The Economic Rationale for Public Agricultural Research in Canada

by
Richard Gray and Simon Weseen*
October 19th, 2007

**The authors would like to thank Sara Olfert for her research assistance. Many thanks to colleagues in the Canadian Agricultural Innovation Research Network and AAFC who provided comments on the manuscript. We would also like to acknowledge the financial assistance from AAFC which made this work possible.*

Please email comments to Richard Gray: Richard.Gray@usask.ca

The Economic Rationale for Public Agricultural Research in Canada

Executive Summary

Stimulated by a broad spectrum of changes occurring in the global marketplace, agricultural research policy in Canada faces many challenges and opportunities. The opportunities have been created by rapidly expanding base of biological science and genetic knowledge at a time when environmental and economic pressures have increased the demand for agricultural products and the need for innovation. The policy challenges include how to create an economic and regulatory environment for agricultural research that will stimulate additional research activity in ways that will increase the rate of innovation and the gains from research in Canada. Given the potential role that agricultural innovation can play in Canadian economic growth it is important that these policy challenges are met.

Using applied welfare economics, this paper develops a framework for categorizing specific research according to the types of benefits that it provides, thus enabling policy makers to identify the types of institutions that are best suited for governing that research. Specific research areas are identified and evaluated in terms of the incentives that they create for private, public and participation sector involvement, emphasizing the role that the public sector can play.

The results of the analysis suggest that the public sector, the private sector, and levy funded research all have an important role to play in funding and governing agricultural research. In some critical areas of agricultural research there are limited incentives for private research, which creates a gap and therefore an important role for public sector research. When property rights are well established, private sector for-profit research can play an important role in funding research and in commercialization, however, with the non-rival nature of research this can lead to freedom to operate issues and industry concentration. Producer controlled levy-funded research can be very effective in creating a strategic industry approach to fund and coordinate research and to disseminate results. However, given existing incentive structures, the financial resources for levy funded research is often very limited.

To maximize the economic gains from research, Canadian agricultural research policy should strive to create an environment with the appropriate mix of incentives and institutions which in turn are able to: 1) undertake the optimum amount of research, 2) develop the appropriate portfolio of research, 3) have the appropriate coordination of research activities, 4) develop mechanisms that provide access to research discoveries across institutions, and 5) to provide incentives and mechanisms for the adoption and commercialization of research discoveries. While it is not possible to design a set policies to fully accomplish these five outcomes on the basis of a single study, it is possible to begin the process by systematically examining existing policies and identifying where improvements can be made.

In the body of the report, after the Introduction in Section 1, we provide a brief history of Canadian agricultural research in Section 2. In Section 3 we describe agricultural research policy in other countries. A description of the global forces shaping the agricultural sector and potential challenges the forces create, are provided in Section 4. Section 5 outlines the economic framework that is applied in section 6 to analyze the types of agricultural research and the impacts of public sector involvement. The lessons learned from the analysis are described as the remaining part of the executive summary.

Lessons Learned

1. Historically, public research has played a very important role in agricultural genetic and agronomic research facilitating the development of the Canadian agricultural sector and the settlement of Western Canada.

2. Many economic studies have found high rates of return to research continuing to present day (Gray and Malla, 2007). The high rates of return suggest a need to find mechanisms to fund areas of public research with high rates of return, where private industry and levy-funded research organizations will not invest. Where the private sector is able to invest, analysis is needed to determine what incentives, if any, are needed to create the maximum net benefit from research.

3. The introduction of intellectual property rights and biotechnology has recently led to significant private investment in crop research concentrated in Canola, Soybeans and Corn. This illustrates that for some crops and some technologies IP can stimulate greater research investment. However, a "one size fits all" approach to the provision and governance of research is unlikely to be optimal because there are many types of "agricultural" research, each addressing different issues, operating in different markets, with a different set of externalities and with different institutions. It is important to recognize that the type of knowledge can affect what type of intellectual property will be most effective.

4. Producer-controlled levy funded research has been introduced for many commodities and has been successful. A recent study by Campbell et al. (2007) finds that these funding mechanisms, constrained by producer support, are limited and on average are equal to .5% of sales, with only a portion of the revenue being spent on research. The ongoing success of these organizations suggest that mechanisms, which might include easier rules for establishment and setting levy rates, and/or matching contributions by governments, are needed to encourage greater levy collection.

5. Research by Veeman et al. (2007) found that the R&D expenditure stock for Canadian agricultural research has shown no growth since 1990 and that prairie crop sector TFP growth has fallen to an average of .51% per year for the 1990 to 2004 period, which is much lower than historic growth rates of close to 2% per year. This slowdown in productivity increase should be a concern for policy makers. If there is desire to increase productivity growth rates, greater and more effective research expenditure is required.

6. Private and social demands for agricultural research in Canada are impacted by the large number of changes occurring in the global agriculture sector. In addition to demand related to higher income, consumer preferences, health, and environmental pressures, the development of a significant global biofuel industry will increase the demand for agricultural output and could sustain higher grain prices for years to come. While these changes increase the overall return to research, they also influence which products from the sector will be in demand.

7. From an economic perspective the inherently non-rival and often non-excludable nature of research means that competitive markets alone will fail to provide the appropriate types and quantities of research. These governance issues are further compounded by the need for "industry voice" and the need to address health and environmental externalities. These inherent complexities often create a continuing role for some public agricultural research along with private industry and levy funded research in Canada.

8. In crops where IP is firmly established, the private sector is constrained by issues of industry concentration and market power, freedom to operate, and downstream positive and negative externalities related to human health and the environment. In these crops there may be a need to stimulate research competition by reducing barriers to entry, addressing FTO issues through new institutional relationships, and augmenting the private incentives to deal with health and environmental externalities.

9. The increases in productivity from private and public research can differ significantly. The downstream productivity benefits of a discovery depend significantly on the price charged for access. Under some general assumptions of a discovery with a linear demand curve, private monopoly prices will reduce downstream gains by 75%. This suggests that public or producer levy–funded ownership of IP should be promoted if farm income and productivity growth are priorities for government.

10. While biotechnology and IPRs have increased the incentives for private research, they have also lead to the fragmentation of research discoveries, where the most desirable genetic traits and biotechnological processes often remain separated by exclusive ownership and control. For small private and public institutions this means they are no longer able to assemble plant varieties that compete with larger private companies that have a greater a scope of activity. More importantly, the natural synergies that could take place between institutions are no longer present, resulting in a duplication of effort and reduced effectiveness of the research that is undertaken. The fragmentation of research discoveries is particularly a problem for public research institutions. In Canada there are dozens of public institutions that do research related to plant genetics including, AAFC, NRC, Provincial Agencies, and many Universities.

Work is needed to develop institutions that will facilitate timely combinations of the current knowledge, germplasm, and research tools that currently exist at numerous public research institutions. These new institutions could include:

1) funding for collaborative research,
2) best management practices for licensing research,
3) sharing and reciprocal access agreements,
4) joint research operations and,
5) a national consolidated research program such as the GRDC

As one of the principle public research institutions in Canada, AAFC is in a natural leadership position to bring the public institutions together to reduce the fragmentation of research discoveries.

11. The introduction of levy funded research is very important for funding research where voice is important and the benefits spillover to farmers and downstream industry participants. Industry levies are also ideal in crops where Canada is a major global exporter because in these instances foreign consumers become the main contributors to research levies. Industry groups will continue to be reluctant to increase research levies without a long-term commitment from governments that increased levies will not reduce public resources. Better institutions, incentives, and long-term public commitments are needed to increase the level of levy funded research.

12. Genomics and related areas such as proteomics and metabolomics, are areas of research that would benefit from better integration of Canadian public research organizations. Not only does this type of basic research require scale and scope to be effective, it cuts across sectors and overlaps with animal and human health research. The optimal form of integration, the amount of integration and the institutions used to govern a more integrated approach, are very complex issues that deserve particular attention in a national science strategy.

13. The private incentive for investment in regional agronomic research is often very limited as farmers can easily mimic the best farming practices without paying royalties. This leaves the role of agronomic research to the participation sector (industry organizations), the government sector, or some combination of the two.

14. The lack of private incentives for research related to plant and animal health, food safety, biosecurity, and the environment and the need to maintain a reservoir of reactive capacity, suggests that publicly funded research is vitally important in these areas.

15. There are very large externalities associated with the market provision of goods for human health. The existence of public health services in conjunction with private insurance means that individuals bear only of small portion of the health care costs associated with their illness, which reduces the private incentive for consumers to pursue wellness and to demand healthier foods. Given that health care costs now make up over 10% of the Canadian GDP, improving human health should be part of national research strategy. The inability of private firms to capture value from basic nutritional research has contributed to lack of research in this area thus suggesting a need for the public sector to find new mechanisms to fund this research.

16. Agricultural research policy will continue to evolve and develop over many years. Ongoing economic research is needed to provide transparency, institutional design and foresighting to inform this process. It is important to emphasize that many recent changes in agriculture require that science and innovation be examined in the context of the emerging global economy. Economic research can therefore play a vital role in creating a more effective innovation strategy.

Acknowledgments
The authors would like to thank Sara Olfert

Table of Contents

The Economic Rationale for Public Agricultural Research in Canada

1.0 Introduction

1.1 Background

A major source of productivity in a nation's economy is research and innovation that occurs in both the public and private sectors. In Canada, public agricultural research was initiated one hundred and twenty years ago as part of the "national policy" for economic development. Agricultural research has continued to be a central pillar of innovation in the sector and has been characterized by high rates of return that continue to this day.

Despite sustained high rates of return, agricultural research and innovation is experiencing numerous challenges and new opportunities resulting from recent changes in the sector. These changes include increased globalization in agricultural markets, increased innovation and complexity of supply chains, increased health and environmental concerns, the emergence of biotechnology and life sciences, and the rise of the bioeconomy. Accompanying many of these changes has been a change in incentives for research that has influenced the relative proportions of public versus private research, as well as the effectiveness of each. An example of this is the recent development of genomics, which allows for the enforcement of intellectual property rights by private firms over a wide range of germplasm and process patents. The greater enforceability of property rights has allowed firms to capture value for their research and has stimulated private investment. These developments have challenged the need for public funding of some types of agricultural research.

The increased enforceability of intellectual property rights has changed the way in which knowledge is shared among researchers and research institutions. Specific concerns may include the presence of "freedom to operate" issues and a restricted ability of some public and private firms to access appropriate technologies that are clearly beneficial to the sector has a whole. It is also increasingly evident that intellectual property management has reduced the communication between researchers and between all types of research institutions. In conjunction with these concerns, it is evident that

public research has stagnated or even withdrawn from some areas that are deemed to be critical to the sector's overall viability. With the recent emergence of environmental concerns, health concerns, and the bioeconomy, as well as the globalization of the agricultural economy in general, the vitality of the public research sector is imperative.

The issues described above have not gone unnoticed in the Federal Government's recent Science and Technology Strategy designed to enhance innovation in Canada. The strategy recognizes the need for increased co-ordination between and among the public and private sectors and an environment that can further increase the quantity and returns to research carried out by both groups. The government has also indicated a desire to examine potential synergies between government-run research institutions and the universities. These priorities suggest there is a need to understand specifically how agricultural research is funded and coordinated in Canada and to identify a model that can be successful in fostering innovation.

1.2 Objectives

The objective of this paper is to use an economic framework to analyze and describe the rationale for future public involvement in Canadian agricultural research. This involves explaining in detail how research objectives are funded, carried out, and provide benefits to intended stakeholders. It also includes identifying and evaluating potential alternatives to these institutions and their processes. The research will pay close attention to the public versus private roles in producing innovation and the relationship that exists between the two sectors.

1.3 Outline

The paper is divided into six sections. Section 2 provides a context for the paper by providing a brief history of agriculture, agricultural policy and the role of research policy in the economic development of the sector and the overall economy. Section 3 compares recent and current agricultural research policies in Canada to agricultural research policies in other countries. Section 4 outlines some of the changes that have recently occurred within the agriculture sector and describes how these changes have impacted (and will continue to impact) the way research is carried out. Section 5 describes how applied welfare economics can be used as a framework for identifying

instances where public agricultural research is required and cases where the public and private can collaborate. Using this framework, Section 6 separates agricultural research into a number of areas, characterizes the outputs of each, and based on these characteristics, suggests which institutions are likely to be most effective for the governance of each type of research.

2.0 History and Research Policy

2.1. The Historical Role of Agriculture

In order to describe the historical role that agricultural research policy has played in the economic development of the agriculture sector and the overall economy in Canada, it is necessary to understand how agriculture evolved in Canada and the political climate that accompanied this evolution. In the earliest days of settlement in Canada, agriculture was used by the government as a tool in the process of colonization, as it was perceived to play a crucial role in building an economic and political empire. Fowke (1946) identifies three colonial purposes of agriculture in the early years, including its role as a defense device, a provisioner of the great staple trades, and in later years, as a commercial provider of wheat, which afforded an assortment of associated investment opportunities. It was thought that encouraging settlement across western Canada would enhance the country's ability to protect this territory from the rapidly expanding US empire, while at the same time expanding its trade routes across Canada. It was also hoped that the prairie region could excel in the production of wheat in much the same way as had occurred in the prairie region of the US. It wasn't until the late 1800s and early 1900s, however, that the commercial importance of wheat as an export commodity was fully realized. In the post 1930s period, agriculture remained important from a commercial perspective, although industries such as mining and manufacturing became more dominant in Central Canada.

2.2 Agriculture Policy

The historical role of agriculture from a national perspective has been reflected in the policy decisions have been made during Canada's history. In 1852, the Canadian

Bureau of Agriculture was created with the sole purpose of dealing with immigration and land settlement policies in an effort to encourage immigration to what were then the territories of western Canada. Around the same time, immigration policies led to proposals for the development of a railroad south to the US and later to the west to allow goods to flow back to eastern Canada. It was also felt that a pacific railway would provide Britain with an opportunity to trade with Asia. Settlement in the west was primarily encouraged through the Dominion Lands Act in 1872, which provided settlers both with land grants for wheat production and support through the establishment of immigration offices.

In 1878, the Canadian government released its National Policy, which was a protectionist policy designed to support the emerging manufacturing industries in Ontario and Quebec, while at the same time encourage westward immigration, agricultural settlement, and the development of a railroad (Fowke, 1946). The policy maintained high tariffs on manufactured imports and low tariffs on raw commodities used to make those goods, and was very popular in central Canada. Despite its intention to encourage agricultural expansion to the west, its positive impact was diminished because it forced farmers to purchase manufactured equipment at inflated prices.

As wheat became more important as a commercial crop in the mid to late 1800s, the Experimental Farms Act (1885) was introduced, which formalized for the first time, the Canadian government's commitment to agriculture research. The Act allowed for the creation of experimental farms that had the primary objective of finding ways to increase wheat production so as to further encourage immigration and settlement of the west. Some success came soon after their establishment with the discovery of summerfallow at the Indian Head Experimental Farm (Fowke, 1946). This agronomic practice, which stored additional soil moisture in the drought prone semi-arid prairies and released additional nitrogen for crop growth, was quickly adopted in Western Canada. The first major genetic breakthrough came with development of Marquis wheat released from the Indian Head Experimental farm in 1907. This variety not only produced high quality bread flour, it matured several days earlier than other varieties, making Marquis well suited to the short growing season of Western Canada. This single variety effectively

established the wheat economy on the Northern Great Plains, and was the predominant variety grown for more than thirty years in both Canada and United States.

From this point forward, agricultural policy in Canada began to focus more on increasing productivity and efficiency, although it is clear that immigration and creating investment opportunities were initially the primary drivers behind much of this policy. Development of the wheat economy was also accelerated during the early 1990's with the Crow Nest Pass Agreement (1897), and the Canada Grain Act (1912), which were targeted at developing efficient transportation and marketing systems for the growing export grain economy.

By the 1930's, it became evident that agriculture's dominant role as an instrument of western expansion was coming to an end. As manufacturing and other industries continued to expand in central Canada and settlement neared completion in western Canada, the importance of agriculture as an economic stimulant diminished. Agriculture policy became more about finding ways to support those directly and indirectly involved in agricultural production rather than finding ways to advance the country's imperial ambitions. Noteworthy policy events include the Wheat Board Act in 1935, and the Agriculture Price Support Act in 1944. These policies had the intention of increasing farm income for producers.

In more recent years a variety of other initiatives have been undertaken in an effort to bolster farm income. The majority of these involve the creation of farm safety nets, disaster relief funds or direct ad hoc payments to struggling farmers. Throughout the last century investments in agricultural research continued in an effort to increase crop yields and other aspects of productivity.

2.3 Canadian Agricultural Research Policy – Past and Present

As mentioned previously, the Canadian government formalized its commitment to agriculture research in 1885 with the introduction of the Experimental Farms Act. At this time it was realized that research could benefit crop production by developing earlier maturing varieties and agronomic practices better suited to the region. The experimental research farms were followed soon after the turn of the century by the establishment of agriculture colleges at universities, which initially specialized in teaching and extension.

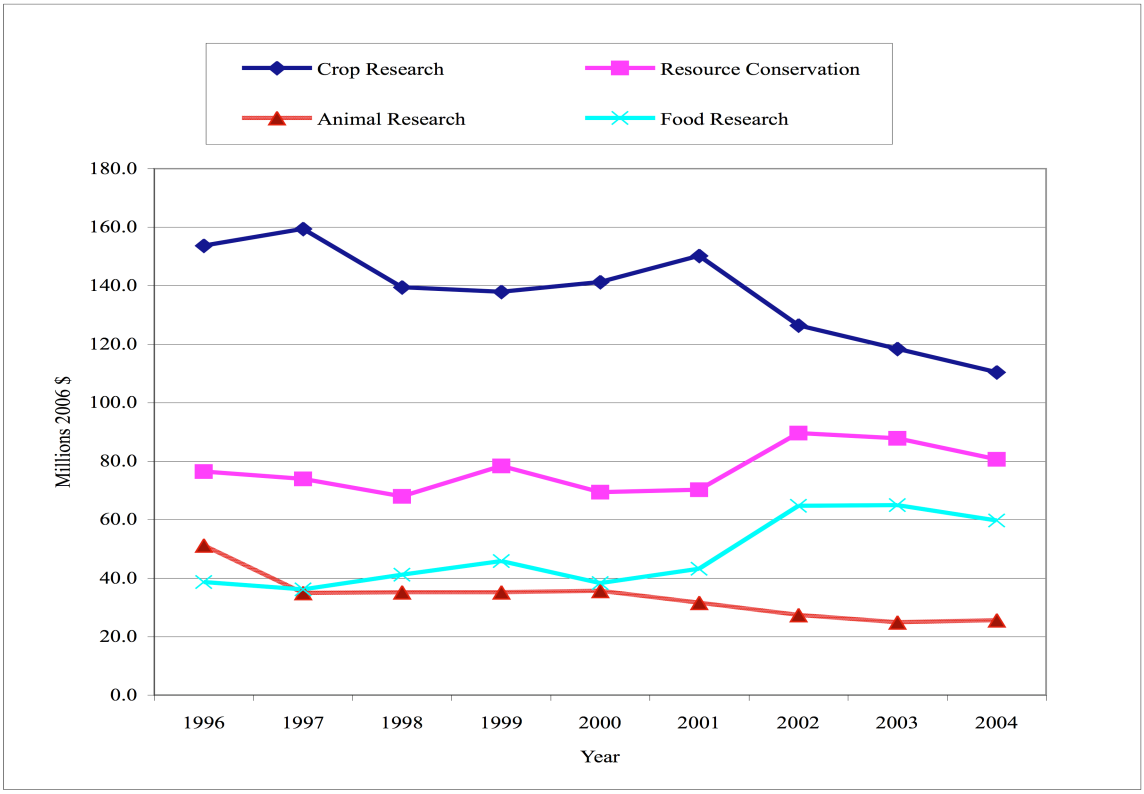
By the 1950's most provincial governments had also created extension divisions in addition to their own research programs. Private industry also began to see the benefits of research and became active in supporting both research and extension, although only on a small scale (Klein, 1985). Collectively, these institutions have, for the most part, been quite effective at increasing productivity and efficiency of the agriculture sector over the last hundred years.

Currently, numerous public and private agencies are active in agriculture research across Canada. Among them are federal government agencies like the AAFC Research Branch, the Animal Pathology Division, the Canadian Grain Commissions Grain Research Laboratory, the National Research Council of Canada, and the Prairie Farm Rehabilitation Administration (PFRA). Agriculture and Agri-food Canada has eighteen research centres located in the various regions of Canada, allowing them to focus on the differing agro-ecological conditions that exist across the country. In many cases, these centres are able to work collaboratively with the eight agriculturally focused university faculties, thus increasing their effectiveness. Some provincial governments also have established research councils that collaborate with universities and private industry to conduct applied research and facilitate the commercialization of new technologies.

In the recent past, agricultural research policy in Canada has undergone numerous changes in an effort to become more effective at increasing crop yields, quality, or production efficiency within a given timeframe. From the 1970s to mid 1980s, reductions in government spending lead to a consolidation of research facilities and an increase in contracted research to private industry and the universities. This policy change had the objective of maintaining essential research programs within a constrained budget, increasing employment in technology fields, fostering closer linkages with the university community, and increasing the extension of research results. These changes were accompanied by a decentralization of research activities into geographical regions (Carew, 2000).

In the mid 1980s to late 1990s, further decreases in research funding necessitated a decreased research role for the federal government, as it chose to focus more on "national" initiatives like international trade, food quality and safety, the environment,

and the development of new technologies (Carew, 2000). As shown in Figure 1 there was



Source: AAFC, 2007

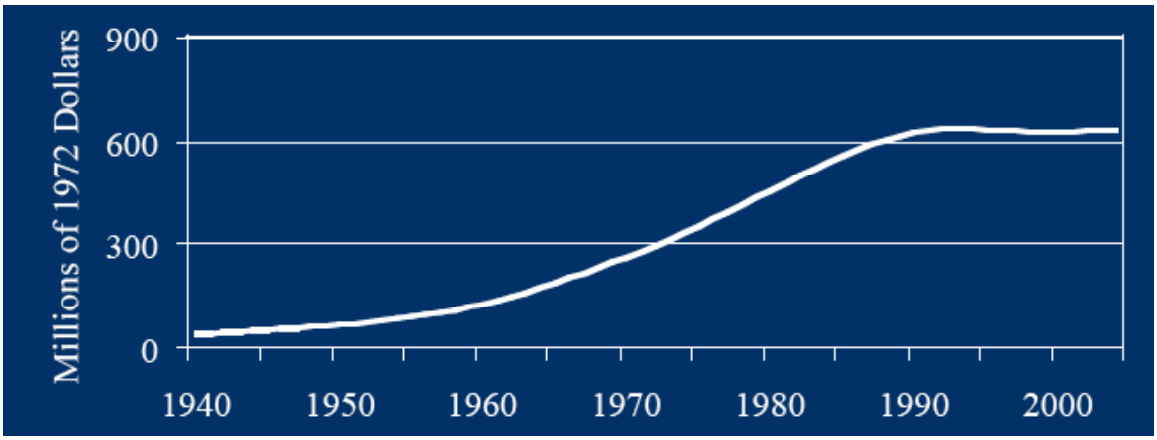
Figure 1: AAFC Research Expenditures by Type 1996- 2006

also a reallocation of agricultural research dollars away from crop and animal productivity research toward food and conservation research. The result was a significant drop in the commitment to productivity increasing research. Veeman et al., 2007 found that after nearly 50 years of growth in the stock of R&D expenditures, that this stock has leveled off since 1990 (see Figure 2). Correspondingly, provincial governments have become more involved in funding agricultural research. These provincial agencies allocate resources toward the issues and the commodities important to their respective province. While some effort has been made to coordinate these activities, most funding decisions are made independently, inevitably leaving both research gaps and some duplication of effort.

The mid 1990s were also characterized by a more concerted effort to promote research within private industry. In 1995, the Matching Investment Initiative (MII) was

introduced, which offered matching funding to private industry for research that was deemed to be of value to the industry. In addition to substantially increasing private research, this program has been very successful in facilitating the development and commercialization of new technologies.

In conjunction with programs like the MII, an increased ability to enforce intellectual property rights over a wide range of new technologies and process patents has meant that the potential to profit from research has increased substantially. As a result, the role of private industry research has continued to expand. The largest influx of private research has occurred in the canola sector where, private firms spend about $200 million per year in research and development. Not surprisingly, this sector also pioneered the use of technical use agreements, enabling the owners to capture an annual return from seed sales. Recently, hybrid technologies have been introduced and are beginning to dominate seed use in the canola sector.



Source: Terry Veeman, Jim Unterschultz, and Bryce Stewart, 2007

Figure 2: Private and Public R&D Expenditure Stocks, 1940-2004 (20 Year Lag in 1972 Dollars)

Levy funded research has also grown in popularity and now plays a role in research for many crops in western Canada. The concept was first used to fund a voluntary marketing levy for rapeseed, which provided operating resources for the

Rapeseed Association of Canada, which later became the Canola Council of Canada. The Saskatchewan Pulse Growers established a research levy in 1984. The Western Grains Research Fund began collecting voluntary research levies from wheat and barley sales in 1993. Voluntary research levies also exist for smaller crops such as oats, mustard, flax and canary seed. The farmer elected boards of directors for these organizations are able to direct resources toward research priorities and have also been effective in procuring matching government funding for much of the research they fund.

While very common across crops, the level of levy funded research remains very limited. Campbell et al. (2007), found that on average levies average .5% of sales and that less that half of this amount is spent on research. While producers supporting these organizations believe it is important to have voice in research, there levy of expenditures remains very limited. Campbell et al. (2007) speculate the low levy of funding is due to number of factors including the voluntary nature of the check offs, the fear of displacing public expenditures and the amount regulatory approval needed to raise levies.

Although beneficial in many ways, recent changes to agricultural research policy in Canada have created some interesting challenges, especially as it relates to the role of public research. In evaluating changes that occurred to Agriculture Canada as it went through its reorganization process in the late 1970s and early 1980s, Klein (1985) has suggested that research administrators have had difficulties establishing research goals and objectives, determining whether each of these are being met, and then evaluating the relative contribution of this research to the development of the agriculture industry as a whole. More recent criticisms are centered on the diminishing role of public research relative to private, a need to publicly fund basic agricultural research that is currently not being carried out, and a reduction in communication between researchers and between all types of research institutions. From an institutional perspective, a challenge for the public sector involves evaluating the implications of production based research in the broader context of the economy as a means of not overlooking broader market conditions that can influence the efficacy of such research. An example of overlooking broader market conditions would be seeking to increase the yield of a crop that is experiencing reduction in market price due to an increase in supply elsewhere in the world. A second example

might be failing to consider the implications of increased production of one commodity on other agricultural commodities (e.g. the impact of ethanol on livestock production).

While is difficult to directly measure the impacts of agricultural research on productivity growth in the sector the analysis by Veeman et al., 2007 (Table 1) shows some troubling results. The results show that the percent annual growth in Total Factor Productivity in the crop sector in western Canada has fallen dramatically since 1990. They show that while TFP growth has averaged nearly 1.8% per year between 1940 and 2004, that TFP growth has averaged only .51% per year in the 1990 – 2004 period. This is a remarkable slowdown, suggesting the changes in research policy could be having profound affects on on-farm productivity growth.

Table 2: Provincial Crop Annual Compound % Productivity Growth Rates

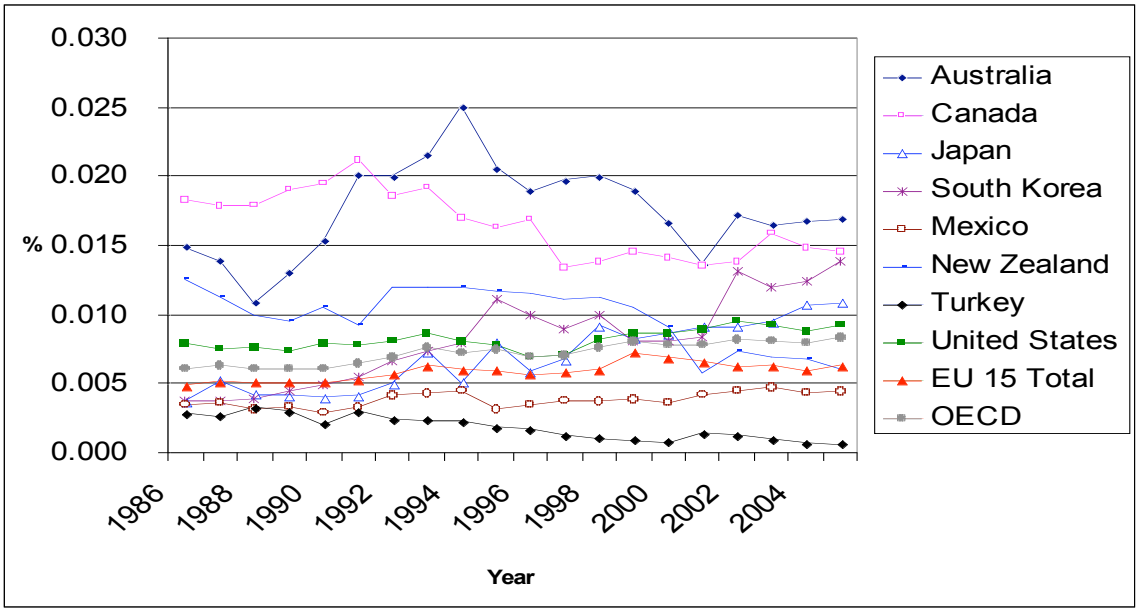
	1940-2004	1990-2004
Province		
Alberta	1.65	-0.05
Saskatchewan	1.76	0.40
Manitoba	2.12	1.75
Prairies	1.77	0.51

Source: Veeman, Untershultz and Stewart, 2007

Research challenges like those described here are not unique to Canada, as many jurisdictions around the world are experiencing many of the same issues. Understanding how other nations are dealing with these challenges can provide important information as Canada seeks to develop its own research policy. The next section of the paper briefly describes the agricultural research situation in the US, the EU, and Australia.

3.0 Agricultural Research Policy in other Countries

As a precursor to providing an overview of research policy issues in the United States, the EU, and Australia, it is useful to get a sense of the historical importance of agricultural research in these countries as it compares to other selected OECD countries. A good proxy for research intensity is dollars spent on research as a percentage of total value of agricultural production. Figure 3 presents this ratio for several OECD countries from 1986 to 2005.

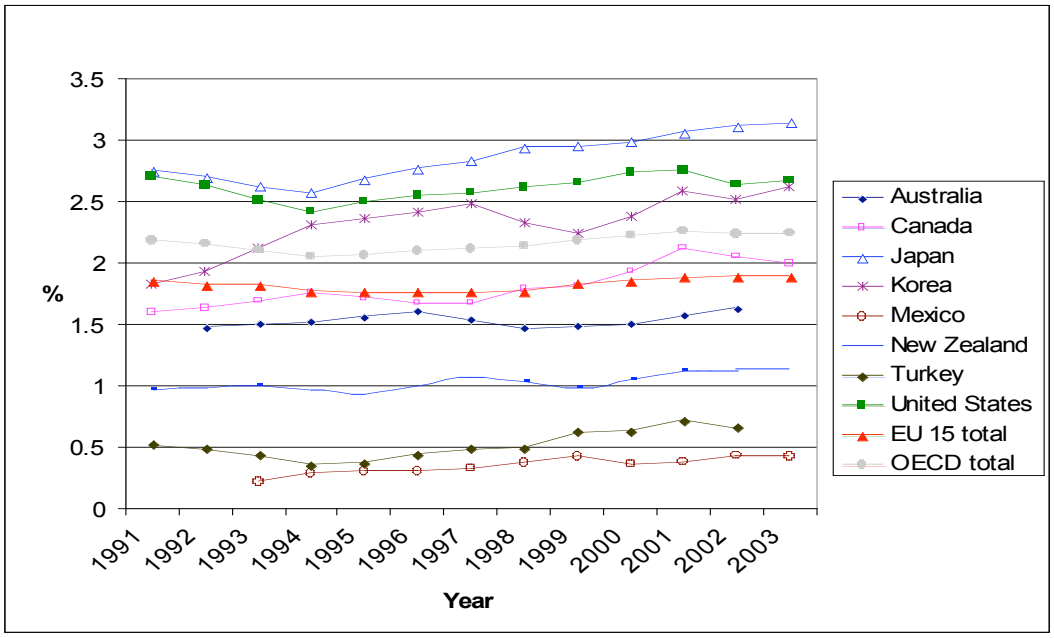


Source: OECD, 2007

Figure 3: Public Research and Development as a % of Total Value of Agricultural Production

It is evident in Figure 3 that as a percentage of value of production, most OECD countries spend relatively little on agricultural research. This is quite surprising given the high rates of return to agricultural research that have been documented over the years. Figure 1 also illustrates that in several OECD countries (e.g. Canada, Australia, and New Zealand) agricultural research intensity has decreased since the early 1990s, while in others it has been increasing. In the United States and the EU, for example, research intensity is on a slight upward trend, while in countries such as South Korea and Japan, the upward trend is more pronounced. Although in some cases (e.g. Japan), these trends may be influenced to a large extent by differing relative changes in the value of production during the time period, it is clear that Canada, Australia and New Zealand are spending less on agricultural research than they did in the mid 1990s.

Given the decreases in agricultural research spending in some countries it is useful to know whether this is a trend with all research and development occurring in these countries or whether the situation is unique to agriculture. Figure 4 presents expenditures on all research and development as a percentage of a country's GDP for the same OECD countries.



Source: OECD, 2007

Figure 4: Total Research and Development Expenditures as a % of Total GDP

With respect to the total economy (as measured by GDP), a comparison of Figures 1 and 2 suggests that research intensity is higher in other industries than it is in agriculture. Although, value of sales and GDP are not exactly the same, it does suggest that in relative terms, agricultural research receives less funding in relation to output produced. With the development of intellectual property rights and increased private research, agriculture is becoming more like other sectors, making this trend somewhat counterintuitive. Perhaps this lack of investment is occurring because agriculture is primarily seen as a provider of food and there currently is not a food crisis in OECD countries.

Figure 4 also reveals a slight upward trend in total research intensity between the mid 1990s and mid 2000s for all countries, which indicates that for countries like Canada, Australia and New Zealand, the decrease in research funding is perhaps unique to agriculture. Given the funding trends identified here, it is not difficult to comprehend some of the research challenges that emerging in the agriculture sector.

3.1 The United States

Having undergone similar changes to those described in Canada, the agricultural sector in the US is facing many of the same issues with respect to research policy. Like in

Canada, the sector has experienced increased environmental and food safety concerns, a declining farm population, and a movement towards regional concentrations of larger more specialized farms. In addition, an increased focus on biotechnology and related sciences, coupled with the enforceability of property rights has stimulated a large increase in the proportion of research that is being funded by private industry. This has resulted in a discussion about the role of public research and a need to find ways to more efficiently allocate public research dollars.

As is the case in Canada, funding for public research in the US is increasingly allocated through a competitive grant process, whereby proposals are solicited by the governments and universities and are then evaluated based on their ability to accomplish broad research objectives but also based on the credentials of the researchers involved. The effectiveness of this allocation process has not been without scrutiny, however, and some research suggests that in comparison to formula-based funding, the competitive grant process can lead to a reduction in efficiency, thus diminishing its ability to have positive outcomes on agricultural production (Huffman and Just, 1994). Despite numerous studies that have confirmed high rates of return to agricultural research in general, concerns with policy pertaining to agricultural research and extension in the US have been ongoing for many years and range from claims that research is "too disciplinary" or "too specialized" to there being an absence of linkages between research, extension and teaching. (Huffman and Just, 1994). So as is the case in Canada, it is evident that the way agricultural research is carried out in the US is undergoing an evaluation process of its own.

3.2 The European Union

Like Canada and the US, the European Union has acknowledged that rapid changes in the agricultural sector have created the need to identify and overcome the various research challenges that are emerging. As a means of facilitating this process, the EU has assembled a Foresight Expert Group (FEG) that has considered "disruption scenarios" within a 20 year time-frame. These scenarios include *climate shock, energy crisis, food crisis, and cooperation with nature,* and are deemed to require both "proactive" and "adaptive" planning to overcome. With respect to research, the FEG concludes that a decentralized approach to decision-making is favourable to a centralized

system and is thus trying to identify instances where centralized decision making is ineffective and can be changed. In addition, it suggests that "knowledge failures", where the research community is not effectively delivering information to end-users, are a major impediment to transitioning to a knowledge-based bioeconomy. Several recommendations have been made by the FEG, most notably the development of a new strategic framework that focuses on issues of sustainability, security, knowledge and competitiveness as a starting point (Foresight Expert Group, 2007).

3.3 Australia

Australia went through a major change in its grains research and development policy in the early 1990s. The introduction of its Primary Industries and Energy Research and Development (PIERD) Act (1989) led to the creation of the Grains Research and Development Corporation (GRDC) and several other development corporations. The GRDC is a statutory corporation created by the Australian federal government that has the goal of bringing about improvements in production, sustainability and profitability in that country's grains industry (GRDC website, 2007). The GRDC is not a supply driven corporation but instead relies on a "demand pull" approach to setting its research priorities. The process of relying on market signals to direct research involves the establishment and maintenance of strong linkages across producer and other business groups, which are accomplished by the creation of a Board and advisory panels that are composed of producers, downstream industry groups, scientists, and executive managers (GRDC website, 2007).

Funding for the GRDC is based on a compulsory 1% levy on grain producers that is matched by the Australian Government up to a total of 0.5% of the gross value of grain production (GVP). As a result, the total levy collected is dependant on a variety of factors including weather, the effects of disease and pest outbreaks, the price of grains, and any market driven changes to the crop mix. In total, the levy is collected on 25 different cereal, oilseed and pulse crops (GRDC website, 2007).

In terms of total funding for crop research and development in Australia, the sector has seen an increase in investment from $67 million in 1984/85 to $541 million in 2005/06. The GRDC functions much like a private sector corporation, developing 5-year

strategic research plans, annual operating plans, annual reports, and regular reports for industry. In addition, the corporation is very active in monitoring its own performance in an effort to improve its efficiency and remain adaptable to challenges and issues as they arise. Performance objectives are established for employees at all levels on an annual basis and are reviewed regularly. The entire system is evaluated on an ongoing basis (GRDC website, 2007).

Challenges in agricultural research policy are compounded by the rapid evolution that is occurring in the agriculture sector. The next section of the paper describes some of the changing aspects of the agriculture sector that have and will continue to influence the way agriculture research is carried out.

4.0 Changes in the Agricultural Sector and Potential Challenges

Over the last several decades, the agriculture sector has experienced numerous changes that have had a profound influence on the way business is conducted and the way research is carried out. Among these changes are; a rapid expansion in international trade leading to globalization of the industry; increased innovation in the areas of biotechnology and genomics (and other "omics" including metabolomics and proteomics) leading to an increased complexity of supply chains; a heightened awareness of human health and environmental degradation; a desire to achieve energy independence contributing to the emergence of a biofuels industry; and institutional changes leading to an increase in private research and an integration of scientific capacity. Each of these changes and their potential to influence agricultural research and research policy are described below.

4.1 Globalization of Agriculture

The globalization of agriculture is a process that has been occurring for many years; however it continues to have a large influence on the way agricultural systems evolve and function. For agriculture, globalization means increased access to international markets, increased trade among nations, as well as transfers of capital, technology and the benefits of research and development. With new technologies and access to investment dollars it also means expanded production in immature markets,

increased efficiency in production and transportation, and increased world supply of many products. The results of this can be increased competition and lower prices, which often lead to greater innovation.

The research requirements resulting from globalization are multi-faceted and range from trying to improving production technologies to trying to gain an understanding of increasingly complicated and integrated markets. This involves finding ways to access new markets, maintaining existing markets, while at the same time striving to decrease transaction and transportation costs associated with trade. There is also a need to find ways to better differentiate products that consumers want, while also trying maintain an awareness of changing consumer preferences. Adapting to the changes associated with globalization will continue to be challenge for the agriculture sector and it is therefore important that agricultural research policy is able to accommodate these changes.

The growing global recognition of innovation as source economic growth could also spur investment in agricultural research. The theories of endogenous growth, which emerged 1980s, set the stage for political acceptance of the notion that institutions, knowledge, and infrastructure play an essential role in national productivity and productivity growth. This perspective has led to renewed interest in the knowledge economy and general increase the research expenditures in most OECD countries. (see Figure 4). In Canada some of the intention to change research structures is already evident in the recently released S&T strategy (Industry Canada, 2007).

4.2 Innovation in Longer Supply Chains

The development of longer and more complicated supply chains are the result of a multitude of factors. Increased trade associated with globalization means that products can change hands numerous times, can undergo significant processing, and are subject to increasingly complicated regulatory and security requirements The demand for products with highly specific attributes can increase processing and traceability requirements (e.g. organics). In turn, traceability and production process standards, link input suppliers into the supply chain. The increased enforceability of property rights and patents can lead to more intricate relationships among supply chain participants. Finally, the need to sustain

a high level of control over processes (e.g. for food safety issues) as products move from the farmgate to the end consumer can also increase the complexity of supply chains. As supply chains increase in length and complexity, there is a need to find ways to increase efficiency, increase quality control, reduce costs, and find technical solutions to a variety of problems. As is the case with other changes in the way goods are supplied, finding ways to meet these objectives will require a substantial research effort.

4.3 Health and Environment

The ageing and increasing obese population in many countries increases the scope and demand for agricultural research. Health budgets in many countries including Canada and the United States are growing far faster than the general rate of inflation. Many observers suggest the health budget will create a fiscal crisis unless obesity and non-communicable disease costs are curtailed, and many experts are looking toward changes in diet as part of the solution. This agenda will require more nutritional research and will eventually create a demand for more functional foods. The development of these new products will require research as part of the innovation process.

On the environmental side, the accumulation of greenhouse gases should affect the demand for agricultural research. Agriculture will increasingly be looked upon as a solution provider for the production of renewable fuels and the sequestration of carbon. The extent to which climate change and GHG mitigation will play role in agricultural research and policy will depend on the immediate public concerns. In the short run, political pressure for policy will be driven by extreme weather events, which refocuses the often fickle public attention to GHG mitigation. Whether, there is scientific basis for it or not, GHG mitigation will be used to sell protection and investment in the biofuels industry.

4.4 Biotech and the Omics – (new tools and processes across sectors)

Perhaps the largest force to revitalize interest in agricultural research will come from scientific discoveries using biotechnology and the emerging "omic" sciences. While transgenics has created a greater potential for genetic modification, it is the related fields of structural genomics, plant physiology, metabolomics, transcriptomics, glycomics and

proteomics that offer the greatest potential for increasing productivity in agriculture. These fields of study create the potential to discover the mechanisms for how plants work. This increased understanding may lead to non-genetic ways to increase plant and animal productivity. An example of this the work by, Dr John Thompson, a Professor of biology from the University of Waterloo, whose team discovered that in one form, a protein referred to as "Factor 5A" would suppress the deoxyhypusine synthase (DHS), which signals plant cells to die. Using this relationship they were able to develop a transgenic canola plant with lower levels of DHS and canola yields that were up to 65% higher[1]. This and similar advances in biotechnology create the potential for a far higher rate of innovation in agriculture.

4.5 Integration of Science Capacity (private mergers and public reorganization)

For most of the last century, many players including federal government, provincial governments, the universities and the private sector have played a role in agricultural research. However, the relative involvement of each group has changed over time depending on various issues facing the sector, the priorities and objectives of governments, as well as the potential for deriving profits from research. Recent trends have seen a much greater involvement of the private sector in agricultural research, a diminishing role of the public sector, and an increased number of private mergers and private-public partnerships. This has occurred to a large extent because the greater enforceability of property rights has allowed firms to capture value for their research.

Changes in the structure and relationships of and between entities carrying out agricultural research can be beneficial in many cases but can also create challenges, especially as it relates to the role of public research. Specific concerns may include the presence of "freedom to operate" (FTO) issues and a restricted ability of some public and private firms to access appropriate technologies that are clearly beneficial to the sector has a whole.

---

[1] This technology has been exclusively licensed by Senesco to Bayer CropScience (http://www.senesco.com/newsitem.php?id=115)

With respect to FTO issues, the introduction of single genetic trait into a product of biotechnology can require the use of many separate pieces of IP. Before the innovator can have FTO, the innovator must reach an agreement with each of the other IP owners (Kowalski et al, 2002). If the ownership of the IP is dispersed, negotiating FTO agreements to share the proceeds from the innovation is an expensive, time consuming process, and can be subject to hold up by any of the parties involved. (Falcon and Fowler, 2002).

The FTO issues have created challenges for both the private and public sectors. In the private research sector the need to acquire freedom to operate has increased the incentive for mergers in the industry such that the requisite pieces of IP are held within a single large company. For smaller companies still operating in the sector, freedom to operate has restricted the processes as well as germplasm available to these firms and at the same time requires more resource expenditure on IP acquisition, management negotiation and sale. In the public sector, FTO issues have increased the need to use Material Transfer Agreements (MTA) even among public researchers. It has also increased the incentive to protect IP so that public researchers can barter and trade their IP to obtain access to IP held by private firms or other public institutions. The overall effect is more resources being spent on IP management, greater secrecy among public researchers and more selective use of processes and germplasm in some sectors. Solving these problems will require investment in trying to find innovative institutional arrangements that can facilitate functional private-public relationships, while at the same time allowing greater access to research benefits for the broader agriculture sector.

4.6 The Rise of the Bioeconomy

The emergence of a global biofuels industry is perhaps one of the most significant changes to occur in the agriculture industry in the last half century and its impact has been, and will continue to be, far reaching within the sector. It has become a major source of elastic demand for grains, sugar and vegetable oil, which has had implications for both grain and livestock farmers. For grain farmers, increased global grain demand has meant increased prices. For livestock farmers the flood of wet and dry distiller's grain and oil

meal has meant an abundant source of cheap protein that has been accompanied by an increasing price for energy contained in animal feed.

The increased demand for grains through bio-products has two primary sources. First, agriculture has become a residual supplier to a much larger fossil fuel market which has created a link between the price of oil and the demand for grains. This relationship is likely to strengthen as the biofuels industry grows and will create a more elastic demand for grain which could serve to remove the treadmill effect of increasing supply against an inelastic demand. The US alone is expected to use over sixty million tonnes of corn in its relatively new ethanol industry. Ethanol is also important in Brazil, where it is produced using sugarcane. Biodiesel production has increased rapidly in Europe and is beginning to become popular in other countries where decisions have been made to mandate its use. In total, the global biofuels industry currently consumes what is equivalent to over 100 million tonnes of grain. This relatively new demand is equivalent to several years of regular global production growth. While periods of higher grain prices will surely slow or even stop expansion of the biofuel industries, the industry will be poised to expand again whenever grain prices fall relative to oil prices.

A second very important source of accelerated demand growth for grains has been the phenomenal income growth experienced in industrializing nations like China and India. As these very populous countries continue to grow they will have an increased demand for protein and while these two large nations have increased their own agricultural production a great deal, it is becoming increasingly apparent that demand growth is likely to outstrip supply growth for the foreseeable future. In high income countries, income growth has meant an increase in the demand for food, variety and safety. This has placed a market premium of innovation and the development of safer supply chains and the development of new food products. In the longer run, income growth will indirectly affect environmental policy, as wealthier consumers can afford to choose stronger environmental policy. This may eventually limit the resources that can be used in agriculture and could serve to create more demand for renewable bio-products.

The net effect of the biofuels industry is that it has become a very important driver for agricultural markets and as a result has created a need for research both in terms of the biofuels industry itself but also in terms its potential impact on other

industries (like the livestock feeding industry). The fact that the biofuels industry has had such a large impact on the entire agriculture sector also underscores the need to have research institutions that are capable of looking at these broader market implications.

4.7 Summary

In summary, it would appear that the stars have aligned for a renewed investment in agricultural research. High income growth, increased biofuel production, and growing environmental concerns suggest stronger markets for agricultural products for some years to come. This should stimulate the demand for and the creation and adoption of new technologies. At the same time biotechnology and advances in related sciences have increased the speed and particularly the scope of the potential gains from life science research. Moreover, the renewed interest in agricultural research is occurring at a time when investment in innovation is recognized as a key to economic growth. If agriculture is recognized as an area of potential wealth generation, the general increase in research expenditures should spillover to increase agricultural research expenditures. Similarly, the institutions that govern agricultural research could be modified as part of a national innovation strategy. Given the combined effect of these forces it would be surprising if we did not see a renewed and revitalized interest in agricultural and life science research.

5.0 The Economics Framework

5.1 Introduction

The large number of changes that the agriculture sector is currently experiencing in conjunction with existing inefficiencies at allocating research dollars and the need to increase the role of public research (in some cases) suggests that an economics framework for making research decisions could be useful. This section of the paper uses applied welfare economics to present a framework that can explain the rationale for public versus private research and to identify instances where public research is required.

5.1 Applied Welfare Economics as Policy Framework[2]

Markets have long been recognized as effective mechanisms for the allocation of goods and services. Adam Smith (1776) pointed out that if competitive firms act in self interest, the resulting market prices will act as an "invisible hand" to guide the optimal production of goods and services. More recent economists have shown, via neoclassical economics and applied welfare economics, that under certain well-defined conditions the market will create the maximum economic surplus for a society, a result that is consistent with Smith's findings.

At the core of this result are three assumptions: (1) that markets behave competitively; (2) that the demand for a product reflects both the marginal private benefit of the product and the marginal social benefit (i.e., the marginal social benefit equals the marginal private benefit); and (3) that the supply of a product reflects both the marginal private cost of production and the marginal social cost of production (i.e., that marginal social cost equals marginal private cost). When the first assumption holds, the equating of supply and demand in a market means that marginal private benefit equals marginal private cost. When the latter two assumptions also hold, the equating of marginal private benefit and marginal private cost means that marginal social benefit equals marginal social cost, and as a consequence social welfare is maximized.

Markets, however, will not result in maximum economic efficiency if: (1) markets are non competitive, (2) marginal private benefits deviate from marginal social benefits, or marginal private costs deviate from marginal social costs. The first condition generally occurs when markets are highly concentrated – e.g., a very small number of firms possess most of the market share. Conditions 2 and 3 occur when some of the costs and benefits are external to the players that buy and sell products – hence the term externalities. These external benefits (costs) are reflected in marginal social benefits (costs) that do not match with the marginal private benefits (costs) used by individuals and firms in their decision-making. Maximizing economic efficiency in such a situation often requires government

[2] The economic framework for this paper draws heavily on the framework presented in Gray, Fulton and Furtan, 2007. With the permission of the authors a significant amount of the text from this earlier document is repeated in this section for the reader's convenience.

intervention. In agriculture research, government intervention has included public research, matching incentives and stronger intellectual property rights.

5.2 The Classification of Goods

Economists classify goods based on two of their key characteristics – excludability and rivalry (see, for example, Romer (1990, 1994)). Excludability refers to the ability of one person to prevent another from using it; if a good is excludable, its owner can limit access to it. The degree of excludability depends on both the technological aspects of the good and the legal system.

Rivalry (also known as subtractability) refers to the extent that the use of a good by one individual precludes the use by someone else. If a good is purely rival, its use by one person or firm means another person or firm cannot use it. If the use of a good by one person or firm in no way restricts others from using the same good, then it is purely non-rival. Many goods and services are rival. For example, burning one litre of gasoline will mean this litre is not available to others to burn. Other goods are purely non-rival; one individual can use a broadcast television signal without reducing the availability to other individuals. Although the degree of rivalry depends largely on the technological aspects of the good, goods may be rival or non-rival depending on their usage. A road is purely non-rival when not congested. As the road becomes somewhat congested it becomes somewhat non-rival as the use by one individual reduces the accessibility to other individuals. When a road reaches its carrying capacity it becomes a rival good because the use by one individual fully displaces access for another.

5.2.1 Implications of Non-rivalry and Non Excludability

If a good is excludable, the owner of the good can trade access to the good in exchange for a payment. If a good is non-excludable, other producers or consumers cannot effectively be excluded from the market and some will use it for free. The result is that there will be some spillover of either the benefits or the costs – i.e., an externality is present. Following from the earlier discussion, the consequence of the existence of non-excludable goods is that the market may not give rise to the efficient allocation of resources.

Non-rival goods have important implications for the cost structure of firms and hence industry concentration. When a firm makes use of non-rival input – a good example would be an information network – the average cost per unit of production decreases with output (i.e., there are economies of size). With this cost structure the marginal cost – i.e., the cost of the last unit produced – is always less than the average cost of production. Goods with this cost structure cannot be produced in a competitive market where price equals marginal cost, since this outcome would result in firms losing money. In order to earn non-negative profits, firms must become large enough (i.e., the industry must become concentrated enough) so that they have the market power to raise price above marginal cost. The push to concentration is also strengthened because the economies of size that they possess provide an incentive to expand output. Since only firms that are roughly as large will be able to be cost competitive, the industry is soon composed of a small number of firms that are able to exert market power.

Non-rival goods can be also be more difficult to make fully excludable since purchasers of the good can share their purchase without cost. Sharing a rival good such as a sandwich reduces the consumption of those sharing the good, whereas sharing a digital copy of a favourite song or movie has no cost. Thus the properties of rivalry and excludability are often interrelated.

5.3 The Types of Goods

Economists have used the properties of rivalry and excludability to classify goods into four types – private goods, toll goods, common pool goods, and public goods (see Table 2). The unique combination of rivalry and excludability for each type of good creates specific issues with their management. Goods that are both rival and excludable are referred to as private goods because private individuals and firms are able to own and control them. Examples of a private good are fuel and sandwiches. Toll goods are excludable and non-rival – their excludability means that a toll or charge can be levied for their use. A good example of a toll good is a toll highway. Common pool goods are rival but non excludable. The fact that these goods are non excludable means private ownership cannot occur – the goods effectively are owned by everyone in a group. Ocean fish are a good example of a common pool good (only after scarcity sets in). Finally public goods are both non-excludable and non-rival. These goods are effectively owned and used by everyone – hence their public nature. Free radio signals are an example of a public good (another example would be public laws or public policy).

Note that the classification of goods in Table 2 is presented as four discrete types. However, given that both excludability and rivalry rarely exist in a pure form, a whole continuum of types exists. For instance a fully excludable good that is somewhat non-rival would be an impure form of a toll good. For more details and examples in this good classification system we refer the reader to Gray, Fulton and Furtan (2007).

Table 2: The Classification of Goods Based on Rivalry and Excludability

	Rival	Non-rival
Excludable	Private good e.g., sandwich, fuel	Toll good e.g., toll highway
Non-excludable	Common-pool good e.g., ocean fish	Pure public good e.g., radio signal

Issues related to market failures associated with non rivalry and non excludability can be applied to the provision of agricultural research, as the outputs of research can be categorized into the four types of goods or some combination of them depending on who it is conducting the research. For example, research conducted by private firms will often provide private benefits that can only be captured by the firm that undertakes the research. This is especially true with the emergence of enforceable property rights and patent processing. In some cases, a private firm may choose to sell the benefits of its research to others, as is the case with technical use agreements for canola. In cases like this, the benefits of research become toll goods and are shared by the private company and individuals paying the toll. Although government may also provide *toll goods*, as the toll highway example given earlier clearly illustrates, there are few examples of this occurring as it pertains to agricultural research. Governments are much more likely to be active in providing research that that is a pure *public good*, as a government's mandate is to maximize net benefits to society. In these cases, research results are available to everyone, and everyone has equal opportunity to benefit from them. Government research can also lead to the provision of *common pool* goods. This is research that benefits a group of people and for which there is no incentive for public firms to provide it. In addition, its "rival" characteristic means that the benefits of this research are likely to diminish as they are consumed. An example of a common pool good provided by government research would be research showing the benefits of irrigation from a finite water source.

5.4 Institutional Choice: The Role of the Public, Private and Participation Sectors in Agricultural Research

Having presented a framework that allows us to categorize various types of research into the four categories of goods, it is now possible to look more closely the types of institutions that are best suited for governing research. In an increasingly competitive global economy, the institutions governing research may be as important as the total amount of resources invested in innovation. In a perfect system, the optimal amount of research resources would be directed toward those areas with the highest economic potential and the research output would be commercialized to maximize

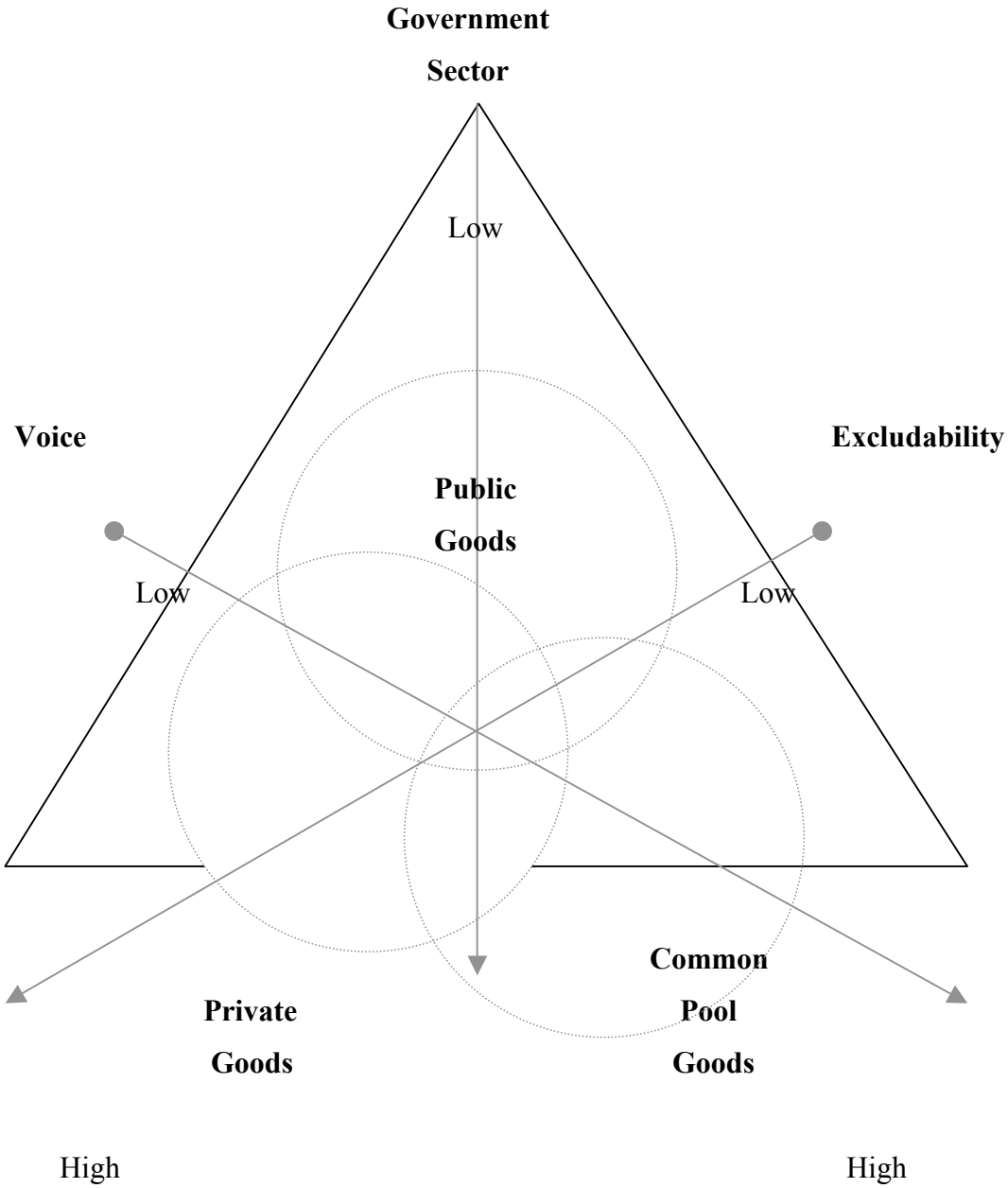
economic growth. Achieving the appropriate mix of public, private and industry institutions will play an increasingly important role in international competitiveness. A subset of this complex problem is to determine the appropriate role for public research.

The emerging area of "new institutional economics" has found that particular institutions tend to be better suited than others to govern particular types of transactions. Picciotto (1995) classifies institutions into three general types and then describes the type of attributes that these institutions best govern. Picciotto adds the dimension of "voice" to the dimensions of excludability and rivalry discussed earlier. In this dimension, some activities require the input or "voice" of the stakeholders to effectively govern the activity. For instance, an effective agronomic research program may need the input of farmers to be effective, whereas this voice may be less important in genomic research. The need for voice along with excludability and rivalry will influence which type of institution is best suited to govern the activity.

In Picciotto's framework three types of institutions exist : the government sector; the private sector; and the participation sector. For the government sector the stakeholders are all citizens of the state. The incentive in this sector is the re-election of the politicians so as to maintain power. Hence, they pursue goals for the best interest of the whole society (i.e. they try to maximize social welfare). A second type of institution is represented by the participation sector. This sector has stakeholders who voluntarily join, as they believe that benefits can be obtained by collective action. In research, the Western Grain Research Foundation would be a good example of this type of institution. The members of the participating sector represent a group in society with a common interest. The last sector is the private sector. Individuals who own property rights are the stakeholders of this sector. The main incentive here is to maximize their return to asset investment (profit). Hence, each sector represents different individuals with different incentives.

By combining the types of goods described in the previous section with the three sectors described by Picciotto, it is possible to visualize the types of institutional arrangements that are best suited for governing various types of research. Figure 5 illustrates how the concepts of rivalry (subtractability), excludability, and the various

types of goods can be used to determine the appropriate role of the three sectors in governing research.



Source: Picciotto 1995.

Figure 5: The Nature of Goods and Services

Within Picciotto's framework some institutional structures tend to be more effective than others at producing particular types of goods. The government sector is best at producing public goods (e.g. basic research) that are consumed by all citizens, and where the voice of interest groups is not important. Public goods are characterized by low excludability and low subtractability (rivalry). In this case, the low excludability makes privatization infeasible, and the broad common interest in provisions is best represented at the government level where free riding can be eliminated.

The participation sector is best at governing common pool goods (e.g., market research) or public goods where voice is important. These goods are non-excludable, which prevents them from becoming private goods. In addition, the benefits of common pool goods are often restricted to a group of individuals or firms who are in the position to use the goods. In this case, it is in the common interest of the group to manage the good (e.g. conduct market research) to their mutual benefit. It is also often the case that some group has greater interest in providing the good than the public at large, and has more of the information required to manage the resource, making voice important. In this case, the participation sector which might be an organization representing these stakeholders, may be able create an institution that is superior to using either the government or the private sector to govern this good provision. Gray, Malla and Phillips (2004) argue that the Rapeseed Association of Canada was instrumental in the development of the canola industry because they were able to systematically direct research resources to the needs most critical for the development of the sector.

The private sector tends to dominate goods that are excludable and non-rival (e.g. a patent protected technology developed through private research). The property of exclusion allows private firms to charge for the use of the good. This allows the producers of the good to sell at the marginal cost of production. Where potential hold-up problems exist (such as where several firms have an ownership claim on a research output), transactions take place within larger private institutions or between institutions

with long term contractual arrangements. However, excludability is not a sufficient condition to make a good the domain of the private sector. If a good has low subtractability then there are economies of size in its provision, resulting in the failure of a natural monopoly and creating the potential need for government intervention. Table 3 provides a summary of the role of each of the sectors, based on the level of excludability, subtractability and voice.

TABLE 3: PICCIOTTO'S TAXONOMY OF ATTRIBUTES FOR GOODS PRODUCED BY DIFFERENT SECTORS

	Excludability	Subtractability	Voice
Government Sector	low	low	low
Private Sector	high	high	-
Participation Sector	low	-	high

Source: Gray, Malla and Phillips, 2004

Table 2 can be used as a guideline for predicting the involvement of each of the sectors in agricultural research. Nonetheless, the fact that research goods vary in their excludability, rivalry, and need for voice, suggests that the potential involvement of more than one sector may be optimal. In general, we can say that public research is required to produce public goods that have high rates of return and in cases where private research (used to create private goods) has caused market failures such as a restriction in "freedom to operate". In the participation sector, firms still have incentive to conduct research but do it collectively. Public research may have a role in the participation sector but public resources may be more useful in "facilitating" collective private research by creating a favourable institutional environment (e.g. one where voice can be heard) for that research to occur. Private research is useful for providing private goods where private companies have exclusive rights to the benefits of that research.

6.0 An Analysis of the Types Agricultural Research and the Impacts of Public Sector Involvement

6.1 Introduction

As mentioned previously, a "one size fits all" approach to the provision and governance of research is unlikely to be optimal because there are many types of "agricultural" research, each addressing different issues, operating in different markets, with a different set of externalities and with different institutions. This section breaks agricultural research into a number of types, characterizes the outputs of each, and based on these characteristics, suggests which institutions are likely to be most effective for governance. The discussion focuses to a large extent on public research and the role it plays in maximizing benefits for society. Each of the research types that we discuss, therefore, have a substantial public research component to them.

Agricultural research is divided into six general types. At this level of resolution the fact that virtually every research endeavor differs in approach and target is obscured; however, it does serve to create a range of research types and allows for a discussion of the role of public research and how it can differ in the various forms of research.

6.2 Germplasm Traits for Improved Productivity

The public research sector has a long history in the development of crop genetics and until recently was involved in research activities ranging from the development of germplasm to the testing and development of registered grain varieties. While many universities, levy funded research organizations, and provincial governments continue in this practice, AAFC typically develops new germplasm for the private sector who further develops and takes ownership of new varieties. The role of the private sector in germplasm development varies a great deal by crop. In canola, large multinational breeding companies still rely on AAFC for germplasm to produce hybrid seeds. Corn has a very long history of private research related to hybrid seed production. For other major crops such as wheat, and to some extent soybeans, the public sector still plays a dominant role in germplasm development. In smaller crops such as mustard, flax or lentils, private

investment remains more limited and provincial and levy funded breeding research are more common. The private sector has made little investment in minor use crops.

For crops where property rights can be enforced through hybrid seed, technical use agreements or marketing agreements, the ability to enforce property rights has allowed firms to capture the downstream benefits from their research effort. This ability to capture benefits has attracted significant research investment, which in the case of canola has driven the social rate of return toward normal levels (Gray and Malla, 1998). In this situation, government subsidies could easily stimulate an excessive amount of research.

In industries where IP is firmly established, the private sector is still constrained by issues of industry concentration and market power, freedom to operate, and the downstream positive and negative externalities related to human health and the environment. In these industries there may be a need to stimulate competition by reducing barriers to entry, addressing FTO issues through new institutional relationships, and augmenting the private incentives to deal with health and environmental externalities.

In those crops where hybrid technologies and alternative IP protections do not exist, the current plant breeder's rights legislation provides only limited private incentive for germplasm and variety development. Once farmers have purchased seed, they are able to multiply and replant the progeny without royalty payments. Thus private plant breeders are able to capture only a small proportion of the downstream benefits of their innovation, allowing farmers, landowners, and other parts of supply change to capture the majority of the rents as spillovers. The lack of private incentive for this type of research has created the need for governments and levy funded organizations to fund this type of research. The prevalence of persistent high rates of return to these types of investment suggests that under funding continues to be an issue for these crops and that additional public research would create additional net social benefits.

The introduction of levy funded research is very important for funding research where the benefits spillover to farmers and downstream industry participants, and in this case, is best provided by a combination of the government and participation sectors. Research levies, if applied on all sales have a taxation incidence in the same proportion as the benefits that result from the research. For instance, when demand is very elastic

relative to supply, most of the burden and benefits accrue to producers. In the case of inelastic demand, consumers pay a portion of the levy through higher prices and accordingly receive a benefit of lower prices if the research increases supply. This feature of levies makes them particularly equitable and easier to govern because the rate of return will be similar across industry participants. Industry levies are also ideal in market conditions where foreign consumers are the main benefactors of research, (and therefore the main contributors to levies).

The need for government involvement in some levy funded research is results from underinvestment on behalf of participation sectors caused by weak market signals. This weakness in market signals comes from at least three sources. First, the voluntary nature of most research levies allows some producers, often larger producers, to free ride on the research expenditures of their neighbors. This "free rider" problem reduces the individual return from paying levies, and as a result, the industry will tend to set the levy below the optimal level in order to maintain participation. Second, levy funded research has a public good aspect and will inevitably create knowledge that will spillover to other locations, other time periods and other crops. Therefore, those who pay the levy may not be around to collect the dividends from their investment and thus have reduced incentive to invest. Finally, industry stakeholders may be concerned that an increase in levy funded research will displace and reduce the government support for research in the sector.

The solution to the free rider problem and the underinvestment by industry in levy based funding can be addressed by the induction of mandatory levies and application of matching funding by government. This is done in Australia with the GRDC, where industry levies are automatically matched with government contributions. In this case, the industry organization can still govern the research expenditures and set the amount of the levy knowing that their investment expenditures will be leveraged and matched by the government.

6.3 Local Adaptive Applied Research for Improved Productivity

The initial research focus of the experimental farms was to examine ways to adapt farming systems to the local agronomic conditions; hence the need for regional farms across Canada. While laboratory and genetic based research tends to have large

economics of scale, localized agronomic research may be required to address local production problems. These research activities also have a natural extension component to them as farmers can observe whether the practices are suitable for their local conditions. This relationship was evident in the adoption of the zero tillage. Davies and Furtan, (2006) found that the rate of zero tillage adoption was statistically higher in Crop Districts that contained AAFC research stations.

The private incentive for investment in regional agronomic research is often very limited as farmers can easily mimic the best farming practices without paying royalties. This leaves the role of agronomic research to the participation sector (industry organizations), the government sector or some combination of the two. In the case of the Canola Council of Canada, farmer involvement in the agronomic research program meant that recommendations were quickly adopted by the industry, thus highlighting the importance of "voice" in this type of research. In the case of zero tillage research, it was very much a three-way partnership between the producer (driven by soil conservation associations), the local AAFC agronomists, and the tillage machine manufacturers who were interested in the development of the technology. Because voice has been shown to be important in these types of research, the role of the participation sector should be emphasized. Governments should therefore find ways to continue supporting local producer driven organizations in agronomic research. To the extent that practices have environmental benefits, government can stimulate a market demand for mechanically based products by creating subsidies for Best Management Practices. For those agronomic technologies that provide an agronomic benefit and yet the technology cannot be embodied in a machine or a patented product, only environmental NGO's or the government will have an incentive to fund these activities.

6.4 Genomics and other Omics

Biotechnology has begun to revolutionize the ways in which crops can be improved. For example, transgenic technologies have allowed single gene traits to be transferred from one species to another, thus leading to the introduction of herbicide tolerant and insect resistant crops. These breakthroughs have not only lowered the cost of

production but have arguably resulted in significant environmental benefits. Other advances in biotechnology, particularly, structural genomics, transcriptomics, proteomics and metabolomics are also becoming important tools in crop improvement. Many aspects of the "omics" are at the frontiers of biological science and they require significant investment and scale of research to be competitive in these rapidly emerging fields.

The ability to enforce property rights and process patents has made research in biotechnology and the omics extremely profitable for private industry. At the same time, it has created externalities like the "freedom to operate" issues noted earlier. The developing standard practice of each new discovery being exclusively licensed to the highest bidder has the potential to create severe freedom to operate problems. As discoveries become more rapid it will become more important to find mechanisms to allow these discoveries to be widely implemented and combined with other discoveries and existing germplasm to create integrated packages that will compete with other crops in other countries. Keeping in mind these facts, it is important that public research focuses on allowing private firms to take advantage of economies of scale and synergies, while at the same time finding better ways to encourage the sharing of information for the benefit of the entire agriculture sector. Given the thrust of public institutions in place to protect IP, the recent movement has been in the opposite direction, which in effect has fragmented the public research effort in these areas.

This is the area of research where integration of Canadian public research organizations would have the greatest benefit. Not only does this type of basic research require scale and scope to be effective, it cuts across sectors and overlaps with animal and human health research. The optimal form of integration, the amount of integration and the institutions used govern a more integrated approach is a very complex issue that deserves particular attention in a national strategy. While examples in other countries may provide some models to consider, integration in Canada will be almost certainly challenged by existing institutions that will have to give up some autonomy.

6.5 Plant and Animal Health

Plant and animal health are commercially very important for the agricultural sector and require research efforts from both the private and government sectors. Private

sector research can help individual firms capture benefits by improving plant and animal health. Issues pertaining to safety are of public concern because a loss by one producer can spread disease to the entire industry. At the same time, the sporadic nature of major disease outbreaks also poses a problem for the private funding of research. An effective plant and animal health program has to maintain and develop capacity even in periods of time when the incidence of the disease and the private willingness to pay for disease mitigation is not there. For example, having experts on avian flu, BSE, and cereal rust, are prerequisites for effective disease management, yet the disease outbreaks are sporadic. Some forms of disease with a persistent presence, can create a commercial interest. In these instances, public agencies can work with the private sector and or industry organizations to undertake research in these areas. International projects and collaboration can also expand capacity in this type of research.

6.6 Food Safety and Biosecurity

The rationale for public research in the areas of food safety and biosecurity are similar to those identified for animal and plant health. The management of a safe food supply requires on-going research to maintain a capacity enabling a rapid response to new pathogens, toxins and terrorist threats. The lack of private incentives to maintain a stock of expertise, however, suggests that publicly funded research will remain important. For some food safety issues, a persistent threat can create a commercial interest and like animal and plant health, the need to maintain food safety has a large non-excludable component. These characteristics make it ideal for public and/or participation sector involvement. The public sector will thus need to collaborate with the participation and/or private sectors to undertake research in these areas.

6.7 Environmental Systems Research - Bio-diversity, GHGs

Environmental health tends to be a common pool resource and yet it is an important public and social issue that remains largely external to the market place. While individuals may collectively benefit by emitting less GHG, there are few private incentives to do so. Given the common pool problem, private markets will fail to allocate

enough resources toward environmental quality. This leaves a good deal of research in the public domain if it is to be done at all.

Where there are both public environmental benefits and other private benefits, such as zero tillage technologies, the private and/or participation sectors can still play a role and be vital partners in the development of new technologies. The private sector controls the vast majority of managed landscapes in the country, and because agriculture is inextricably linked to the environment, the private sector can have a large impact on GHG emissions, water pollution, and the provision of environmental amenities such as wildlife habitat. As with many forms of research, however, as long as a portion of the environmental benefits are external to the market, the private sector will tend to under-invest in these activities. It may therefore be important for the government sector to support these activities to bring about the optimal amount of research. The introduction of market mechanisms, such as payments for carbon sequestration, can also facilitate the development of a private or participation research sector, as industry adopting these technologies may become willing to pay for it.

6.8 Human Nutrition

Long-term productivity improvement has led to income growth and citizens have become generally wealthier. Wealthier citizens, whose basic needs have been met, now place a greater emphasis on the quality of life, increasing the political and economic importance of improved human health. The importance of human health is further augmented by an aging population, which has increased the overall cost of health care to society. Given that health care costs now make up over 10% of the Canadian GDP, improving human health should be part of national research strategy.

Despite its economic and political importance, there are very large externalities associated with the market provision of human health. For example, the existence of public health services in conjunction with private insurance means that individuals bear only of small portion of the health care costs associated with their illness. In effect, the health insurance creates a moral hazard, and reduces the private incentive for consumers to pursue wellness and to demand healthier foods.

While private companies are able to capture significant benefits from the production of new pharmaceuticals, this process is much more difficult with functional foods and neutraceuticals. The lack of human nutritional research is apparent across a very wide spectrum of food products. A good example is the recent studies on Vitamin D that show this nutrient can significantly lower the risk of cancer. Although this was identified as an important vitamin many decades ago, the Canadian Cancer Society has only limited very information to base its new recommendations on. The inability of private firms to capture value from nutrients has contributed to the lack of nutritional research. The lack of private incentive to undertake this research suggests a need for the public sector to find new mechanisms to fund this research.

Agriculture is linked to human health through nutrition and also through food and animal born diseases. Food borne diseases can have a direct negative impact on human health, so managing the foods system to protect consumer from these illnesses has been an important role of public agencies. Recent examples of this are outbreaks of BSE and avian flu. Some would argue that research in the area of health and nutrition falls outside the scope of agriculture yet these concerns do have a direct impact on what is produced and eaten in Canada. Therefore, it is a good example of where agricultural research may have a natural area of overlap with research in another sector of the economy.

6.9 Economics Research – Transparency, Foresight , and Institution Building

Over the past century, public research efforts have focused to a large extent on increasing the productivity and efficiency of crop and animal production. It is important to emphasize that many of recent changes in agriculture require that science and innovation be examined in the context of the emerging global economy. Economic research can play a vital role in the governance of an economy in three areas: transparency, foresight, and institutional development. Each of these is defined below.

- Transparency - The economic analysis of existing regulations, policies, and institutions, can improve transparency by estimating economic and social impacts.
- Foresight - Economic analysis is a useful tool in anticipating the outcome of changes in technology, prices, consumer tastes and government policy.

- Institutional development - By understanding the response to incentives, economics can be a useful tool in developing institutions that better align participants in achieving a particular outcome.

Economic research can fall within the private or public domain. When used as a tool for internal decision making of a private firm it can be a private good. Economic research that is targeted at policy analysis or industry analysis and foresight, tends to produce non-rival, non-excludable, public goods, and will therefore tend to exist only in the public domain. The outcome of economic research is often perceived as most valuable when seen to be the result of an impartial third party analysis. This can create a dilemma for public organizations as they wish to have an impartial analysis but at the same time can be the only source of funding for the research. This creates a demand for new institutions to manage economic research that are publicly funded but yet can operate at arms length from the day-to-day funding decisions of the government in power.

References

Campbell, Z., Jalili, R. and J. Vercammen, 2007. *Producer-Funded R&D for Prairie Agriculture.* Policy Brief of Canadian Agricultural Innovation Research Network (CAIRN). Saskatoon, SK.

Carew, Richard. 2000. *Intellectual property rights: Implications for the canola sector and publicly funded research.* Canadian Journal of Agricultural Economics 48 (2): 175–94.

Davies, K. and H. Furtan, 2006. *Factors which affect the adoption decision of conservation tillage in the Prairie Region of Canada*. An unpublished paper Department of Agricultural Economics, University of Saskatchewan, SK.

Falcon and Fowler, 2002. *Carving up the commons—emergence of a new international regime for germplasm development and transfer*. Food Policy 27 (2002), pp. 197–222.

Foresight Expert Group, 2007. *Towards Future Challenges of Agricultural Research in Europe*. A discussion paper based on the EU conference in Stockholm, Sweden.

Fowke, V. 1946. *Canadian agricultural policy: the historical pattern*. University of Toronto Press: Toronto, ON.

Gray, R., Fulton, M. and H. Furtan, 2007. *The Provision of Goods and Farm Policy in Canada*. Working Paper. Department of Agricultural Economics, University of Saskatchewan, Saskatoon, SK.

Gray, R.S., Malla, S. and P. Phillips, 2006. *Product Innovation in the Canadian Canola Sector*. Supply Chain Management: An International Journal, 11(1): pp 65-74.

Gray, R. and S. Malla, 2001. *The Evaluation of the Economic and External Health Benefits from Canola Research*. In Julian M. Alston and Philip Pardey and Michel Taylor (eds.), Agricultural Science Policy, John Hopkins University Press.

GRDC Website, 2007. http://www.grdc.com.au/

Huffman W. and R. Just, 1992. *Economic Principles and Incentives: Structure, Management, and Funding of Agricultural Research in the United States*. American Journal of Agricultural Economics, V. 74 (5), pp. 1101-08.

Industry Canada, 2007. Canada's New Government: Mobilizing Science and Technology Strategy. Ottawa, ON.

Klein, K.K., 1985. *Chapter 1: Economics, Research, and Agriculture*. In Economics of Agricultural Research in Canada. K. Klein and W.H. Furtan (eds). University of Calgary Press.

Kowalski, Stanley P., Reynaldo V. Ebora, R. David Kryder and Robert H. Potter, (2002) *Transgenic crops, biotechnology and ownership rights: what scientists need to know*. The Plant Journal 31(4):407-421.

OECD, 2007. *Main Science and Technology Indicators - Principaux indicateurs de la science et de la technologie*. Vol. 2007, no. 1, pp. 1 - 102

Picciotto, R. 1995. *Putting Institutional Economics to Work: From Participation to Governance*. The World Bank Discussion Paper 304. Washington, DC: The World Bank.

Romer, P.M. 1990. *Endogenous Technological Change*. Journal of Political Economy 98(5, Part 2): 71-102.

Romer, P.M. 1994. *The Origins of Endogenous Growth.* Journal of Economic Perspectives 8(1): 3-22.

Smith, Adam (1776). *The Wealth of Nations*. Edited by Edwin Cannan, 1904. Reprint edition 1937. New York, Modern Library.

Veeman, T., Untershultz J. and B. Stewart, 2007. *Canadian and Prairie Agricultural Productivity: Measurement, Causes, and Policy Implications*. Presentation made at CAES Conference on Food and Fuel: The Implications for Agricultural Research Policy, Saskatoon, SK.