CAIRN Policy Brief

Canadian Agricultural Innovation Research Network

Number 11, October 2007

CAIRN

The Rate of Return to Agricultural Research in Canada

By Richard Gray and Stavroula Malla

The Issue

One of the prerequisites for continued support for public agricultural research has to be high rates of return from the investment of scarce tax dollars. Government of Canada research stations were first established in the 1880s and played a critical role in productivity improvements and the development of the agricultural sector. The support for public investment in these institutions was sustained due to a long history of demonstrated high rates of return.

In the last twenty-five years, there has been some profound changes in many aspects of agricultural research, including: 1) the science of genetic improvement; 2) enhanced intellectual property rights; 3) increased private sector involvement; 4) new roles and relationships for public research; and 5) a reduction in the level of public investment in research. The purpose of this brief is to provide an updated overview of the studies that examine the rate of return in Canadian agricultural research, and to summarize the results for policy makers.

Policy Implications and Conclusions

Economic theory suggests that the incentives for private investment in research are inadequate if some research spillover benefits go to others who do not pay for the research. This lack of private incentive creates underinvestment in research and correspondingly creates a high social rate of return for the limited dollars that are expended. The extent to which underinvestment persists in Canadian agricultural research is an empirical question addressed in this brief.

Our review of rate of return studies found a significant amount of compelling evidence that the rate of return from investment in agricultural research has historically been very high and generally remained so. These high rates of return, which are consistent with many international studies, suggest a persistent underinvestment in agricultural research by both the public and private sectors.

The one exception to the general finding of high rates of return to applied research is in the canola sector, where significant private investment has occurred. Not surprisingly, this is also the crop sector that makes widespread use of patented technology and more recently hybridization, both of which virtually eliminate downstream spillovers. Given the ability to capture full value from their research, large private investment has driven the rate of return down closer to general market rates of return.

The persistent high rates of return to applied research in most crop sectors strongly suggest that, from a Canadian perspective, additional research is desirable. How to best achieve this result, and the extent that it should be public or private, are important and difficult policy questions. Each form of policy will have implications as to how much research is done and its effectiveness, as well as who will pay for the research and who will benefit.

Canadian Agricultural Innovation Research Network
51 Campus Drive
Saskatoon, SK
S7N 5A8

General Inquiries: 306.966.4026
Fax: 306.966.8413
Email: cairn@usask.ca

Additional briefs at:
www.ag-innovation.usask.ca

For those crop sectors where there is little prospect of non-farmer private investment, a *prima facie* case can be made to divert safety net expenditures toward additional public expenditures on applied research. With high rates of return, money invested in research could be a cost effective means of increasing sector competitiveness and reducing the need for income support.

Background

Historically, most agricultural research in Canada was carried out in public institutions, either at federal government experimental farms or publicly funded university research farms. For the most part, research funds came from government, particularly the federal government. The output from the research, whether new varieties of seed (Marquis wheat), new crops (canola), or improvements in livestock techniques, was deemed to be a "public good" and was therefore given freely to producers (e.g., Huffman & Evenson, 1993; Alston & Pardey, 1999; Gray, Malla, & Ferguson, 2001).

The need for public research in Canada was initially driven by a lack of private investment in research. Many products or ideas generated from research could easily be reproduced and shared without remuneration to the researcher. This was evident in agronomic practices that could be mimicked and in the production of new crop varieties where crop output could be retained and shared to provide seed for future years. Given the inability for a researcher to capture full value from the research, private investment in these essential forms was very limited.

Without research, adapting agricultural systems to the harsh climate in western Canada was a formidable barrier to settlement. By 1885, it was clear the strategy to settle the west was failing, while at the same time the success of the U.S. land grant research system was apparent. In the 1886, when experimental farms were established in Canada, agricultural research was seen as a necessary but missing element of the national policy to develop the wheat economy and settle the West (Fowke,1946). Soon after their establishment, experimental farms played a key role in developing the agronomic practice of summerfallow and producing the Marquis wheat variety. The public funding of agricultural research has continued to be a significant aspect of Canadian agricultural policy until today.

In recent years, property rights have been established for many of the products of agricultural research. Following the negotiation of a new "International Union for the Protection of New Varieties of Plants" (UPOV) agreement in 1978, Canada began to talk about implementing plant breeders rights domestically, a new form of intellectual property rights for the agri-food sector. The Canadian Plant Breeders Rights Act was passed in 1990 (Malla, Gray, & Phillips, 1998). In 1980, a U.S. Supreme Court decision explicitly allowed patents for living organisms (Lesser, 1998). Many patents of biotechnological processes have also registered. Moreover, changes in technology for some crops such as the creation of herbicide-tolerant varieties and hybrids have also increased the ability of private research firms to capture value from the products of research. The changes in law and technologies have created enforceable property rights, which, in turn, have conferred monopolistic rights to the inventor, leading to increased private investment in agricultural research.

The privatization of research has created a number of new issues. Intellectual property rights (IPRs) create non-rival excludable goods, which alter the structure of agricultural industry. Traditionally, technological advantage was a non-rival and non-excludable good.[1] The product of research and development (R&D) work, which can be new product, new technology, or even new knowledge, is a non-rival good, meaning that one can use the technology created from R&D repeatedly without exhaustion. With IPRs, the innovator has the ability to exclude others from using, reproducing, or selling the new technology or product created from R&D (e.g., Fulton, 1997). Moreover, the inherent non-rival nature of agricultural research output tends to create a concentrated private industry as firms move to capture economies of scale and scope (Fulton & Giannakas, 2001). Furthermore, the transaction cost of negotiating a "freedom to operate" is quite high, especially when there are many owners of the IPR to enabling or primary technologies. This high transaction cost "shuts out" breeding firms and deters entry by other firms. A further push toward integration occurs as firms adopt strategies, such as vertical integration, mergers, acquisitions, and joint venture arrangements to preserve their own freedom to operate (e.g., Kalaitzandonakes & Bjornson, 1997; Lesser, 1998; Lindner, 1999; Falcon & Fowler, 2002). Finally, the concentrated nature of the research industry and the exclusive ownership of key pieces of IPRs give research firms some degree of market power, which, through higher prices, reduces the incentive for product innovation and adoption downstream (e.g., Mochini & Lapan, 1997; Malla & Gray, 2003; Lindner, 1993; Perrin, 1994; Fulton & Keyowski, 1999; Alston & Venner, 2000; Malla & Gray, 2005).

The increased incentive for private research has resulted in a dramatic increase in the private funding of crop research in Canada. This has been particularly apparent in canola research, where research has shifted from a modest public research program to a large research industry dominated by private sector participation. In 1970, eighty-three percent of the total research spending on canola ($3 million) was public investment, while seventeen percent was private investment. Ten years later, research investment was sixty-three percent public vs. thirty-seven percent private. By 2001, the private firms were capturing over $250 million in revenue and had nearly completely crowded out public sector sales (Canola Research Survey, 2000). This funding shift is consistent with the registration of new varieties. Prior to 1973, all varieties (thirteen varieties) were public, while in the 1990-98 period eighty-six percent of varieties (162 varieties) were private (Gray, Malla, & Phillips 2001). Furthermore, by 2000, about eighty percent of the canola acreage was seeded to herbicide-tolerant varieties that required annual technology use agreements or the use of a specific herbicide.

Policy implications

There have also been many concerns raised about potential adverse effects from the privatization of agricultural research, which suggest a need for government involvement in R&D. Examples of these include increased input costs, reduced competition in research sector, and breeding firms' freedom to operate. Others have raised concerns that private research is often biased toward applied research, creating a potential vacuum in basic research when all research is privately funded. Without basic research, real breakthroughs may not be made. Canola, for example, would never have been developed without many years of publicly funded basic research.

The price of basic research or how access to the public innovation is granted, and the appropriate management of public intellectual property, is a very important economic issue. In general, when basic research creates rents for applied research, then giving away or under-pricing will result in exhaustion from entry and reduction in social welfare relative to the case where product is properly priced. Moreover, public and private research firms are integrally linked through numerous types of research spillovers. It has been shown that publicly funded basic and applied research both had positive effects on private research productivity and profitability.

Lastly, it has been shown that private firms invest less in R&D than the socially optimal amount even with fully appropriable IPRs because they cannot fully appropriate all the research benefits generated from their investment. Given that the research firm making the investment in research cannot capture the increase in surplus going to the buyers of their product (i.e., farmers), their private marginal benefit from research is less than the socially marginal benefit. Research firms are only concerned with their private benefits from an R&D investment and not the spillover effects that their action may have on others. Therefore they will underinvest in R&D relative to the social optimum.

Summary

While the public sector has historically played a very significant role in the direct provision of agricultural research (based on the notion that research output was a public good), the appropriate role of government in the future is no longer apparent in a world of intellectual property rights and a concentrated privatized biotech research industry. When IPRs are incomplete, there are inadequate incentives for private research, creating a market failure. To the converse, most pulse crops and wheat varieties are freely distributed, or distributed with minor royalty costs.

Agricultural research has undergone a major transformation in Canada. In recent years, intellectual property rights have been established for many of the products of agricultural research. Moreover, government funding of research has also changed. These changes have increased the incentive for private research, which in turn has resulted in a dramatic increase in the private funding of crop research in Canada. The large influx of private investment has led to the conclusion by some that the establishment of property rights for products of agricultural research has been so successful that there is no longer a role for public investment in crop research. Concerns by others, however, have been raised about potential adverse effects from the privatization of agricultural research, suggesting a need for government involvement in agricultural R&D.

Returns to Research

The main nature of the evidence supporting government involvement in R&D is high rates of return. There have been many studies that have examined the rate of return to agricultural research within specific crops and have found very high rate of return, often thirty to fifty percent or greater. The following section presents a brief summary of return to research studies.

Alston, Marra, Pardey, and Wyatt (1998) collected post-war 294 studies, which provided 1,858 estimates of returns to R&D investment. They analyzed the results of these studies to examine the returns to agricultural R&D literature and to examine the sources of differences among studies. They found some very high rates of return to research with a lot of variation, and concluded that:

> In the 95 percent data set, the overall average rate of return across all 1,144 observations was 58.6 percent per annum, with a standard deviation of 51.7 (the estimated annual rate of returns averaged 64.2 percent for research only, 46.3 percent for research and extension combined, and 75.6 percent for extension only.) In the second data set the overall average rate of return across all 1,181 observations was 63.4 percent per annum with a standard deviation of 66.7 (the rate of return averaged 70.5 percent for research only, 49.7 percent for research and extension, and 75.6 percent for extension only) …. There is no evidence to support the view that the rate of return has declined over time (p. 27).[2]

Brinkman (2004) provided a summary of returns to agricultural research Canadian studies from 1978-2001, and showed that agricultural research typically generates very high returns on investment (see Table 1). Specifically:

> The benefit-cost ratio was 27.5:1 for the aggregate total of Ontario agricultural research undertaken between 1950 and 1972. Federal government livestock research activities undertaken in the 1970s and mid 1980s also generated high benefit-cost ratios, ranging up to 114.6:1 for dairy and 48.3:1 for beef cattle. Lower returns were realized for hogs at 9.5:1 and for sheep at 2.1:1, primarily because of less effective research in the case of hogs and a very small market in the case of sheep. Research studies in western Canada also show high returns, with benefit-cost ratios ranging from 12.1:1 to 34.1:1 for barley, wheat and rapeseed, and 37.1:1 for beef. The returns to agricultural research also tend to be considerably higher than for other types of public agricultural investment activities …. Overall, it appears that public agricultural research is one of the highest payback uses of public funds (p. 132).

Returns to canola, wheat, pulse research in Canada

Previous research has shown very high rates of return for canola research. Nagy and Furtan (1978) published the first evaluation of public investment in canola research and development. For the period 1960–1974, they calculated the internal rate of return (IRR) from improved yield research to be 101%. Ulrich, Furtan, and Downey (1984) updated the estimates of IRR in canola research for period 1951 to 1982, and calculated the IRR from improved yield research to be 51%. Ulrich and Furtan (1985) incorporated trade effects and found the estimated Canadian IRR from higher yielding varieties to be 50%.

Canola research in Canada has moved from a small publicly funded research program to a large privately dominated research industry with recent annual investment exceeding 160 million dollars per year. This phenomenally large private growth in research investment might suggest a very high rate of return to Canola research. However, Malla and Gray (1999) reached the opposite conclusion. Their analysis shows that the large influx of investment in the 1980s and 1990s was not accompanied with significantly faster increases in crop yields. The rate of return has diminished since the early 1980s and approached market rates by the mid-1990s. Their analysis shows that the average IRR initially exceeded 25% per year and declined steadily during 1970 to 1999, ultimately approaching the level of market returns. The IRR for the marginal dollars invested each year shows a much more dramatic decline and is well below the market rates of returns during the 1990s.

In Canada, quantitative estimates of the return to public investment in crop research and development have been relatively recent. **Zentner (1982)** performed the earliest published evaluation of public investment in wheat R&D, examining the period 1946-1979. Zentner's results revealed that the average IRR to government investment in wheat breeding research was 34% per year and the marginal IRR 44% per year. He also found the average IRR due to all wheat research and extension programs equaled 39%, and the marginal IRR equaled 59%. Two years later, these findings were published in an academic journal as Zentner and Peterson (1984).

The Ulrich and Furtan (1985) two-sector model, which included Canada and foreign countries, revealed that the Canadian IRR from higher yielding varieties was 28% per year, and the total IRR from higher yielding varieties was 28%. In dollar terms, they found marginal Canadian benefits of $77.60 for every additional dollar spent on wheat breeding in Canada.

Klein, Freeze, and Walburger (1996) estimated the rate of return to yield-increasing research on wheat for the period 1962-1991. They estimated the cost of yield-increasing research for the 1962-1992 period and the benefit for the 1972-2001 period. According to Klein, Freeze, and Walburger's 1995 study, the IRR from improved research ranged between 27% and 33% at low 1991 prices and from 34% to 38.9% at high 1991 prices.

Gray and Malla (2000) estimated the annual return to yield increasing wheat research. Wheat research expenditures have remained nearly stable, with a small decline in recent years. Unlike canola research, the private sector has not invested substantially in wheat research. Although canola has become a major crop in western Canada, wheat continues to be the largest crop grown in the region. Three points are worthy of note. First, the rate of return has averaged about 40% per annum. This high rate of returns in part is due to the large area of wheat grown each year. Second, the rate of return fluctuates a great deal. This indicates that the research is risky and that it is often many years between breakthrough varieties. The peaks correspond to rapid increases in the yield index due to the release and adoption of the breakthrough varieties, while the troughs represent the years where the yield index is not increasing (the sporadic returns is due to the kernel hardness constraints and the hexaploid nature of wheat). Three, there is no sign that these rates of return are decreasing.

Pulse research in Canada remains dominated by the public sector with significant support from producer check-off funds. The return to yield increasing research is difficult to estimate given the short history of these crops. Gray, Malla, and Ferguson's (2001) preliminary estimate of the rate of return on green and yellow peas (assuming that 1999's crop acreage will continue into the future) was just over a 20% annual rate of return. This calculation suggests that investments in pulse research have, to this point, been a good use of taxpayer and producer dollars. If these crops continue to grow in acreage as expected, the rate of return will increase further. It is also important to note that the gain to the pulse crop research was very limited for the first decade, suggesting very long lags between research expenditure yield improvement.

Recent returns to research studies in Canada

More recently, Gray and Scott (2003), Scott, Guzel, Furtan, and Gray (2005), and Scott, Furtan, Guzel, and Gray (2005) estimated the returns to agricultural research in Canada.

Gray and Scott (2003) estimated the returns to the Saskatchewan Pulse Growers' (SPG) research. Since 1984, the SPG, which is a grower-funded agency, has been collecting check-offs from growers, subsequently investing them in research and development.

An overall industry benefit/cost was calculated, which included producer surplus, consumer surplus, and value-added-in related sectors, as well as benefit to cost ratio and internal rate of return for growers. The study compared the stream of benefits and cost "with SPG" and "without SPG" while considering the stream of benefits over two different time periods (1984-2020 and 1984-2008).

For the period 1984-2020, the results show that the overall producers' benefit to cost ratio is 15.63 to one (12.80 to one on genetics research and 16.98 to one on development acceleration), while the IRR on genetic research is estimated at 20.4 %. The overall benefit to cost ratio is reduced to 6.07 to one (16.98 to one on genetics research and 13.46 to one on development acceleration), and the IPRs on genetic research is estimated at 18.0%. Similarly, an overall industry benefit to cost ratio is equal to 24.38 to one (34.57 to one on genetics research and 31.32 on development acceleration) in the period 1984-2020, while it is 15.05 to one (34.57 to one on genetics research and 28.35 to one on development acceleration) for the period 1984-2008. To sum up, Gray and Scott (2003) found quite high benefit to cost ratios, hence very significant returns to pulse research.

Scott, Guzel, Furtan, and Gray (2005) estimated the economic returns to western Canadian wheat and barley growers from Western Grains Research Foundation (WGRF) R&D check-off investments in crop genetics for wheat and barley. Specifically, the benefit to cost ratio and internal rate of returns to growers were calculated on WGRF check-off expenditures on wheat and barley breeding programs. The study compared the producers' returns "with WGRF check-off" to "without WGRF check-off," and the difference of the two results in the return to wheat and barley producer check-off investments in crop genetics R&D. On the cost side, the WGRF has administrated almost $40 million of check-off contributions ($33 million from the wheat and $7 million from the barley producers) between 1995 and 2004. The producers' benefits are estimated as the returns to fixed factors of production (producer surplus) for the period 1998 to 2020.

Scott, Guzel, Furtan, and Gray (2005) have shown significant returns to producers' check-off investments. Specifically, for wheat growers, the benefit to cost ratio is 4.4. to one while the IRR is 23.8%. Similarly, the benefit to cost ratio for producers for the barley check-offs is 12.4 to one, and the IRR is 36 %. Hence, every check-off dollar invested in crop genetics R&D results in a $12.40 increase in producer surplus for barley producers and $4.40 for wheat producers.

Scott, Furtan, Guzel, and Gray (2005) estimated the returns to research by Saskatchewan agriculture and the Food's Agriculture Development Fund (ADF) expenditures on crop genetics R&D. Specifically, the study calculates the benefit to cost ratios and the internal rate to return for ADF investment on R&D; the rationale for ADF involvement in crop genetic R&D; the broader benefits beyond Saskatchewan borders of ADF research investment; and the benefits for the University of Saskatchewan's teaching capacity. On the cost side, the ADF's (1985-2004) and the federal/provincial Agri-Food Innovation Fund's (AFIF) (1995-2004) costs are an estimated $68.4 million. The producer's benefits are estimated as increases in producer surplus for canola, pulses, wheat, durum, barley, oats, flax, and stream from 1990 to 2020.

Scott, Furtan, Guzel, and Gray (2005) estimated that the Saskatchewan producers' (or producer surplus) benefit to cost ratio is 3.43 to one for ADF crop genetic R&D investment, while the IRR is 17.8%. Similarly, the total (producers and consumers surplus) benefit to cost ratio is .95 to one and the IRR is 20.6%. Hence, every dollar invested in crop genetic R&D generates $4.95 in producer and consumer surplus ($3.43 increased in producer surplus). The study also concluded that the high returns to research to ADF investment reinforced the ADF role on R&D.

Scott, Furtan, Guzel, and Gray (2005) also stated:

> For a number of reasons, there is a strong policy rationale for ADF, as a provincial agency, to be involved in funding crop genetics R&D. First, ADF can assist in developing varieties for crops which are not large enough in acreage to attract private sector investment. Second, ADF can support the R&D often required to adapt

Table 1: Returns to Research

Study	Commodity	Returns to Research	
		Benefits to costs ratio (B/C), (Ratio)	Internal Rate of Returns (IRR), (%)
Alston, Marra, Pardey, and Wyatt, 1998	Meta analysis (294 studies)		58.6-63.4
Nagy and Furtan, 1978	Canola	17.64[1]	101
Zentner 1982	Wheat		34-59
Prentice and Brinkman, 1982	Total Ontario ag. research	27.5[1]	
Ulrich, Furtan, and Downey, 1984	Canola		51
Bates, 1984	Ontario canola Wheat	20.0[1]	
Zentner and Peterson, 1984	Wheat	14.5[1]	
Ulrich and Furtan, 1985	Wheat	77.6	28
Ulrich and Furtan, 1985	Canola		50
Farrell and Funk, 1985	Plant biotech	n.a[1]	
Ulrich, Furtan, and Schmitz, 1986	Malt barley	12.1[1]	
Furtan and Ulrich, 1987	Rapeseed	34.1[1]	
Guindo, 1987	Ontario hybrid corn	23.6[1]	
Widmer, Fox, and Brinkman, 1988	Beef cattle	48.3[1]	
Horbasz, Fox, and Brinkman, 1988	Sheep	2.1[1]	
Haque, Fox, and Brinkman, 1989	Egg layers	34.4[1]	
Huot, Fox, and Brinkman, 1989	Hogs	25.0[1]	
Zachariah, Fox, and Brinkman, 1989	Chickens	9.5[1]	
Fox, Roberts, and Brinkman, 1992	Dairy cattle	26.9[1]	
Thomas et al, 2001	Hogs	13.2[1]	
Klein et al, 1994	Beef; Beef and crops	114.6[1]	
Klein et al., 1996	Wheat	6.4-24.6[1]	27-38.9
Malla and Gray 1999	Canola		Initially exceeded 25; declined to market returns; (40⑧7)
Gray and Malla, 2000	Wheat		40
Gray, Malla, and Ferguson, 2001	Pulse		20
Gray and Scott, 2003	Saskatchewan Pulse Growers (SPG)	28.35 - 31.32	
Scott, Guzel, Furtan, and Gray, 2005	Western Grains Research Foundation (WGRF) Check-off Investments Wheat Barley	4.6 13.1	24.4 36.8
Scott, Furtan, Guzel, and Gray, 2005	Agriculture Development Fund (ADF)/Agri-Food Innovation Fund (AFIF) Crop Genetics R&D	4.95	20.6

[1] Brinkman. 2004: 133.

crops to Saskatchewan's environment. Third, ADF involvement can mean getting research results into farmers' hands at more competitive costs. Fourth, ADF can directly assist and complement Saskatchewan producers' efforts, such as check-off systems, to deal with these same challenges with respect to crop genetics technology (p. v).

Overall Results

High rates of returns (a large number of studies have found a very high social rate of return to agricultural R&D, often 30-50% or greater); many small producers; poor property rights; "freedom to operate"; underprice (public) basic research; low agricultural research incentives; and underinvestment in R&D are evidence supporting government involvement in R&D.

Overall, there is a role for public support of agricultural research, even with establishment of completely enforceable IPRs and biotechnologies, but this role has probably changed in today's agriculture.

References

Alston, J.M., Marra, M.C., Pardey, P.G., & Wyatt, T.J. (1998). Research returns redux: A meta-analysis of the returns to agricultural R&D. *EPTD Discussion Paper No. 38*, 44 pp.

Alston, J.M., & Venner, R.J. (2000). The effects of the U.S. Plant Variety Protection Act on wheat genetic improvement. *EPTD Discussion Paper No. 62*, 33pp.

Brinkman, G.L. (2004). Strategic policy issues for agricultural research in Canada. *Current Agriculture, Food & Resource Issues 5*, 131-147.

Canola Research Survey. (2000). College of Agriculture, University of Saskatchewan.

Falcon W.P., & Fowler, C. (2002). Carving up the commons—emergence of a new international regime for germplasm development and transfer. *Food Policy*. Retrieved 15 September 2006, from the World Wide Web: www.elsevier.com/locte/foodpol.

Fulton, M.E. (1997). The economics of intellectual property rights: A discussion. *American Journal of Agricultural Economics 79*, 1592-94.

Fulton, M., & Giannakas, K. (2001). Agricultural biotechnology and industry structure. *AgBioForum 4*(2),137-51.

Fulton, M.E., & Keyowski, L. (1999). The producer benefits of herbicide-resistant canola. *AgBioForum*. Retrieved 15 September 2006, from the World Wide Web: http://www.agbioforum.org/v2n2/v2n2a04-fulton.htm

Gray, R., & Malla, S. (2000). *The effectiveness of research funding in the wheat industry.* A report prepared for Agriculture Development Fund.

Gray, R., Malla, S., & Ferguson, S. (2001). *Agricultural research policy in Canada: Past experience and future directions*. A report prepared for Saskatchewan Agriculture and Food.

Gray, R., Malla, S., & Phillips, P. (2001). Industrial development and collective action. In P. Phillips and G.G. Khachatourians (Eds.), *The biotechnology revolution in global agriculture: Invention, innovation and investment in the canola sector* (pp. 83-105). Wallingford, Oxon, UK: CABI Publishing.

Gray R., & Scott, T. G. (2003). The returns to research. A report prepared for Saskatchewan Pulse Growers, No. GEN 0320. Saskatoon: University of Saskatchewan.

Huffman, W.E. & Evenson, R.E. (1993). *Science for agriculture: A long-term perspective.* Ames: Iowa State University Press.

Kalaitzandonakes, N., & Bjornson, B. (1997). Vertical and horizontal coordination in the agrobiotechnology industry: Evidence and implications. *Journal of Agricultural and Applied Economics 29*(1), 129-39.

Klein, K. K., B. Freeze, & Walburger, A. M. (1996). Economic returns to yield-increasing research on wheat in western Canada. *Canadian Journal of Agricultural Economics 44*(3), 207–208.

Lesser, W. (1998). Intellectual property rights and concentration in agricultural biotechnology. *AgBioForum*. Retrieved 15 September 2006, from the World Wide Web: http://www.agbioforum.org/v1n2/v1n2a03-lesser.htm

Lesser, W. (1998). *Managing IPR and the agricultural research process: Lessons from university technology transfer offices*. Paper presented to

the NC-208 meeting at CIMMYT.
Lindner, R. (1999). *Prospects for public plant breeding in a small country*. Presented at the ICABR conference, The Shape of the Coming Agricultural Biotechnology Transformation: Strategic Investment and Policy Approaches from an Economic Perspective. University of Rome, Tor Vergata, Rome and Ravello.
Lindner, R.K. (1993). Privatizing the production of knowledge: Promise and pitfalls of agricultural research and extension. *Austrian Journal Agricultural Economics 37*, 205-225.
Malla, S., & Gray, R. (1999). *The effectiveness of research funding in the canola industry.* A report prepared for Saskatchewan Agriculture Development Fund. Regina.
Malla, S., & Gray, R. (2003). Public research policy for today's agricultural biotech research industry. *Canadian Journal of Agricultural Economics 51*, 347-369.
Malla, S., & Gray, R. (2005). The crowding effects of basic and applied research: A theoretical and empirical analysis of an agricultural biotech industry. *American Journal of Agricultural Economics* 87(2), 423-438.
Malla, S., Gray, R., & Phillips, P. (1998). *The evaluation of canola research: An example of success*. A report prepared for the Saskatchewan Agriculture Development Fund.
Moschini, G. & Lapan, H. (1997). Intellectual property rights and the welfare effects of agricultural R&D. *American Journal of Agricultural Economics 79*, 1229-42.
Nagy, J.G., & Furtan, W.H. (1978). Economic costs and returns from crop development research: The case of rapeseed breeding in Canada. *Canadian Journal of Agricultural Economics 26*, 1-14.
Perrin, R.K. (1994). Intellectual property rights in agricultural development. In J.R. Anderson (Ed.), *Agricultural Technology: Policy Issues for the International Community* (Chapter 27). Wallingford: CAB International.
Scott T.G., Furtan, H., Guzel, A., & Gray, R. (2005). *Returns to research, Agriculture Development Fund, expenditures on crop genetics*. Saskatoon: University of Saskatchewan.
Scott T., Guzel, A., Furtan, H., & Gray, R. (2005). *Returns to research, Western Grains Research Foundation, wheat and barley check-offs*. Saskatoon: University of Saskatchewan.
Ulrich, A., Furtan, H., & Downey, K. (1984). *Biotechnology and rapeseed breeding: Some economic considerations*. A manuscript report prepared for the Science Council of Canada.
Ulrich, A.W., & Furtan, W.H. (1985). An investigation in the rates of return from the Canadian Crop Breeding Program. Saskatoon: University of Saskatchewan.
Zentner, R.P. (1982). *An economic evaluation of public wheat research expenditures in Canada*. Unpublished doctoral dissertation, University of Minnesota.
Zentner, R. P., & Peterson, W. L. (1984). An economic evaluation of public wheat [incomplete cite]

Appendix 1: The Changing Public Role in Agricultural Research for Prairie Agriculture

Origins of Agricultural Research Policy

The commitment to public agricultural research in western Canada began in 1885 with the passage by Parliament of an act creating the system of federal experimental farms.

> The experimental farm idea in Canada had a long and confused evolution in British North America, but a national emergency was necessary to force its acceptance. The emergency was the realisation that after nearly twenty years of Confederation the western territories were not serving their national purposes; they were not attracting the great droves of immigrants which, it had been anticipated, would create anew the moving frontier of economic activity so necessary for the support of the developmental overhead already incurred by government, and for the prosperity of commercial, financial and industrial centres of the Dominion (Fowke, 1946).

Thus, experimental farms were put into place for the purpose of research and experiment in an effort to make agriculture feasible on the prairies and attract more settlers to the West.

> The first Central Experimental Farm, was established at Ottawa in 1886. The act provided for four additional stations, which ended up being located in Nappan, NS, Brandon, MB, Indian Head, SK, and

> Agassiz, BC. Over the next two decades federal agricultural research stations were established in every province (excluding Newfoundland which was not a province at that time) (White, 1995).

William Saunders, the man in charge of overseeing implementation of experimental farms, believed that the need for agriculture education could be better fulfilled at agricultural colleges rather than via experimental farms. Canada's first agricultural college was established in Guelph, Ontario in 1874. From 1890-1913, agricultural colleges sprang up across Canada to supply graduates with experience and training to the growing agricultural industry of western Canada (White, 1995). Over fifty percent of Canada's population lived on farms at this time, and for the most part had little or no education. The government of the day was convinced that contributing resources towards an agricultural education institution would be beneficial to a large sector of the population and thus help that industry prosper, help attract more immigrants to Canada, and thus work towards fulfilling the national policies of the day. Although the agricultural colleges eventually expanded to include both research and education, for many years their primary role was education. Thus, in western Canada the experimental farms and the agricultural colleges were two separate vehicles that operated in tandem to develop and disseminate knowledge to enhance the viability of agriculture and promote rapid settlement of the prairies.

This development strategy in western Canada was undertaken for largely the same reasons as the U.S. land grant system, but it was not an exact copy. The U.S. model created in the United States under the Morill Act of 1862 differed in two important ways. The first concerned the process of funding. In the U.S., "each state agricultural college was funded by its endowment of 30,000 acres from the federal government (which it sold) and the income from the sale used to support teachers within the states' Land-Grant College" (University of Florida, 1994). On the other hand, federal government cash transfers initially funded Canadian agricultural colleges and experimental farms (B. Martin, personal communication, 2000). The second difference is that unlike the agricultural colleges in Canada, the U.S. land grant colleges took on a dual role of research and education from the outset. Thus there was one set of U.S. institutions rather than two. Despite these differences in approach, both systems provided education and research to enhance the development of the agricultural sector and to promote settlement of the West.

The Changing Roles of Public, Civil, and Private Research

The evolution of crop research in Canada is a complex process, involving a mix of many public and private institutions. For more background on the history of field crop breeding, see *Harvest of Gold* (Slinkard & Knot, 1995). Although many crops owe their origin to federally funded research, more recent developments have included research from provincial and international public institutions. Producer and industry check-offs have also played an important role in some crops. With the creation of plant breeders' rights and other property rights, the private sector has also made significant investments in crop research. The evolution of roles has also differed a great deal across crops, making generalizations difficult.

Although research for each specific crop has its own history, the legal and regulatory frameworks and several non-government organizations have had an ubiquitous effect on crop research in Canada. In terms of regulatory framework, the Grain Inspection Act, 1885-86 and the Canada Grain Act, 1905 established the grading system for grain and required that varieties of a type of grain have kernel visual distinguishability from grain with different qualities. It also established very high minimum quality standards, particularly for bread wheat. This ensured a consistent quality within grade classes, but also served to make breeding for other traits more difficult. A more recent change in the regulatory frame occurred with the establishment of plant breeders rights within the Canada Seed Act of 1989 (De Paw, Boughton, & Knott, 1995). These provisions allowed creators of a variety to command a royalty whenever the variety was sold for seed purposes, creating some private incentive for crop research. Most recently, the U.S. patent office has accepted patents on the biotech processes used to develop new varieties, further enhancing the ability of the private sector to capture value from research. Check-off legislation to allow producer groups to collect a levy from the sale of crops has also played a significant role in western Canadian crop research.

The many organizations and committees that have served to co-ordinate agricultural research in Canada and abroad have also played a significant role in shaping crop research in Canada. These non-profit organizations exist within and across different crops. The "Registration Recommending Committees" had a large influence on what varieties were licensed for seed, and indirectly had an significant influence on the type of variety development that took place (Harvey, 1995). "The National Research Council (NRC) Associate Committees" date back to 1916 (Harvey, 1995). These and later committees brought together groups of scientists to co-ordinate work on rust and other crop diseases. These committees served to co-ordinate activities, share information, and reduce unnecessary duplication in crop research in Canada.

Industry organizations have also played a very important role in co-ordinating and, in some cases, funding crop research. The Rapeseed Association of Canada and the Saskatchewan Pulse Growers have also been important drivers of research, but have further served to facilitate the rapid adoption and marketing of new technology. While these organizations have worked well with public research institutions, the long-term relationship with private research firms is uncertain.

References

De Pauw, R.M., Boughton, G.R., & Knott, D.R. (1995). Hard red spring wheat. In A.E. Slinkard and D.R. Knott (Eds.), *Harvest of gold: The history of field crop breeding in Canada*. Saskatoon, SK: University Extension Press.

Fowke, V.C. (1946). *Canadian agricultural policy: The historical pattern*. Toronto: The University of Toronto Press.

Harvey, B.L. The western grain registration recommending committees and their role in cultivar development. In A.E. Slinkard and D.R. Knott (Eds.), *Harvest of gold: The history of field crop breeding in Canada*. Saskatoon, SK: University Extension Press.

Slinkard, A. E. & Knott, D. R. (Eds.). (1995). *Harvest of gold: The history of field crop breeding in Canada*. Saskatoon, SK: University Extension Press.

University of Florida. (1994). *Land grants: Events leading to the establishment of land-grant universities*. Retrieved 15 May 1998, from the World Wide Web: http://www.ifas.ufl.edu/www.ls_grant/whatislg.htm

White, W.J. (1995). Plant breeding in Canada's formative years. In A.E. Slinkard and D.R. Knott (Eds.), *Harvest of gold: The history of field crop breeding in Canada*. Saskatoon, SK: University Extension Press.

Endnotes

[1] A good is characterized as rival when its use by a person or firm precludes others from using the good; the opposite is true for non-rival goods. A good is characterized as excludable when a person or firm can be prevented from using the good either by technological aspects of the good or by legal means. Hence, rivalry is a technological attribute of a good, while excludability depends on both the technological and legal system (i.e., penalties). Public crop research outcomes tend to be non-rival and non-excludable, while private research outcomes tend to be non-rival and excludable.

[2] They also found: "(1) There is no evidence to support the view that the rate of return has declined over time. (2) The rate of return to research is higher when the research is conducted in more developed countries or when it is adopted in less - developed countries. (3) The rate of return to research varies according to problematic focus, in ways that make intuitive sense. In general we would expect to see longer production cycles associated with lower rates of return, and the regression results indicate a significantly lower rate of return for natural resource management research (primarily forestry) compared with the other categories. (4) The rate of return is not significantly different between research and extension included individually, but a lower rate of return is found in studies that combine research and extension, which we suspect is a reflection of omitted variable bias in the other studies. (5) Characteristics of the research evaluation itself, and the analyst conducting the evaluation, were found to have important systematic effects on the estimated rates of return, and most of these effects are reasonable."