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Strategic Policy Issues for Agricultural Research in Canada

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The Issue

Agricultural research has been a very important factor in enhancing the productivity and competitiveness of the Canadian agri-food sector. Science and innovation have been identified as together forming one of the five pillars in the Canadian Agri-food Policy Framework (APF). A major focus of the science and innovation section of the APF is to plan to realign public and private research efforts into a more comprehensive strategic approach for research and innovation in Canada. Despite the importance of research and the need for a strategic approach, however, assessment of critical strategic research policy issues for the Canadian agri-food sector has been limited.

Implications and Conclusions

This article addresses a variety of strategic policy issues facing the agricultural research establishment in Canada. First, the returns to public agricultural research are examined to show that agricultural research typically generates very high returns and is a very good investment of public funds. The distribution of benefits between producers and consumers is then examined to show that most of the benefits of public agricultural research in Canada go to producers, making it one of our most cost effective policies for improving farm incomes. Next, changes in agri-food research and technology transfer capacity in Canada are assessed; significant declines in the level of public sector research effort in recent years and the potential impacts on future competitiveness are documented. Finally,

components of commodity research strategies are identified and related issues are discussed in order to provide a basis for strategic research planning and allocation in the coming decade.

Returns to Public Agricultural Research

With the increasing pressure for accountability for public funding, an important issue is whether funding for agricultural research is a good use of public (and private) funds. This section will show that agricultural research typically generates rates of return that are both very high and better than those for most other types of public expenditure. The high return to public agricultural research occurs in part because of the investment nature of the expenditures, which is characterized by an initial investment followed by several to many years of payback. In contrast, public expenditures for income transfers generate only a one-time impact and therefore produce much lower levels of overall returns.

Table 1 provides a summary of returns for a variety of Canadian agricultural research studies conducted since 1978. Public agricultural research typically has provided very high returns on investment and represents one of the highest payback activities for the Canadian public sector. Benefit-cost ratios for agricultural research typically have been 20:1 or more for individual commodities. 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, such as grading (2.6:1 to 11.6:1 [Brinkman et al., 1985a, 1985b]), meat hygiene (10.1:1 [Brinkman et al., 1986]), seed assurance (15.9:1 [Brinkman and Fox, 1989a]) and seed potato assurance (4.1:1 [Brinkman and Fox, 1989b]). Overall, it appears that public agricultural research is one of the highest payback uses of public funds.

Who Benefits from Public Agricultural Research?

The distribution pattern of the benefits of publicly funded activities among consumers, producers, and others in society is important. In determining the distribution of the benefits of research between consumers and producers, the most important factor is the nature of demand. Most of the literature on this question has been generated in the United States and identifies the main beneficiaries as consumers. This finding arises because the United States is a large country and its producers primarily face a large inelastic domestic U.S. demand. Under an inelastic demand, increases in supply induced by agricultural

Table 1 Ratios of Benefits to Costs and Distribution of Benefits between Producers and Consumers for Agricultural Research in Canada

Study	Commodity	Time period for research expenditures	Ratio of benefits to costs @ 5% discount rate	% Distribution of benefits	
				Producers	Consumers
Nagy and Furtan, 1978	Rapeseed	1960-1975	17.64	47.0	53.0
Prentice and Brinkman, 1982	Total Ontario ag. research	1950-1972	27.5		
Bates, 1984	Ontario canola	1978-1984	20.0		
Zentner and Peterson, 1984	Wheat	1946-1979	14.5[a]		
Farrell and Funk, 1985	Plant biotech	Future proj.	n.a.[b]		
Ulrich, Furtan and Schmitz, 1986	Malt barley	1951-1981	12.1[a]	74.1	25.9
Furtan and Ulrich, 1987	Rapeseed	1951-1981	34.1		
Guindo, 1987	Ontario hybrid corn	1951-1981	23.6	90	10
Federal Govt. livestock research					
Widmer, Fox & Brinkman, 1988	Beef cattle	1968-1984	48.3	89.6	10.4
Horbasz, Fox & Brinkman, 1988	Sheep	1968-1984	2.1	100.0	0
Haque, Fox & Brinkman, 1989	Egg layers	1968-1984			
Supply management			34.4	-109.7	209.7
Open market			25.0	100.0	0
Huot, Fox & Brinkman, 1989	Hogs	1968-1984	9.5	85.7	14.3
Zachariah, Fox & Brinkman, 1989	Chickens	1968-1984			
Supply management			26.9	-32.4	132.4
Open market			13.2	100.0	0
Fox, Roberts & Brinkman, 1992	Dairy cattle	1968-1984			
Supply management			114.6	-26.5	126.5
Thomas et al., 2001	Hogs	1974-1997	6.4 - 24.6		
Klein et al., 1994	Beef	1972-1986	37.0		
	Beef and crops	1972-1986	30.4		
Klein et al., 1996	Wheat	1962-1991	23.9 - 33.4	96.5	3.5

[a] Benefit-cost ratios were not provided in the original article but were calculated from the schedule of costs and benefits provided.
[b] Benefit-cost ratios could not be calculated. Internal rates of return ranged from 14.6 to 40.8 percent.

research typically cause the equilibrium prices to decline, with most of the benefits going to consumers. Conventional wisdom typically has relied heavily on information from the United States to promote the idea that consumers therefore are the main beneficiaries of agricultural research. The Canadian situation is different. In contrast to the United States, Canada is a small country, and therefore is not typically a price maker. Prices for Canadian products that are traded internationally are set in the international marketplace, where producers primarily face an elastic international demand curve rather than an inelastic domestic demand curve. Faced with an elastic demand curve, Canada may increase its production and see only slight declines in prices. The results are substantial benefits in increased volume without significant changes in price. As a result of the elastic international demand curve facing most Canadian producers, the main beneficiaries of public agricultural research in Canada are producers rather than consumers, a point that often is not well understood, but that should be emphasized. Since public agricultural research has a very high return, such research has been the most effective farm assistance program we have had in Canada.

In addition to showing the level of benefits, table 1 also shows the distribution of benefits from agricultural research programs. For commodities that are traded internationally, Canadian producers typically have received up to 85 to 96 percent of the benefits from public research. For non-traded livestock products such as those under supply management, however, consumers gain most of the benefits; this occurs because of the lack of trade and the restriction of production primarily to the domestic market, where demand is inelastic. The table indicates, for example, that over the period studied all of the research benefits for supply-managed products went to consumers, and producers may even have lost benefits due to decreased prices to consumers. Table 1 indicates that consumers gained 126.5 percent of the benefits from dairy research, 209.7 percent of the benefits from egg-layer research, and 132.4 percent of the benefits from chicken research. It should be noted, however, that the distributions of these benefits were calculated at an earlier time period when strict cost-of-production pricing was used to pass the benefits in input-cost reductions from agricultural research on to consumers. In recent years the strict formula-pricing procedures have been dropped for some of the supply-managed commodities such as turkeys, and prices have been negotiated on a supply and demand basis. Market forces are also used in the dairy industry to try to adjust prices more according to supply and demand, thereby allowing producers to capture some of the research benefits. Under these circumstances the distributions of benefits from agricultural research for supply-managed commodities likely are substantially different from those shown in table 1, and some supply-management producers now would be capturing a significantly greater portion of the benefits than indicated.

Table 2 Summary of Person-years[a] of Research Effort for Canada by Origin of Research, Selected Years 1991-2002

Origin of research	1991[b]	1995	1999	2002	% change 95-99	% change 95-02	% change 99-02
Federal govt.	1024	1011	602	642	-40.5	-36.5	+6.6
Provincial govt.	157	190	61	65	-67.9	-65.8	+6.6
Universities	1123	902	669	609	-25.8	-32.5	-9.0
Total public sector	2304	2103	1332	1315	-36.7	-37.5	-1.3
Private industries/ institutions	n.a.	192	149	154	-22.4	-19.8	+3.4
Total	2304	2295	1481	1470	-35.5	-36.0	-0.8

[a] Rounded to nearest whole number
[b] Public sector research only for 1991
Source: ICAR

Changes in Research and Technology Transfer Capacity

Despite the high returns to agricultural research, commitments to research activities have declined in recent years. From 1995 to 1999, for example, total research person-years (PYs) reported by the Inventory of Canadian Agri-food Research (ICAR) declined by about one-third before leveling off through 2002. Tables 2, 3, and 4 summarize changes in research by origin of research, by province, and by major area of study. Table 2 summarizes the PYs of research effort (measured in full-time-equivalents) for Canada by major area of study. In 1991, ICAR reported 2304 PYs of agricultural research supported by the public sector. This figure did not include private sector research, which likely contributed about another 200 PYs. By 1995 public research accounted for 2103 PYs and private sector research contributed another 192 PYs, for a total of 2295 PYs. This represented about a 210 person-year decline from the estimated 1991 total of combined public and private sector research. The total level of PY research activity reported by ICAR declined further to 1481 PYs by 1999 and then to 1469 in 2002. The large decline through 1999 was in part due to the cutbacks in agricultural research funding by federal and provincial organizations and the change in policy to shift more of the research effort to the private sector. This table shows federal government funding (including funding for research conducted by ministries other than AAFC and for research throughout all provinces) declining from 1024 PYs in 1991 and 1011 in 1995 to 602 in 1999 and 642 in 2002, a reduction of 36.5 percent from 1995 to 2002. Provincial governments traditionally have been limited in their research activities, conducting only 157 PYs of research in 1991 and 190 in 1995. By 2002, provincial PYs of research had declined to only 65, a reduction

Table 3 Summary of ICAR Public Sector Person-years[a] of Agri-food Research Effort for Canada by Province and NCR, Selected Years 1991-2002

Location	1991	1995	1999	2002	% change 95-99	% change 95-02	% change 99-02
British Columbia	130	109	52	68	-52.3	-37.6	+30.7
Alberta	241	238	178	199	-25.2	-16.4	+11.8
Saskatchewan	269	257	227	137	-11.7	-46.7	-39.6
Manitoba	178	171	117	112	-31.6	-34.5	-4.3
Ontario	560	268	138	216	-48.5	-19.4	+56.5
Quebec	402	557	408	330	-26.8	-40.8	-19.1
New Brunswick	41	41	33	35	-19.5	-14.6	+6.1
Nova Scotia	78	56	31	46	-44.6	-17.9	+48.4
PEI	38	23	45	53	+95.6	+130.4	+17.8
Newfoundland	15	11	15	17	+36.4	+54.5	+13.3
NCR	352	372	88	103	-76.3	-72.3	+17.0
Total	2304	2103	1331	1315	-36.7	-37.5	-1.2

[a] Rounded to nearest whole number
Source: ICAR

of 65.8 percent since 1995. Universities typically have provided nearly as many PYs as the federal government, but their research resources also declined in the 1990s. Person-years of research conducted at universities were 1123 in 1991, 902 in 1995, 669 in 1999, and 609 in 2002. This represents a reduction of 32.5 percent since 1995. Private industry/institution research PYs are not fully reported in ICAR, but the private PY numbers that are included in the ICAR database showed a decline from 192 in 1995 to 154 in 2002, or a reduction of 19.8 percent. These changes in agricultural research funding for PYs represent a significant decline for Canada, amounting to a 37.5 percent decline in the public sector alone since 1995. This decline raises serious questions about the future viability of the agricultural sector and the competitiveness of Canadian farmers in an international marketplace.

Table 3 summarizes the PYs of public research effort for Canada by province as well as the National Capital Region (NCR). The figures for each province represent all ICAR-reported federal, provincial, and university research activities undertaken within that province. The figures for NCR represent research conducted by the federal government within the NCR. Since 1995, the greatest percentage declines in public agricultural

Table 4 Summary of ICAR Person-years[a] of Agri-food Research Effort for Canada by Major Area of Study, Selected Years, 1991-2002

Major area of study	1991[b]	1995	1999	2002	% change 95-99	% change 95-02	% change 99-02
			Public sector research				
Animals	629	513	355	406	-30.8	-20.9	+14.4
Aquaculture		56	49	58	-12.5	+3.6	+18.4
Field crops	934	662	479	407	-27.6	-38.5	-15.0
Horticulture crops		400	236	218	-41.0	-45.5	-7.6
Resources/environment	282	230	149	153	-35.2	-34.4	+2.7
Human-related	311	142	29	25	-79.6	-82.4	-13.8
Other	148	99	34	48	-65.7	-51.5	+41.2
Total	2304	2103	1331	1315	-36.7	-37.5	-1.2
			Total ICAR public and private research				
Animals	629	572	408	466	-28.7	-18.5	+14.2
Aquaculture		63	55	62	-12.7	-1.6	+12.7
Field crops	934	760	548	459	-27.9	-39.6	-16.2
Horticulture crops		420	248	233	-41.0	-44.5	-6.0
Resources/environment	282	231	153	163	-33.8	-29.4	+6.5
Human-related	311	142	30	37	-78.2	-73.9	+23.3
Other	148	107	38	50	-64.6	-53.3	+31.6
Total	2304	2295	1480	1470	-35.5	-35.9	-0.7

[a] Rounded to nearest whole number
[b] Public sector only for 1991
Source: ICAR

research have occurred in the NCR (72.3 percent), Saskatchewan (46.7 percent), Quebec (40.8 percent), and British Columbia (37.6 percent). From 1991 to 2002, Ontario and the National Capital Region experienced the largest total, as well as the largest percentage, declines, with Ontario losing 344 PYs (61.4 percent) and NCR losing 244 PYs (70.7 percent). Through 1999 Saskatchewan was nearly able to maintain its research effort, losing only 11 percent from 1995 to 1999, before experiencing a further drop of 39.6 percent from 1999 to 2002. Only PEI (130.4 percent) and Newfoundland (54.5 percent) were able to show increases.

Table 5 Expenditures at Public Institutions on Agri-food Research and on Technology Transfer in Canada by Major Area of Study, 1991, 1996 and 1999 ($ million)

Major area of study	Research				Technology transfer[a]			
	1991	1996	1999	% change since 1996	1991	1996	1999	% change since 1996
Animals	123.2	135.8	103.9	-23	51.3	35.3	30.3	-14
Field crops	274.4	359.9	108.7	-46	55.1	76.3	12.6	-76
Horticulture crops			84.3				5.7	
Resources/env.	78.4	74.7	88.1	18	32.3	29.8	7.7	-74
Food & human nutr.	67.2	61.1	65.4	7	11.4	7.4	4.7	-39
Socio economic	11.2	13.6	8.7	-36	39.9	22.3	17.7	-21
Other	5.6	34.0	2.8	-92		14.9	4.7	-68
Total	560.0	679.0	461.8	-32	190.0	186.0	83.6	-55

[a] Excludes British Columbia, New Brunswick, and Newfoundland

Sources: 1991 Rennie survey and 1996 Weaver survey reported in Weaver, 1996; 1999 Brinkman survey reported in Brinkman, 2001.

As indicated in table 4, the greatest declines in public sector research by subject area since 1995 have been in human-related research at 82.4 percent (including agricultural economics), other (51.5 percent), horticulture (45.5 percent), field crops (38.5 percent) and resource economics (34.4 percent). Animal research decreased by 20.9 percent and aquaculture reasearch increased by 3.6 percent.

Table 5 summarizes expenditures for agricultural research and technology transfer for 1991, 1996, and 1999. The table shows that expenditures for agricultural research have declined at an even faster rate than the rate of decline for person-years: 32 percent from 1996 to 1999 compared to 34 percent for PYs from 1995 to 2000. The rate of decline in expenditures for technology transfer has been even greater: 55 percent from 1996 to 1999. This extreme decline could have strong implications for farm viability.

Another important consideration is that the nature of public research, particularly at the federal level, has changed substantially. The biggest change is a shift from primarily public research to projects funded under the Matching Investment Initiative program, resulting in a substantial portion of research being conducted for private companies on a proprietary basis. The net result of this shift has been that although Canada has increased its productivity, a large share of the net benefits of research has been transferred from the producer to the agribusiness firm. As a consequence, the effectiveness of agricultural

research as a resource for improving farm incomes has diminished as the share of benefits to agribusiness firms has increased.

Since 1990 aggregate annual farm incomes in Canada have shown little improvement, ranging from $2.0 to 3.8 billion per year from 1990 to 1996, and then falling to a 31-year low of $1.3 billion in 2002. In addition, more and more of the net income since 1996 has come from net government payments to farmers, steadily increasing from 23.7 percent of net income in 1996 to 245 percent in 2002 ($1.27 billion in net aggregate income, with $3.11 billion coming from net government transfers and rebates) (Statistics Canada, Nov. 2003, Agricultural Statistics online data). Many factors have contributed to Canada's poor farming income performance in recent years (international subsidies, growing competitiveness from South America, droughts, etc.), so the shift to more proprietary private research should not be singled out as the main factor. The poor performance does indicate, however, that agricultural research in recent years no longer has been able to offset other factors that have negatively affected farm income levels. In essence, Canadian farmers are improving their productivity, but not their incomes. In the long run the redistribution of benefits within the private sector could pose a serious concern for the viability of the Canadian producer and could jeopardize the success of the Agri-food Policy Framework.

Because of the high proportion of benefits of public agricultural research received by farmers, it can be argued that farmers should pay for their own research, allowing a reduction in government funding. Indeed, support for agricultural research is a good investment for farmers, and recent efforts have been made through check-offs and other measures to generate more farmer support for research. This does not necessarily mean that governments should withdraw from public agricultural research. As long as governments continue their commitment to provide high levels of income support to the agricultural sector, reductions in research funding may not result in savings in public funds. With the high level of return to public agricultural research and the high share of benefits going to producers, continuation of research funding is likely to generate far more income over time than would the same level of funding delivered through transfer payments. As a result, agricultural research is a much more efficient approach to farm sector support than are safety nets and transfer payments.

Commodity Research Strategies

Currently Canada has both a set of national research committees that report on research priorities in different subject matter areas and a set of provincial research/agricultural service coordinating committees that identify regional priorities. This committee structure has been effective in identifying directions for research and in helping to formulate research priority areas across Canada. The committee structure, however, has been less successful in developing specific research strategies for different commodities. In particular, from a farm income standpoint, we need to focus on creating the greatest

competitive edge for Canadian producers, rather than just focusing on the top scientific problems. In some cases, solving the top scientific problems (such as a North American disease problem) may even create a competitive disadvantage for Canadian producers if the new technology is more applicable to another region or to producers with a different farm structure (size of operation, business arrangements, etc.) than that found in Canada.

Effective commodity research funding strategies to increase our competitiveness may become more important in the future as the priorities and funding sources of agricultural research continue to change. It will be very important to address both the strategic direction and the scope of research in order to make the most efficient use of research funding for the Canadian agri-food sector.

Priorities for Scope of Research

"Scope of research" refers to such issues as public versus private funding, sectoral versus regional funding, and other factors such as potential rates of adoption of new technologies for Canadian producers relative to rates for producers in other areas. These critical considerations in the development of effective commodity research strategies are discussed below.

Public versus Private Sector Research

The first issue in deciding the scope of future research involves the allocation between research that needs to be undertaken by public agencies versus research that can be undertaken appropriately by the private sector. With the recent growth of private sector research and the development of technologies that enhance the capability of private companies to capture research benefits, a significant shift from public to private research is occurring in both the crop and the livestock sectors. Because public sector funds for research are limited, strategies for research allocation must consider shifting funds from research projects that can be implemented effectively by the private sector to those that still require public sector support. In the swine industry, for example, private sector research is increasing in such areas as breeding, reproduction, and meat quality. This research is being undertaken by large pig-breeding companies such as PIC, with technological advances being provided to pork producers through the sale of improved genetic stock. Murphy Farms in the United States, with seven million pigs raised a year, does not do any breeding research, but relies exclusively on the private sector for these activities. PIC, for example, has eight to ten meat specialists on staff, who provide a critical mass to develop this dimension of their research in a very effective fashion. Those research areas such as breeding that can be developed effectively in the private sector may no longer need the level of attention they received previously from the public sector.

With the increased involvement of the private sector in agricultural research, several public sector issues are becoming more important. These involve the role of the public sector in providing an alternate competitive product to that supplied by private technology; the appropriate role of the public sector with respect to patented technology

and the proprietary use of such technology; the distribution of effort between basic versus applied research; and the development of an appropriate overall role for public sector research.

Public Research as a Competitive Source of New Technology. Access to agricultural research developments has typically been free of charge to the general public, thereby providing a direct pass-through of benefits to the producer. This has resulted in the high level of research benefits and their distribution to producers described in table 1. With the growing level of private sector research and the cost of research development, and with technological user agreements (TUAs), a substantial portion of research benefits is now being captured by private sector input supply companies rather than producers. Research still generates substantial benefits, but the distribution between producers and research providers has changed. Public agricultural research can play an effective role as an alternative source of new technology to provide competition and prevent excessive prices for certain types of private sector research developments.

Public versus Proprietary (Patented) Technology. The second issue with respect to the role of the public sector in the development of patented technology is perhaps even more important in the long run. Research discoveries typically build upon previous advancements and thereby result in a cumulative impact. Under the current system the private sector is developing new research techniques that are patented and may be used in a proprietary fashion. In other words, some of the emerging building-block technologies are now restricted from general use, and access to these technologies is no longer available to the public sector. Such restrictions could result in the public sector being shut out from entire areas of technological development. In this context it is extremely important for the public sector to be involved in the development of its own patentable, building-block research technologies, which can be traded off to gain access to proprietary private sector research. This could be one of the fundamental requirements for public sector involvement if the pattern of biotechnological advancements with a high level of private sector patenting continues. Future public sector research funding may need to encompass opportunities for development of patents as well as the potential for improvements in technology.

Basic versus Applied Research. Another fundamental question that continually arises in agricultural research is the distribution of effort between basic and applied research. Basic research focuses on the fundamental processes and principles of technological development, whereas applied research develops basic research ideas into direct applications that can be immediately employed in production and marketing. As we encourage more and more private sector research and even require private sector partnerships (through such programs as the Matching Investment Initiative) we are apt to see a significant shift from basic to applied research. In the past, the public sector has taken on the role of undertaking basic research. Under present conditions, however, it is becoming much more difficult to justify and generate matching funds for basic research

undertaken within universities and other public sector institutions. The increased emphasis on applied research may generate a number of short-run advantages by increasing the development of applied technology, but the shift in focus and funding could have implications for the long-run competitiveness of Canada.

An Appropriate Role for the Public Sector. As we look to the future and consider the appropriate role of the public sector in agricultural research, it is apparent that a strong public sector presence will continue to generate substantial benefits for the Canadian agri-food system and will be needed to ensure long-term competitiveness of the sector. Public sector research will need to recognize the shift to an increased private sector presence and acknowledge the transfer of substantial parts of the applied research agenda to the private sector. A prominent role for public sector research, however, will be necessary in the following areas: developing competitive products; undertaking basic research and social science research; and developing patented, building-block technologies that can be traded off with the private sector to gain access to private patented technologies. The direction and selection of public sector research projects will need to evolve in a strategic fashion, identifying critical areas where public sector research will not duplicate, but rather will add to, the overall research output of the country.

Sector versus Regional Importance

A second dimension within the scope of research relates to the degree of focus on total-sector issues versus regional/local issues. In the selection of research areas that will yield a high payback, attention typically is devoted to those issues that have a broad impact throughout an entire sector. Examples are improving the competitiveness of one species of livestock over another and technological advancement of a specific crop. A sectorwide focus in research, however, does not address whether or not the technology will be more appropriate for one region than another, or for one type of production and marketing structure than another. It is possible, for example, that Ontario researchers under this type of approach could develop livestock technology or even basic crop technology that would be employed more effectively by their competitors in the United States or western Canada, thereby reducing Ontario's competitiveness rather than increasing it. For example, certain kinds of technology may be more easily employed by Murphy Farms (swine) or large western feedlots (beef) than by the smaller producers in eastern Canada. Serious consideration must therefore be given to the appropriate level of sectorwide research.

For some commodities, national research is supported by a uniform check-off levied on all producers in the sector. This is the case for beef producers in Canada and pork producers in the United States. A check-off enables all participants in the system to benefit and spreads the burden of research funding among all participants.

In Canada a significant portion of research funding is provided by provincial sources. In the future we may need to develop a different system, as provincial funding is an

inequitable way of funding sectoral research. Furthermore, livestock technologies tend to transfer easily across different locations, which suggests there is an incentive to use the spill-in effects of research from other sources rather than devote large-scale funding from local/regional sources to issues in this sector.

In contrast to sectoral research funding, a significant priority of provincial research should be to focus on special provincial/local issues such as locally adapted crop varieties, diseases with a high incidence in a particular province, housing, environment, feeding, management, and marketing challenges that face provincial livestock producers, and other sectoral challenges with a high incidence in the province. A focus on special problems within a province can enhance the effectiveness of provincial research funding and create a *relative* advancement in the competitiveness of that province's producers.

Rates of Technology Adoption

A third consideration in the scope of research relates to the potential rates of adoption of research outputs. Not all technologies will be adopted at the same speed in different regions, and not all farmers have the capability, given the structure and operational characteristics of their farms, to utilize all types of technology. A major consideration in the scope of research therefore should be the potential adoption rate of a new technology in one location compared to its potential adoption rate in the rest of North America (and even South America). High priorities should be placed on selecting research projects that are particularly adaptable to the operations of Canadian and/or local farmers and are compatible with their criteria for adopting technology.

Probability of Success and Level of Benefits

A fourth consideration in the scope of research relates to the probability of success and the level of producer/processor/sector benefits. These criteria relate specifically to the selection of individual projects, but their overall impact on the scope of research also relates to the types of projects that should be undertaken. Considerations include the past records of success of individual researchers working in particular areas and the nature of specific projects.

Development and Sale of Proprietary Technology

The last criterion in this section has to do with the potential for research activities to develop specific technology and marketing rights through patents, etc., as mentioned earlier in the section on public versus private research. With the shift to private sector research, the development and sale of proprietary technology has become a direct benefit and outcome of agricultural research. Research may be seen as a pure investment in itself, generating returns from the sale of rights rather than generating benefits through the use of new technology by individual farmers. In some cases the potential direct pay-offs from technology development are substantial, and must be a significant consideration in the future allocation of research funding. In cases with a large potential for direct technology

sales, research programs may place a high priority on activities that will generate direct returns to the program rather than focus exclusively on endeavours that will generate traditional returns through improved farm production throughout the sector.

Further Issues in Strategic Research Funding Allocation

The previous sections addressed a variety of issues related to setting research priorities. This section outlines a series of additional questions Canadian researchers and research supporters should address in setting their priorities.

1. Is there convincing evidence that this research addresses an important existing problem in the industry?
2. Will this research, if it is successful, produce at least a temporary comparative advantage for the Canadian/regional industry?
3. Does this research address a gap between federal, provincial, and existing private sector funding?
4. Would funding this project be an opportunity to strategically influence the direction of federal, provincial, or private sector research?
5. Is there an appropriate level of diversification in the portfolio of projects that have been approved for funding?
6. Do the projects cover critical emerging issues throughout the entire supply chain rather than focusing exclusively on production?

Asking these questions should improve the effectiveness of Canadian research funding; they should become important considerations in future research strategies.

Summary and Conclusions

Agricultural research is undergoing a significant transition in Canada. Historically, agricultural research has generated some of the highest returns available from public sources, typically creating benefit-to-cost ratios in excess of 20:1. Most of the benefits have gone to producers, making agricultural research Canada's most effective farm assistance program. Despite these high returns, public funding for agricultural research has continued to decline, with a decrease of 37.5 percent in the level of public professional support since 1995. As public funding sources have declined, more of the research effort has shifted to private sources and jointly funded public-private activities. This change in funding calls for both a reexamination of research support and the development of public-private research strategies.

Commodity research strategies should not focus exclusively on basic scientific problems, but rather should be structured to maximize our competitive advantage. Strategies should focus on both identifying the appropriate scope of research and strategically selecting research priorities to provide the greatest competitive edge for the Canadian agri-food sector. Important considerations include establishing the appropriate

balance between public and private research and developing an appropriate role for the public sector that would enable it to do the following: provide a competitive source of new technology vis-à-vis the private sector; develop patents and proprietary research technologies that can be traded off with the private sector; and undertake sufficient basic research. Additional considerations include establishing an appropriate balance between sectoral and regional problems, developing technology that will be readily adopted by Canadian producers, and selecting projects with a high probability of success relative to the potential level of benefits. These considerations need to be incorporated into public-private sector research strategies to enhance the effectiveness of future research efforts and to maintain the long-run competitiveness of the Canadian agri-food sector.

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