the publication of scientific papers and second in terms of patenting activities in the US (Observatoire des Sciences et des Technologies, cited by Genome Canada (2004))—many governments and agencies are not satisfied and are seeking to expand our capacity further. In support of this, the federal and many provincial governments have engaged in significant policy development and supported a range of new investments to support the development of life science research, development and commercialization.

The National Biotechnology Strategy begun in 1982 was renewed and updated in the late 1990s. In 1998, the federal government released the Canadian Biotechnology Strategy, which has formed the basis for all subsequent federal government action. The vision in the updated Canadian Biotechnology Strategy was “to enhance the quality of life of Canadians—in terms of health, safety, the environment and social and economic development—by positioning Canada as a responsible world leader in biotechnology.” The strategy proposed to realize that goal by: modernizing the regulatory system; supporting cutting-edge R&D; increasing access to investment capital; strengthening Canada’s intellectual capital (at least partly by updating patent laws); engaging Canadians directly in shaping relevant policies; and creating highly qualified human resource capacity in the country. Various committees were also established to oversee the development and implementation of the broad policy issues associated with biotechnology. The most notable of these was the Biotechnology Ministerial Coordinating Committee (BMCC), which included the ministers of Industry, Agriculture and Agri-Food, Health, Environment, Fisheries and Oceans, Natural Resources and International Trade. The Canadian Biotechnology Advisory Committee (CBAC) was also created to provide external advice to government. The most significant new initiative of the federal government is the announcement in 2007 of the national science strategy (Government of Canada, 2007),
Table 3: Genome Canada (GC) investments in products as of November 26, 2007.

<table>
<thead>
<tr>
<th>Sector</th>
<th># Projects</th>
<th>% total</th>
<th>GC Funding</th>
<th>% total</th>
<th>Total Funding</th>
<th>% total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>8</td>
<td>7%</td>
<td>$36.3</td>
<td>6%</td>
<td>$133.8</td>
<td>9%</td>
</tr>
<tr>
<td>Bioinformatics</td>
<td>1</td>
<td>1%</td>
<td>$12.5</td>
<td>2%</td>
<td>$26.9</td>
<td>2%</td>
</tr>
<tr>
<td>Development of New Technology</td>
<td>3</td>
<td>3%</td>
<td>$14.5</td>
<td>2%</td>
<td>$30.6</td>
<td>2%</td>
</tr>
<tr>
<td>Environment</td>
<td>4</td>
<td>3%</td>
<td>$14.5</td>
<td>2%</td>
<td>$29.0</td>
<td>2%</td>
</tr>
<tr>
<td>Fisheries</td>
<td>3</td>
<td>3%</td>
<td>$19.5</td>
<td>3%</td>
<td>$39.6</td>
<td>3%</td>
</tr>
<tr>
<td>Forestry</td>
<td>6</td>
<td>5%</td>
<td>$30.1</td>
<td>5%</td>
<td>$63.1</td>
<td>4%</td>
</tr>
<tr>
<td>GE3LS</td>
<td>9</td>
<td>8%</td>
<td>$16.7</td>
<td>3%</td>
<td>$33.4</td>
<td>2%</td>
</tr>
<tr>
<td>Human Health</td>
<td>71</td>
<td>62%</td>
<td>$402.9</td>
<td>63%</td>
<td>$942.2</td>
<td>66%</td>
</tr>
<tr>
<td>Sub-Total, Projects</td>
<td>105</td>
<td>91%</td>
<td>$547.0</td>
<td>85%</td>
<td>$1,298.6</td>
<td>91%</td>
</tr>
<tr>
<td>S&amp;T Platforms</td>
<td>10</td>
<td>9%</td>
<td>$95.0</td>
<td>15%</td>
<td>$126.0</td>
<td>9%</td>
</tr>
<tr>
<td>Total (Projects &amp; Platforms)</td>
<td>115</td>
<td>100%</td>
<td>$642.0</td>
<td>100%</td>
<td>$1,424.6</td>
<td>100%</td>
</tr>
</tbody>
</table>

Source: Genome Canada special tabulation, as at November 26, 2007 (in millions of dollars)

through which it has been slowly reconciling the priorities of the science and technology funding agencies.

In support of its policy, the federal government allocated significant resources to biotechnology and genomics research over the past few years. In recent years the federal government has invested more than $600 million annually in science and technology expenditures on biotechnology (up sharply from earlier years). One key development was the creation of Genome Canada in 2000. At the beginning, Dr. Friesen, the founding Chairman of the new agency, asserted that its “goal is to improve our overall rating so that we stand second only to the United States within five years.” (Friesen, 2000). Up to the end of 2007, the federal government had allocated $700 million to the new agency, which reports its leveraged more than that from others to pursue research in strategic research areas. In the first three rounds of competitions, Genome Canada awarded $642 million to 115 projects, with the lion’s share directed to health related research (Table 3). Genome Canada launched a planning process in 2007 to plan for a fourth round of investments. Unlike in earlier rounds where the GC investment tended to be small (average of $5.6 million), the new focus is on developing larger, more strategic investment (the first two theme areas are each targeted to receive a minimum of $60 million from Genome Canada).

Shortly thereafter, in 2002, the federal Departments of Industry and Human Resources Development unveiled a new national innovation strategy, that proposed a series of complementary policies and programs, including a strategic effort to develop and nurture 10 world-class economic innovation clusters in Canada by 2012. While this the NRC continues to pursue this strategic goal, the 2007 federal science and technology strategy downplayed some of the specific biotechnology focus and instead announced a preference for more general strategies and policies in support of innovation and entrepreneurship.

Provinces and cities have also been active, particularly embracing the con-
cept of clusters and providing financial, policy and moral support. Virtually all provinces have indicated strong support for genomics-based projects, at times offering automatic matching funding (e.g., Quebec) and at other times integrating existing local and regional capacity with new research.

While interest is high and activity abounds, it is not clear that all of the strategic directions are appropriate or relevant. A brief review of the CBS core targets raises some red flags. While federal regulatory agencies have spent a lot of time and energy examining and reviewing the regulatory system for the life sciences, it has had difficulty converting recommendations and advice into action (Canadian Biotechnology Advisory Committee (CBAC), 2003). The federal government would appear to have had success in accelerating investment in R&D, but the dominant strategy of leveraging private capital, differentially supporting large collaborative ventures and focusing on patentable outputs may impede long-run development (Phillips and Dierker, 2002). While Industry Canada and many of the scientific agencies have identified the need for more investment capital in the sector, market developments actually worked to reduce private placements in the recent years (McDonald and Associates, 2004). Similarly, Canada’s commitment to strengthen its intellectual capital has had mixed results. Recent federal reinvestment in post secondary education (via the Canadian Foundation for Innovation, Canada Research Chairs and various Council programs) has raised human resource capacity, but recent Supreme Court rulings on intellectual property for life science inventions (e.g., Harvard College v. Canada (Commissioner of Patents), 2002; Monsanto Canada Inc. v. Schmeiser, 2004) have muddied the waters about what is or is not patentable in Canada. Finally, while there have been extensive efforts by federal departments and agencies (including CBAC in 1999–2007) to engage Canadians directly in shaping relevant policies, many of those initiatives have not fundamentally altered the nature of our regulation, our investments or public perceptions of the value of the technologies. Clearly, a more rigorous policy analysis of the basis for and performance of these strategic initiatives is called for.

6 Conclusions

The imperative for engaging in the life science economy appears to be well grounded in theory and evidence. Advanced, industrial economies like Canada have little choice. If they fail to develop, adapt and adopt the latest technologies, they face the risk of losing their comparative advantage in traditional industries, which would lead to declining incomes and ultimately a decline in our absolute and relative welfare.

The challenge is that while the imperative may be clear, the path is uncertain. Canada has aggressively positioned many of its policies, programs and institutions to support an innovation agenda, but it is unclear whether it can fundamentally reform its system in a way that will generate better outcomes.
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