Who Is Minding the Store? Innovation Strategy and Agro-Biotechnology Research in Canada*

Alison Blay-Palmer
Department of Geography and Environmental Studies
Wilfrid Laurier University,
75 University Avenue West,
Waterloo, Ontario, Canada N2L 3C5
ablaypalmer@wlu.ca

The merits of basic research for national innovation systems are well-established. It is understood that basic research creates the knowledge, infrastructure and human capital needed to stay at the front of the innovation pack. In the current age of knowledge-based economies experts assert that basic knowledge is critical for sustained economic development as it affords competitive advantage. However, policy shifts in countries such as Canada and the US that tie public research dollars to applied output may be undermining future national innovative capacity. This paper explores these questions using the case of the Canadian agro-biotechnology industry. The research results highlight the role of corporations as a distorting influence on the direction and form of research in Canada. The findings expose tensions between the public good and public policy. They raise questions about the conflicts between on the one hand, the lack of public support for agro-biotechnology and on the other hand, government policy that funds industry defined agro-biotechnology research. The research also raises questions about the wisdom of policy that emphasizes applied over basic research, potentially compromising the future innovative capacity of Canada.

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Basic Research: Why Bother?

Basic research is an essential constituent for future innovation, and is therefore linked to economic prosperity. As a critical component for all other future research – both additional fundamental and applied – basic research is a key economic propellant so that "understandings that come from [basic] science seldom lead immediately or directly to the solution of practical problems. Rather, they provide the knowledge and the tools [including human capital] to wrestle with them more effectively." (Nelson 2004: 457). In pointing to the merits of basic research, Desai (1993) explains: "Both basic and applied research are subject to externalities, and both justify subsidies. But obviously, subsidies will have a much greater effect on the scale of basic research; applied research can survive without subsidies as long as corporations find it profitable" (Desai 1993: 250). The fundamental role of basic research and the national benefits of funding this activity from public money become clear when one reflects on contributions from corporations and universities to innovative capacity. Stanford and MIT exemplify the role that university basic research plays as a foundational to future innovative capacity regionally and nationally. Bell Labs and other companies provide examples of the role that basic research has played in building US innovative capacity over the long-term.

The story of MIT and Stanford provide insights into the role that university basic research plays in national and regional competitiveness. Saxenian (1994), in her now classic book Regional Advantage, compares the rise of Silicon Valley and Boston's Route 128 post-World War II:

> "Researchers at the Massachusetts Institute of Technology (MIT) and Stanford University, as leading beneficiaries of defense and aerospace contracts, spearheaded the economic transformation of Eastern Massachusetts and Northern California. Their pioneering research in radar, solid state electronics and computing created localized pools of technical skill and suppliers that attracted established corporations and supported the formation of new enterprises. Fuelled initially by federal funds, the process of entrepreneurship and technology advance became self-sustaining by the early 1970s and ensured the position of Route 128 and Silicon Valley as the nation's leading centers of electronics innovation and production" (Saxenian 1994: 11).

Gibbons (2000) estimated that Silicon Valley (SV) companies spun-off from Stanford teams and technologies accounted for between 50 and 60 % of SV revenues in both 1988 and 1996. These spin-off companies are born in part from basic research that comes out of the universities, as well as the human assets that make the region more viable and dynamic.

On the corporate side, Bell Labs has been dubbed a US 'national resource'. Innovations including the laser, the Unix operating system, the solar cell, the transistor, coaxial cable, microwave radio, satellite communications, submarine telephone cable and digital transmission methods all emerged from work in Bell Labs (Stoeffels 1998). Bell Labs has two Nobel Prizes in Physics to its credit, and

4 other shared Nobel prizes (Chamberlin 2006). By 1983 the Bell Labs held over 20,000 patents and was publishing over 2,000 technical papers annually. Similar benefits have accrued from other companies, including the Xerox Palo Alto Research Centre, General Electric and Hewlett Packard in the US, Nortel in Ottawa, and initiatives in the EU to fund projects in genome and nanotechnology research (Commission on European Communities 2004; Gibbons 2000; Walko 2003; Chamberlin 2006). Nortel invests over $CDN1billion in its own core R&D. These investments in research shape the Information and Communication Technology (ICT) industry. For example, Nortel and General Dynamics Canada have collectively spun off over 150 companies (OCRI 2005). These benefits should not be treated lightly, as the evidence suggests it is difficult to catch up with countries that have established this kind of competitive advantage (Verspagen 2000; Archibugi and Michie 1997). As Turner, science advisor to former US President Clinton put it, “Once you get off the technology elevator, it is hard to get back on.”

The benefits of basic research are also reflected in industry performance. Scott et al (2001) indicate that substantial economic returns are related to basic research. In reviewing studies that focused on the economic benefits of basic agricultural research, they determined that the rate of return ranged from 20-67 %. In a study aimed at quantifying the impact of basic research in the pharmaceutical industry, Toole (2000) found that increasing the stock of basic research by 1 % created a corresponding increase of between 2.0 and 2.4 % in the number of new products. There is also evidence to support the need for broad-based scientific activity as a stimulus for product innovation over multiple industrial sectors. An analysis of science-based industries in OECD countries revealed that industrial chemicals, pharmaceuticals, office and computing machinery, aerospace and the instrumentation industries all rely on the national generation of strong general scientific research (Laursen and Salter 2002). The economic spin-off benefits of these innovations are obvious, as are the synergies between basic research, human capital and innovative capacity (Pavitt 1991). Keeping in mind the importance of basic research, it is interesting to explore the changing role of firms in the context of globalization pressures.

Firms, Basic Research and Intellectual Property

Despite the clear benefits of basic research, there are three concerns about a dominant role for private companies in its creation. First, the profit focus of corporations and the pressures from globalization means that they are less likely to engage in basic research. Since the 1940s (Bush 1945; Nelson 1959), we have understood that the long timelines and the pervasive nature of basic research results mean that private companies are less likely to engage in fundamental science. It is not in their interests to fund research that has such general applications that companies cannot capture the rewards from their investments. This is particularly the case when competition forces companies to focus on short-term profit horizons. Although companies in North America engage in basic research as a way to attract and maintain the currency of their top scientists (Rosenberg

1990), globalization has pushed them away from business models supportive of this type of innovation. Increased competition and the reorganization of companies into business units and the decentralization of labs mean it is unlikely companies will continue to fund basic research at previous levels (Noll 2003). For example, the divestiture of Bell Labs in 1984 and the creation of the Baby Bells have seriously compromised the basic research momentum for the telecommunications industry. After the first five years of this restructuring, the commitment to basic research had diminished. This was reflected in a one third decrease in the number of researchers (Noll 2003). In the US more money is being spent on development and less on basic research. If we break down R&D spending by US industries in 1998, development accounted for 71.2 %, applied research for 22.3 % and basic research for 6.5 % of overall R&D spending. This is down from the early 1990s when industry funding split out so that 61 % was spent on development and 18 % on basic research (Varma 2002). The basic issue is aptly summarized:

> "…support has shifted to low risk, mission-oriented, and short-term research, and an extensive involvement of business elements in research activities. Basic research projects seem to be completely gone from centralized corporate research laboratories. In the long run, the shift away from the untargeted inquiry can be problematic to the company, as well as to the country" (Varma 2002: 1).

By increasing competition, globalization leads firms to gain short term profits through faster innovation within an existing, rather than a new stock of knowledge (Chesnais and Serfati 1997). As a result of these changes, there are concerns in the US about future innovative capacity and its ability to keep pace with EU and Asian countries (Task Force on the Future of American Innovation 2005). Noll (2003) sees a pending crisis for telecommunications, and suggests that service-providers, suppliers and the government need to combine resources to ensure that the industry remains competitive. Added to the diminished role of core private firms is the shift to suppliers for the development of applied innovations and universities for basic research (Stoeffels 1998). Universities inhabit a special space in the creation of innovation. In the UK, for example:

> "…firms have the comparative advantage in applied research, but what they lack is the ability or the incentives to do the more curiosity-oriented research, which is vital to them in the longer term. For this they depend on the universities and public laboratory system" (Coombs and Metcalfe 2000: 11).

This speaks to the need for government money to fund basic research in its own labs, or in universities.

The second reason to consider the role of private firms in basic research is the potential for private interests to dominate and control platform technologies needed for future innovation. The concentration of ownership and market domination in the agricultural industry is a case in point. Concentration in the agrochemical industry has been increasing substantially since the late 1990s. The three leading corporate groups (Bayer, Syngenta and BASF) would account for approximately half the global market (by 2004 reported sales).

The largest agrochemical companies branched out into plant biotechnology and the seed business, heralding a move towards unprecedented convergence between the key segments of the agriculture market (agrochemicals, seeds, and agricultural biotechnology).

The agricultural biotechnology industry remains one of the most concentrated in the world, with much of the intellectual property in agricultural biotechnology aggregated by a few very large IP [intellectual property] portfolios held by the agrochemical giants (UNCTAD Secretariat 2006:1).

The USDA reported that in the US in 1998 the top four seed companies firms controlled 67 per cent of the corn seed sales; 49 per cent for soybean; and 87 per cent for cotton (UNCTAD Secretariat 2006: 9).

At the same time that this corporate concentration is occurring there is an increase in the number and scope of patents (Nelson 2004). This adds to the potential for corporations to control the direction of research. Although the goal of IP law is to balance the protection and stimulation of invention with the need to circulate knowledge and protect the public good (Doern 1999), it is possible to circumvent licensing requirements and tie up IP. This can limit access to knowledge, create monopolies through licensing and use agreements, or deny access to information or platform technologies. Heller and Eisenberg refer to this as, "tollbooths on the road to product development" (1998: 699). These 'tollbooths' can be so onerous they can derail downstream innovation. Dupont's use of IP – for example, the 'oncomouse' and Cre-loxP (Marshall 2000) – is a case in point. Dupont, in an effort to capitalize on their IP, built into their initial use agreements for the Oncomouse and Cre-loxP – veto rights over the development of new technologies that emerged from work involving their IP. Dupont's goal was "to leverage its proprietary position in upstream research tools into a broad veto right over downstream research and product development" (Heller and Eisenberg 1998: 699; see also Marshall 2000). Clearly then, access to IP is an important consideration for direction of future innovation as the rights of the patent holder/ licensee can take precedence over the desire to disseminate information and the interest of the social good (Gotsch and Reider 1995; Scotchmer 1991; Foray 1995). David (2001) provides an example of the conflict that results from limiting access to IP that may need to remain in the public domain. In his examination of the digital data industry and the European Community's Database Directive, David explains that access to knowledge that belongs in the public domain is under threat:

> "an unchecked bias towards expanding the domain of information goods within which private property institutions and market mechanisms flourish, is steadily encroaching upon the domain of public information. In doing so, it has tended to weaken, and may in the end, seriously undermine those non-market institutions which historically have proved themselves to be especially effective in sustaining rapid growth in the scientific and technological knowledge base that is available to be exploited" (David 2001: 3).

David cautions that an unintended boomerang effect may return to harm those institutions that formulated the laws and policies in the first place as IP protection may deny them access to basic innovations that should be in the public domain.

In the university context, IP ownership and an emphasis on technology transfer have created serious tensions between the responsibility to conduct research and the need to generate profits from technology transfer and licensing. Further, in these cases, the move to increased patenting by universities has not created positive revenue streams except for the top R&D universities (e.g. Stanford, Columbia and the University of California). But in the wake of Bayh-Dole in the US, the emphasis on technology transfer and changing funding expectations, there is evidence that the increased use of IP has shifted the focus of universities more to profit and away from basic scientific inquiry. In the last decades universities have had to move from sharing information to trying to make money (Mowery et al 2004; Nelson 2004). This undermines future innovative capacity (Task Force on the Future of American Innovation 2005).

The final concern about the changing role of firms with respect to basic research and IP is the threat to open science. New patent regimes in the US have expanded what is patentable from the immediately applicable invention to processes that may or may not be part of a broader innovative process. The concern is that this creates a less open research environment in all research institutions as researchers are reluctant to share something that may, down the road, be patentable, and hence have value (Nelson 2004). Nelson is concerned that this trend will ultimately undermine the process of open science and undermine the basic innovation process.

This returns us to the initial discussion and the question of the public good – just who is minding the store? To a certain extent, basic research is socially contextualized and mediated (Gibbons et al 2000; Cooke 2004). Controversy over stem-cell research is an excellent example of society providing input to the scientific community about where the ethical lines get drawn for future research. However, there are more subtle facets of this discussion, including the extent to which companies set national research agendas and the reflection of public priorities and concerns in future research directions. We will examine these challenges using Canadian Innovation policy and a case study of ago-biotechnology research in Ontario.

Canadian Agricultural Innovation Policy and Agro-Biotechnology Research

Since the 1987 Science and Technology policy, Canada has adopted a strong focus on funding economically relevant research (Godin et al 2002). Despite this emphasis, Canada has lagged behind other OECD countries in overall R&D investment (Government of Canada 2004; OECD 2001). In step with US policy over the last fifteen years, Canadian government funding for agricultural research has been largely tied to matching dollars from industry. As indicated in the next section, this threatens to create serious gaps for future innovative capacity in basic research.

This trend contradicts the stated goals of the federal government whose most recent position on the creation of new knowledge through basic research is that:

> "New knowledge needs to fuel Canadian innovation that, in turn, affects every aspect of food and non-food production, changing the way Canadians grow, process, preserve, transport, distribute, and use the products derived from agriculture. In other words, new discoveries and their application are crucial to ensuring Canadian farmers and the Canadian public benefit from Canada's natural advantage, i.e. its ability to produce food and an ever-increasing range of non-food products from the land. Examples of these new applications include new bio-materials, bio-medical and bio-health products, bio-fuels, bio-energy, bio-chemicals, and bio-pharmaceuticals" (AAFC 2006: 1).

Given the desire to stimulate economic benefits through the creation of new knowledge, it is important to understand existing and future innovation capacity to achieve this goal. As a step towards advancing our understanding about this potential, the next section presents results on basic research and innovative capacity for the agro-biotechnology industry in Ontario.

Agro-Biotechnology Case Study

The evidence presented comes from a case study of agro-biotechnology innovators in southwestern Ontario in the springs of 1998 and 2001. Sixty interviews were conducted with innovators in government, private and university research labs. Policy-makers were also interviewed to provide a context for innovation. This section reports on the importance of basic research for agro-biotechnology and provides comments about the role of intellectual property rights in the context of basic research. These observations offer insights about access to corporate controlled IP and the extent to which this affects public innovative capacity.

Recall that basic, curiosity driven research is critical as it leads in new and unexpected directions (Pavitt 1991; Doern 1999; Nelson 2004). This is the case in Canada, as the following examples make clear. In one case, a public research lab inadvertently developed a new biotechnology identification method from an unrelated and unintended discovery. This innovation replaces an existing method that is owned by private interests and that was becoming expensive to access. Although the development of the identification method was not the goal of the public lab's initial research, it produced an innovation that offers all researchers an alternative identification method that is readily available in the public domain. As the key informant explained, having this IP in the public domain means there will be more ready access to this IP; and, that it will be available at a more reasonable cost. This will help to fuel more research and is a clear example of the unpredictable and important spin-offs from publicly-funded, basic research (Rey and Winter 1998; Doern 1999).

The second example of serendipitous innovation is the unexpected creation

TABLE 1 Ownership of Soybean Varieties 1967-1998

Year	Total #of varieties offered by year	# of public varieties listed in Field Crop Trials or OOPSCC trials	# of private varieties listed in OOPSCC trials
1967 - 74	5-9	Up to 9 100 %	0 0 %
1975	10	9 90 %	1 10 %
1986	45	13 29 %	32 71 %
1998	132	13 10 %	119 90 %

Source: Smithers and Blay-Palmer 2001)

of a cold-tolerant variety of soybeans through conventional breeding practices in the 1970s. While engaged in traditional breeding of another trait using germplasm from cold tolerant eastern European plant varieties, breeders at the University of Guelph and the Ottawa AAFC research lab remarked that some of their plants were able to withstand cold conditions better than others. This led to the deliberate breeding for this trait, and the eventual development of a cold tolerant variety of soybeans that enabled soybeans to be grown in eastern Ontario. The two examples of unpredictable research results provide evidence of the merits of basic research to the agricultural industry.

The next part of the soybean story helps to underscore the importance of basic innovations for future innovative capacity and the spin-off benefits for private companies. In this case, the increase in soybean growing area that resulted from the cold-tolerant varieties – soybeans could then be grown across southwestern Ontario to eastern Ontario and into Quebec – attracted the attention of MNCs. The improved commercial viability of soybeans is reflected in the shift in the ownership of soybean varieties between 1975 and 1998 (Table 1). In 1975 90 % of soybean varieties were publicly owned. In a complete reversal, by 1998 only 10 % of the varieties were publicly owned. The development of soybean varieties into the 1990s by MNCs dovetailed with GMO research and resulted in the creation of RoundUp Ready Soybeans. Technical use agreements signed by farmers who purchase RoundupReady soybean seed ensure that farmers will not save their seed to replant the next year. This effectively ties up a market for seed companies as farmers are obligated to buy seed every year from seed companies. As a result, seed companies are able to justify increased investment in R&D for soybeans. Commenting on the creation of the GMO RoundUp Ready soybeans, experts indicated when interviewed that as they can now recoup on their R&D investment through IP, more innovation is occurring for this crop. This point was underlined by comparing research in soybeans and wheat. As one key informant reported, wheat attracts the same level of investment in R&D as soybeans despite the fact that soybeans are grown on only one tenth the acreage. According to one key informant: “there is increased reinvestment in R&D where protection exists”. The case of soybeans underscores the value of this research as a building block in the cumulative innovation process (Nelson 2004).

Expert informants explained that the protection of IP is also imperative for the *continuation* of capital-intensive research and development. But, for example, in the case of biotechnology, this presents interesting challenges as this type of research is largely incremental and cumulative (Horbulyk 1993), where the first discovery establishes a "chain of dependency…in a whole cascade of linked products" (Cassier 2002: 90). So the patenting of core processes and platform technologies increases the cost of developing next generation innovations for other researchers who need to buy access to the new technology (Marshall 2000). Although in Canada public researchers have free access to all technologies for pure research purposes,[1] key informants raised two challenges they deal with on a regular basis. First, just because they have access to a technology does not mean that they understand how to, or are able to, use it. Training or special equipment may be needed to take advantage of previous innovations (Foss 1998). These prerequisites may put the patented innovation beyond the reach of public innovators, blocking further research along that trajectory. Second is the cost of bringing the innovation to the market. The cumulative nature of innovation translates into increased product costs as licensing fees for each step in the process raises the end cost of a product – previously referred to as development tollbooths (Heller and Eisenberg 1998). Looking further down the road to the production stream, one innovator explained that if there are too many licensing and royalty fees to pay, innovators will not pursue a particular research direction (Merz 2000). This prevents research from unfolding along a serendipitous path, and impedes overall innovation, but in particular it slows basic research. This is entirely consistent with concerns expressed about publicly accessible knowledge (David 2001, Nelson 2004). These "technological roadblocks" demand that innovations be created to somehow engineer around these impediments. Key informants explained that in some instances there are positive benefits as new innovations are developed to circumvent existing patents. In many cases though, valuable time and money are wasted as new directions must be explored, developed and tested.

A lack of access to corporate controlled IP occurs as some companies refuse to license technologies for use, or limit access as in the case of the Dupont oncomouse. This then truly blocks innovation (Merz 2000; Cassier 2002). One public innovator explained that:

> It is not always possible to gain access to the best IP or reagents to do the job. Companies often put unreasonable restrictions on access. Public institutions and government laboratories need sufficient resources to acquire or develop enabling technologies that allow them to compete with private companies.

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1. This access is under threat for US universities (see the Madey v. Duke ruling in Nelson 2004: 466)

There are also access issues between private firms (Scotchmer 1998). One key informant explained that between companies "with competitive intelligence, people play their cards a lot closer to their chest" (Nelson 2001). IP raised contradictory issues for innovators working within MNCs. In some cases, it fosters innovation. For these innovators it "gives you currency, [you] can trade it for what you need. Today cash is probably the least interesting piece of currency you can offer when interacting with other companies". In other cases, it produces an atmosphere where people are protective of their innovations, "driving IP into dark corners as IP has value". Even when IP is accessible, it may require, "multiple agreements to conduct research". Negotiating these agreements and putting them in place can delay collaboration and access to funding, slowing down the research process and increasing transaction costs.

The sources of funding can have an effect. In Canada, funding for university research comes from both provincial and national sources. Basic research is funded largely through the National Science and Engineering Research Council (NSERC). At the time of the interviews, this pot of money was considered too small and researchers were calling for more basic research funding. And, the balance of money for publicly funded research in Canada is channeled through specific programs. Importantly, this money is awarded to research programs that are able to solicit matching dollars from the private sector. Inevitably, this spins research projects in the direction of applied research (Bordt and Read 1999; NBAC 1999). Consistent with research by Toole (2000) and Scott et al (2002), one person interviewed explained that business driving research directions is bad for basic science, "There is always a conflict between good science and the need to address industry issues". Many at Agriculture and Agri-Food Canada (AAFC) indicated that there is an on-going compromise between conducting the research they need and the research they can get matched funding for. As one innovator explained, they must, "fit ideas onto the list [of acceptable projects]". The pull in the applied direction is clear so that, "Funding opportunities require industry support however we need to have basic research, not just applied with companies. It [research] should not just be driven by the market." Not only does this matched funding model undermine basic research, it also compromises the careers of public researchers as the,

> "…respect of peers, international recognition [is] important. In order to get this, [you] need to be engaged in fundamental research, but industry only funds research to get it done. Peer review affects promotion and tenure; how much money you bring in determines prestige in [the] university".

As these researchers are the ones pushing the envelope on behalf of Canada and extracting value from the public investment in research, limiting their careers means that Canada as a whole is compromised in its ability to innovate.

An additional difficulty is that federal and provincial funding is not long-term. Essentially, there is a lack of patient capital that is critical for innovation (Gertler and diGiovanna 1997). In the case of provincial funding, money is allocated annually. This means that longitudinal research cannot be planned for reliably. As one public key informant explained, there is, "limited money that is allocated annually. [It is possible to have] Only short-term research strategies, long-term can be planned for but not committed to. We only have money for one year to the next." This lack of funding stability results in less than ideal innovative environments. Although the Innovation Strategy did attempt to redress this problem through commitments to infrastructure and administrative costs, there is a continued lack of money to fund successful labs over the long-term and to offer permanent positions to researchers. Clearly, this undermines a lab's ability to attract 'the best and the brightest'. Similar concerns were expressed by innovators working in federal research facilities. They also feel the need for more stable funding. One researcher explained, "we need strong, uninterrupted funding for progress in long-term research. The constant worry about money is stressful." One private innovator expressed concern as it impairs the ability to plan and is "bad for innovation". The inability to commit to long-term research affects the types of projects undertaken and the researchers that are attracted to Canadian labs. World class researchers are not easily tempted to join public research facilities where the best they can hope for are a series of short-term contracts. This poor work environment further undermines long-term Canadian innovative capacity.

Agro-Biotechnology and the Public Good

Recalling the general question concerning public versus corporate priorities, it is important to examine the public's position on government supported research – in this case, public opinion about agro-biotechnology. In a 2004 report prepared by Agriculture Canada, it was reported that 77 % of Canadians have concerns about the safety of food that contains GMOs (Genetically Modified Organisms) – that is food created through the application of agro-biotechnology. In research polls about food safety, consistently 85 % or more Canadians want food containing GMOs to be labeled as such (e.g. Environics Research Group 2001; DECIMA 2003). Despite a clear message from the public and experts about their concerns (Royal Society of Canada 2002), the federal government continues to pour tens of millions of public research dollars every year into food related biotechnology research. In the case of agro-biotechnology in Canada, there is a disconnect between the public good and government policy. In Europe, New Zealand and Japan there is strong opposition to GMO food. This is has an impact on public researchers in Canada with some interviewees reporting that research projects had been scaled down or cancelled as a result of this uncertainty.[2] Most innovators indicated that consumer questions and concerns are reasonable and should be addressed. One researcher expressed concern about popular opinion when indicating that there is, "some uncertainty about GMOs at all levels. First products were

2. This is consistent with research in other countries, for example the May 2006 closure of the Cambridge research branch of Biogemma and the loss of 37 jobs (Fountain 2006).

brought to market too quickly. [There] could always be increased research. We need to do open research… information used in government assessment should be available to public researchers." Another scientist explained, "In general people are respectful of science, although there are some questions about GMO and the extent to which it serves industry instead of people. These are reasonable questions."

Conclusion

This paper confirms that basic research is a key constituent for future innovation. The research reported in this paper points to conflicts between public policy directed at improving the innovation capacity in agriculture and the challenges faced by innovators in agro-biotechnology. As the research has shown, in order to secure funding public researchers must pursue research projects that serve the needs of private industry. Researchers reported that this type of funding model restricts their ability to conduct basic research, and threatens to undermine the future innovative capacity in Canada. A second point raised from the research is the conflict the government faces as representative of the public good and promoter of economic development strategies. Part of the dilemma lies in the funding formulas that link public research dollars to matched funding, primarily from private sources. This has meant that industry is able to direct the kind of research that gets done in university and government labs. The emphasis on technology transfer by universities shifted the focus to public-private partnerships and the protection of IP through patents; these factors will likely lead to a less open innovation environment (David 2001, Nelson 2004). The Royal Society of Canada (2002) explains its concern about the narrowing of options as private industry interests collide with those of public funding agencies. In its report, 'Elements of Precaution: Recommendations for the Regulation of Food Biotechnology in Canada' the expert Panel cautions that risk regulation is also compromised from:

> "…the extensive and growing conflicts of interest within the scientific community due to entrepreneurial interests in resulting technologies and the increasing domination of the research agenda by private corporate interest (2002: 14).

It has also strengthened the ties between industry and government. Finally, both the literature review and the interviews indicate that the players that have IP are better positioned to participate in the R&D market. This has the effect of further concentrating power in the hands of an increasingly smaller number of corporations that have been able to develop and acquire key platform technologies (UNCTAD Secretariat 2006).

Essentially then the policy question becomes is it possible to reconcile conflicting federal government roles as Economic Development Officer and Protector of the Public Good? The EU offers some creative suggestions in this regard. First, it may be useful to consider broadening the scope of our research programs beyond specific target areas, along the lines of the EU, so that the spirit of innovation is considered, not the specific technology:

> "To launch the corresponding activities with a significant effect, the Union's research budget needs to be increased…Funding would be allocated according to three principles: a balance between current and new activities; between research for the advancement of knowledge and its industrial application; and between support for human and material research capabilities" (Commission of the European Communities 2004: 4-5).

Second, there are other organizational and institutional arrangements that may serve the public good better than others. The Centre for the Study of Human Polymorphism (CEPH) based in France offers an excellent template. The CEPH formed a collective network of genome researchers all conducting research on 40 French families and Mormon families from Utah. All genetic research was conducted using this database, so identified gene markers and chromosome maps were gradually constructed from this small sample. This permitted the identification of sequences for the same people and more reliable sequences. Two results of this project are especially notable: 1. all findings had to be published within two years; and, 2. none of the discoveries were patented. This created an invaluable public human genomic database for future research, and a model for a cooperative research strategy. In other cases, consortiums have emerged that centralize IP and manage in a collective manner (Cassier 2002). This mitigates the bottlenecks described by Nelson (2004) and Heller and Eisenberg (1998). Cassier (2002) concludes his paper with two recommendations that are relevant for the Canadian context. We can, 1) deny patents for genetic material; 2) place all genetic patents in the public domain and develop a coordinated database of available resources. This solution addresses questions of the public good and research agendas as it offers the potential for public input into the process of defining research directions and priorities.

I can now ask the question about future innovative capacity. As previously stated, "Once you get off the technology elevator, it is hard to get back on". Public researchers were very clear about the need for more basic, and less market-driven, research. The level of basic research that is needed to sustain innovation is at risk (Toole 2000, Scott et al 2002). Canada may be facing similar challenges as the US where it is recognized that science and hence innovative capacity is slipping:

Research, education, the technical workforce, scientific discovery, innovation and economic growth are intertwined. To remain competitive on the global stage, we must ensure that each remains vigorous and healthy. That requires sustained investments and informed policies. Federal support of science and engineering research in universities and national laboratories has been key to America's prosperity for more than half a century. A robust educational system to support and train the best U.S. scientists and engineers and to attract outstanding students from other nations is essential for producing a world-class workforce and enabling the R&D enterprise it underpins. But in recent years federal investments in the physical sciences, math and engineering have not kept pace with the demands of a knowledge economy, declining sharply as a percentage of the gross domestic product. This has placed future innovation and our economic competitiveness at risk (Task Force on the Future of American Innovation 2005: 1).

This has practical implications as more money is needed to support researchers so they can stay at the top of their fields. As well, dedicated, long-term funding is needed so research labs can attract and retain world-class researchers and technical staff.

A few important theoretical insights flow from this research. First, it raises interesting questions about the changing role of governments and the transformations we are witnessing in democratic institutions. This research points to a shift on the part of public institutions – both governments and universities—from knowledge creation to profit driven. The extent of these shifts is remarkable over the long-term. Finally, I return to the question first posed in this paper, what is the role of social voice in the evolution of policy? The results presented raise serious concerns about the extent to which people are able to engage in the political process in a meaningful way. This may speak to more practical issues such as voter apathy, political malaise and the overall buyout from the political process by many in developed countries.

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