# CHAPTER 6

# The Shifting Patterns of Agricultural Production and Productivity in Canada

**Terrence S. Veeman and Richard Gray**

## 1. INTRODUCTION

Canadian agriculture has been substantively transformed over the past century. In absolute terms, agricultural production has increased considerably over time. For example, the production of wheat, a major Canadian crop, based initially on the improved variety Marquis, tripled from 1908 to 2008 (Statistics Canada 2009). New crops, such as canola on the Prairies and soybeans in Ontario, have captured significant acreage. The livestock numbers have greatly increased since World War I, the number of cattle and calves nearly doubling, the number of pigs growing about fourfold, and the number of chickens tripling (Statistics Canada 2009).

In relative terms, however, primary agriculture's share of the Canadian economy has shrunk to account for 1% to 2% of gross domestic product and some 2% of national employment. Such structural change has been common in developed nations. Agriculture's role in the economy overall is, of course, somewhat larger if the related input- and output-processing industries of the entire agricultural and agri-food system are considered.

Associated with economy-wide changes in the structure of agriculture, agricultural productivity has increased considerably over time, whether measured

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The authors gratefully acknowledge the assistance of the following individuals: Cecil Nagy, Jill McDonald, and Simon Weseen at the University of Saskatchewan; Bryce Stewart, formerly of the University of Alberta; and Verna Mitura of Statistics Canada.

in terms of increases in crop yields, livestock yield gains, or estimated growth in agricultural total factor productivity. For instance, during the previous century, as a result of crop breeding, increased use of agro-chemicals, and improved practices and technology, the crop yields for wheat, barley, oats, and grain corn grew moderately, leading each of these to more than double (Statistics Canada 2009). Similarly, cattle carcass weights and piglets per sow have risen over time because of improved genetics and management. More specific estimates of overall total factor productivity growth suggest that agricultural productivity in Western Canada increased by more than 1.5% per annum from 1940 to 2004, with crop productivity growth considerably outdistancing livestock productivity growth in much of this period, but not since 1990 (Stewart 2006).

### 1.1. An Overview of Canadian Agriculture

Nearly 40% of Canadian farms are designated as crop farms, followed in importance by beef farms, which comprise 26.6% of all farms. However, the mix of agricultural commodities varies across the country (AAFC 2005). Production of red meats, along with dairy, is most important in Ontario and Quebec. Red meats, grains, and oilseeds typically account for over 80% of market receipts in the Prairies. In British Columbia, where a range of commodities is produced, fruits and vegetables are somewhat more important, whereas in Atlantic Canada, potatoes and dairy predominate. In 2006, nearly 7% of the farms in Canada reported growing organic products for sale, but only one-quarter of these farms were actually certified.

Agriculture uses only 7% of Canada's land mass and is concentrated in the southern portion of the country, chiefly in the Canadian Prairies and the southerly reaches of Ontario and Quebec. The current Canadian farmland area of 67.8 million hectares has remained relatively constant since World War II, although the land area in crops has crept upward to some 36 million hectares (Statistics Canada 2007). Other significant land-use changes include continuing decline, for more than three decades, in the area of summer fallow and an increase in improved (versus unimproved) pasture. In Western Canada there has been a significant move away from cereal-crop rotations that primarily included wheat and barley, to rotations that include more broadleaf crops such as oilseeds (chiefly canola) and pulse crops (such as field peas and lentils). In terms of cropped area, King Wheat continues to retain the crown, with spring wheat still leading planted acres. This is followed by hay and other fodder crops, with canola now ahead of barley in third place as the second most important cash crop. Since

1990 farmers have also adopted no-till farming techniques, and no-till acreage now covers roughly half the crop area.

Beef production shifted somewhat from eastern to western Canada, and the Prairie region experienced the largest growth in pig production, at least until 2006. Farm size has also increased in terms of herd size; from 1971 until 2001, the average number of cows per dairy farm more than tripled, while the number of pigs per hog farm rose by more than 10-fold (AAFC 2005). But the cattle and hog sectors have experienced considerable structural change, especially in hogs, with falling farm numbers but rising animal numbers. The number of farms reporting cattle and calves dropped 41% between 1981 and 2006, while cattle numbers rose to 15.8 million by 2006 (Mitura 2007) but declined thereafter. Beef cattle production became increasingly specialized into two distinct operations: cow/calf ranching and cattle feedlot finishing. The majority of beef cattle farms—some three-quarters—are now cow/calf operations. The number of farms reporting hogs decreased greatly from 1981 to 2006, dropping 80% to only 11,500 farms, each with an average of 1,162 pigs. In 1992 Canada had 31,200 dairy farms with an average herd size of 44 cows. By 2008, the number of dairy farms in Canada had decreased by 56.5%, to 13,587 dairy farms, with an average herd size of 67 cows. These trends were evident in the latest Census of Agriculture (2006) with fewer and larger farms in Canada recorded, reflecting continuing consolidation and specialization in Canadian agriculture. The number of farms had dropped to 229,000, continuing the steady decline since 1941 (Statistics Canada 2007; Mitura 2007). Average farm size recorded in the 2006 Census was 295 hectares. This average, of course, masks considerable differences across Canada, ranging from more intensive 100-hectare farms in Central Canada (Ontario and Quebec) to more extensive farms in Saskatchewan, which average nearly 600 hectares in size (AAFC 2007).

Agricultural production, as in the United States, is increasingly concentrated on larger farms. In 2005, there were some 5,900 "million-dollar" farms (with gross farm receipts exceeding this figure), representing only 2.6% of all farms in Canada and earning nearly 40% of total receipts. In contrast, the farms with less than Can$100,000 in farm receipts comprised 65.6% of all farms and generated only 9.9% of all farm receipts (Mitura 2007).

Concurrently, farm operators in Canada are an aging demographic, now averaging 52 years of age (Statistics Canada 2007). Fewer young farm operators are being attracted to and retained in the industry. Some 28% of the 327,000 farm operators recorded in the latest (2006) census were women. Increasingly the economic well-being of farm households is linked to the nonfarm economy, with nearly half of all farms reporting off-farm income (Mitura 2007). Further, for unincorporated farms in 2006, off-farm income from all sources was four times as important to farm family income as net operating income from farming (AAFC 2009). In terms of operating arrangements, 57% of Canadian farms were sole proprietorships, 27% were partnerships, and 16% were incorporated. This corporate share has been rising, but an important distinction is the fact these "corporate" operations are still largely family incorporations.

Trade, particularly with the United States, is very important to Canadian agriculture. The red meat sectors became increasingly integrated within the North American market in the past 15 years. Some 70% of Canadians' food purchases are produced domestically, with the United States providing 57% of Canada's food imports (Statistics Canada 2009). Further, slightly over half of Canada's food exports go to the United States. Canadian farm producers are more export-dependent than American or European producers. Canadian grain and oilseed farmers have long relied on export sales, and red meat producers are increasingly export oriented (AAFC 2005).

**1.2. Crops and Livestock in Canada: Shifting Patterns over Time**

Canada is ranked eighth in world cereal production and tenth in world meat production (Statistics Canada 2009). During the decade from 1999 to 2008, on average about 48% of total farm cash receipts in Canada came from livestock receipts, some 41.3% from crop receipts, and the remaining 10.7% from government program payments (CANSIM Database).[1] The changing relative importance of these three major shares (crops, livestock, and direct payments) from 1971 until 2008 is illustrated in Figure 6.1. Livestock receipts, at roughly half the total, have generally exceeded crop receipts over this period, with 2007 and 2008 being recent notable exceptions, associated with stronger grain prices and adverse fortunes for red meat producers. Government payments have tended to increase, often on an ad hoc basis, in years of drought, animal disease, border problems, and financial stress.

Some features of the changing crop acreages over time have already been mentioned. It is also of interest, and even more revealing, to examine the chang-

[1]Note that indirect transfers from consumers, arising from Canada's supply management systems for dairy and poultry products, are reflected in the receipts for these sectors.

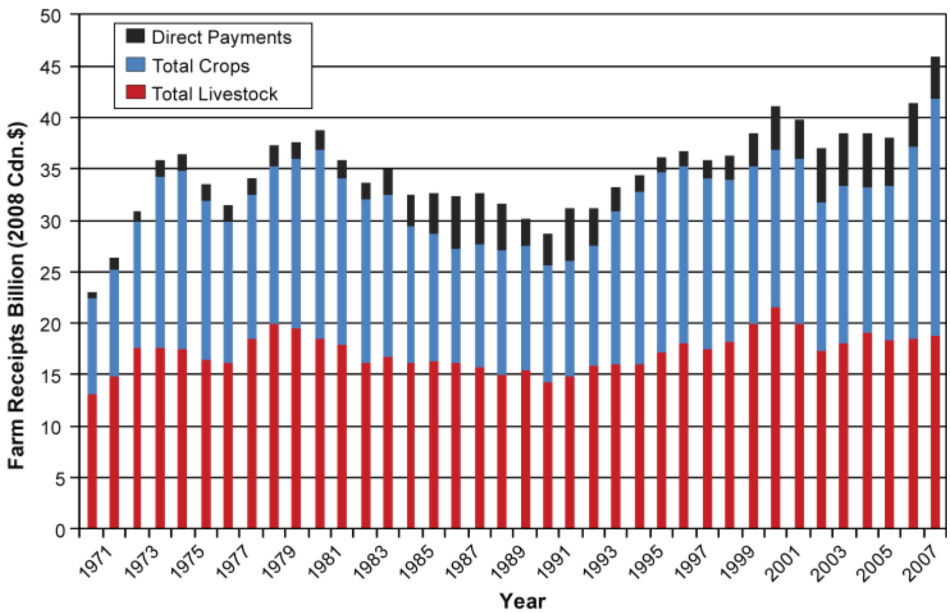


**Figure 6.1. Shares of total farm cash receipts from crops, livestock, and direct payments, Canada, 1971-2008**

*Source:* Authors' calculations from CANSIM Database.

ing pattern of crop receipts over time, as shown in Figure 6.2. The large share of the "other crops" category (which had been rising, at least until 2004) reflects the wide range of crop commodities grown across Canada and the increasing diversification of Canadian crop production. The considerable relative decline of wheat (excluding durum) as a source of farm crop receipts is clearly evidenced in Figure 6.2. Similarly, the significant relative rise in canola receipts and the relative decline in barley are portrayed. Corn and soybeans have both risen in relative importance, but they still only contribute approximately 6% and 5%, respectively, to Canadian crop receipts. Corn for biofuel production is not currently significant in Canada.

The relative breakdown of livestock receipts in Canada from 1971 to 2008 is shown in Figure 6.3. In the last decade of this period, cattle and calves contributed nearly 33% of total livestock receipts in Canada, with hogs providing 19%, dairy 26%, and chickens and hens 9%. The share of receipts from cattle and calves has dropped somewhat over time (especially since 2002) while the hog share of total livestock receipts increased from the 1990s until 2004 but sharply dropped thereafter.

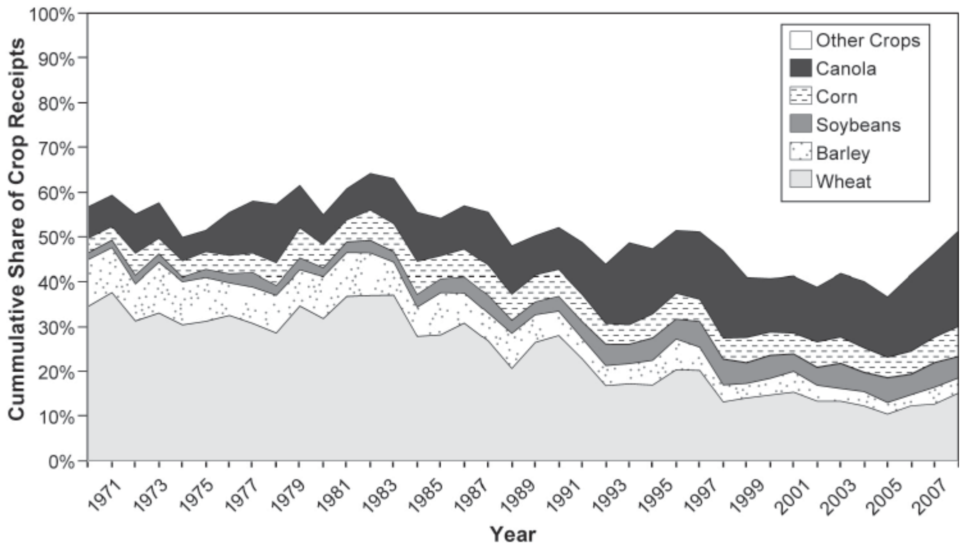


**Figure 6.2. Shares of total crop receipts by individual crops, Canada, 1971-2008**

*Source:* Authors' calculations from CANSIM Database.

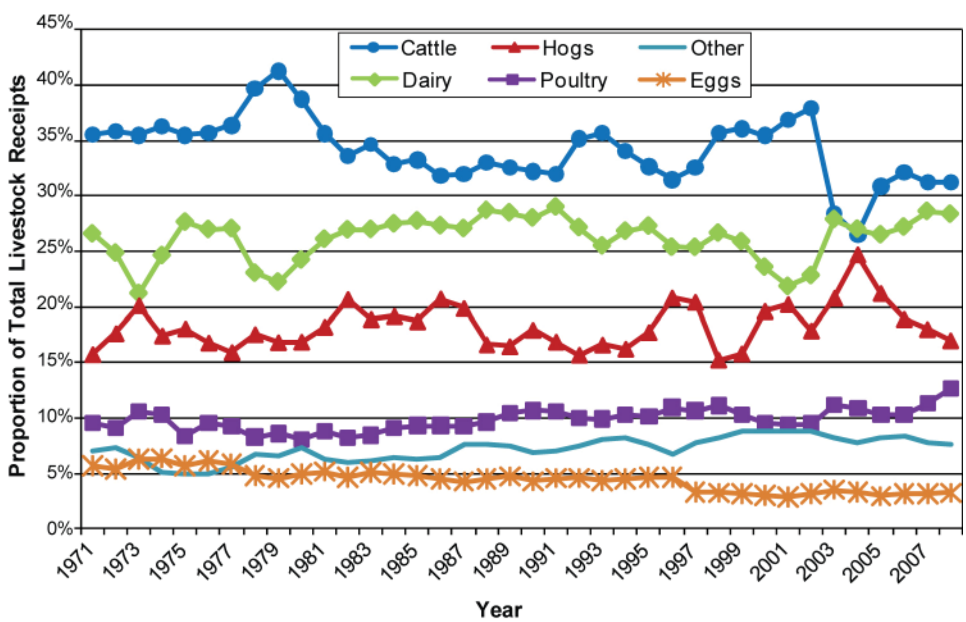


**Figure 6.3. Shares of total livestock receipts by individual livestock categories, Canada, 1971-2008**

*Source:* Authors' calculations from CANSIM Database.

### 1.3. Key Socioeconomic Factors Underlying These Changes

Many factors underlie the changes in Canadian agriculture and its crop and livestock production, and of these, only a few can be briefly highlighted. On the demand side, declining responsiveness of demand to global income growth (reflected in Engel's Law) has been important for many agricultural commodities, particularly for food staples such as wheat. Red meat demand and production have seen negative influences, from shifts in domestic consumers' preferences toward chicken and fish, and positive influences, as Canadian red meat production increasingly became integrated into the North American market (subject, of course, to market access at the border). On the supply side, Canadian agricultural production has been subject to the pervasive historical forces of capital-for-labor substitution and technological change. Crop production has become increasingly consolidated into large-scale farming operations, especially in Western Canada. Over time, most Canadian red meat production, particularly cattle feeding and hog production, has also become increasingly concentrated in intensive livestock operations.

## 2. PARTIAL PRODUCTIVITY MEASURES FOR CANADIAN AGRICULTURE

The Canadian agricultural sector has changed significantly in many ways during the past 50 years. Despite long-term declines in globally determined real prices the output of the sector has increased through improvements in productivity, which have lowered the cost of production. In this section we examine some partial measures of productivity improvement and describe some of the changes in technology that have contributed to productivity improvement. Changes in total factor productivity for Canadian agriculture are reported in the third section of this chapter. The remainder of this section is organized in two parts, each representing an important aspect of productivity improvements. The first part describes crop yields and changes in the crop sector over time, while the second describes changes and productivity gains specific to the livestock sector. Changes to labor productivity that are common to both crops and livestock in the Canadian context are briefly discussed in a subsequent section in which total factor productivity growth rates, from Statistics Canada time-series data, are introduced and compared.

### 2.1. Crop Yields (Land Productivity)

Changes in crop yields are the most readily available measures of productivity gains in Canadian agriculture. In Canada and elsewhere, slowly increasing crop yields have allowed the sector to feed a growing population on a relatively finite land base. As shown in Figure 6.4, the yields of the major field crops grown in Canada, (wheat, barley, canola, corn, soybeans, and peas) all increased from the 1960s until the present. Several features are noteworthy, including the volatile nature of yields even at the national level, highlighting the important continuing role of weather in influencing annual yields. Further, indexed against a base of the 1960-64 average, yields of all these crops follow a similar trend, increasing by about 60% during the 47-year period, to the point that statistical testing could not reject an identical linear trend coefficient for corn, wheat, canola, and peas.[2] This is remarkable considering the varying locations, biological properties, farming systems, and research institutions associated with each crop. The linear trend suggests a constant absolute growth in yields, which implies a declining proportional growth rate, since the same absolute increase per year is a smaller percentage of the growing base—in fact, a 60% decline in the proportional rate of growth over the period.

The yields shown in Figure 6.4 are based on yield per seeded acre and do not reflect changes in cropping intensity that have occurred in Western Canada,

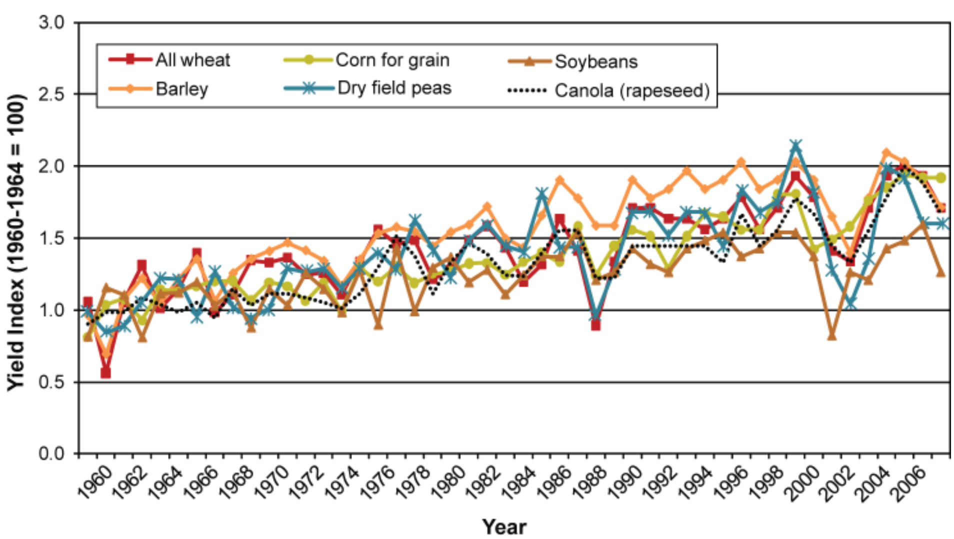


**Figure 6.4. Canadian crop yields, 1960-2007 (base 1960:1964 = 100)**

*Source:* CANSIM Database.

[2]Yield index data (1960-64 =100) were pooled and each index was estimated as a simple linear function of time. A cross-equation restriction that all trends were equal across crops could not be statistically rejected, with the exception of soybeans, which had a slower trend.

which have been a major factor in increased productivity within the crops sector. During the 1960s summer fallow was a dominant cultural practice in much of Western Canada. In a summer-fallow rotation the land is left fallow for 18 months after harvesting a crop, and weeds are controlled by tillage or herbicides for the summer in between cropping years. While this practice releases nitrogen from the soil organic matter and accumulates more moisture in the soil, it also reduces cropping intensity by postponing production by an additional year. As a result of the decline in summer-fallow area, annual cropping intensity in Western Canada has increased from 62% to 87% of cultivated area. If this increase in cropping intensity was reflected in yields, the yield growth per cultivated area of wheat, barley, canola, and peas would be closer to 100% over the 47-year period.

In contrast to trends in actual farm crop yields, acreage-weighted research trial yield indexes diverge markedly among Canadian crops (Figure 6.5). Both wheat and durum yields in experimental trials[3] exhibited slow linear trends, increasing to 122% of the 1960-64 base yield over the period to 2006. Canola yields in experimental trials grew rapidly until 1972, but this growth was reversed from 1975 to 1983 as canola, with low glucosinolate and low eurcic acid replaced rapeseed, with the accompanying yield drag of any major crop transformation. Canola trial yields then increased significantly from 1986 to 1994, only to retreat in the late 1990s as herbicide-tolerant varieties were adopted, with major agronomic benefits to growers in terms of weed control but again with the accompanying yield limitations of a major change in the available varieties. Since 1998, canola yields have again grown rapidly, as hybrid varieties have been developed and widely adopted.

In experimental trials, pea yields tracked wheat yields until 1994, but since 1994 pea yield growth has accelerated significantly. The period of rapid trial yield growth for peas corresponds to the pea research output of the Crop Development Center, which is funded by research check-offs from Saskatchewan pulse growers. The cumulative result of these changes is that, compared with the base yield indexes in 1960, in 2006 the canola yield index was 180%, the peas index was 148%, and the wheat and durum yield indexes were just over 120% of the base.

The contrast between the growth patterns in the acreage-weighted experimental yield indexes and the Canadian average realized yields of these various

[3]New varieties of grain are tested in experimental cooperative trials that use side-by-side comparisons with established varieties to establish a yield index of each new variety.

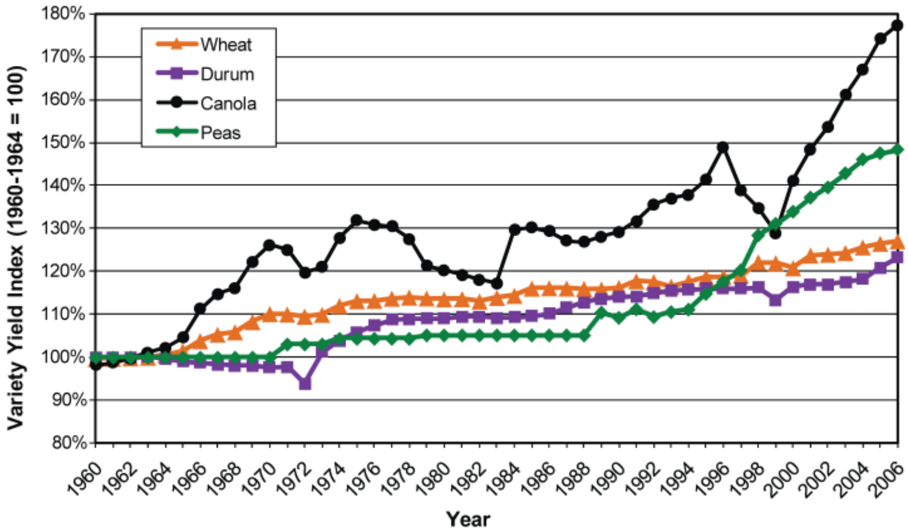


**Figure 6.5. Research trial yield indexes for selected Canadian crops, 1960-2006 (1960-1964=100)**

*Source:* Authors' calculations based on research trial data and seeded area.

crops is most intriguing. Despite very different patterns of growth in experimental yield indexes across crops, the trends in the actual farm crop yields of peas, wheat, and canola could not be statistically distinguished from each other. One could speculate that changes in seeded area and disease pressures have caused convergence in the actual crop yields. Further analysis is needed to reconcile the differences between the experimental yield indexes and the patterns in Canadian average realized yields of various crops.

Important quality changes, which increase value but are not captured in the yield figures, have also occurred for many crops. Spring wheat varieties were confined to hard red spring wheat in the 1960s. While hard red spring wheat still dominates planting, new classes of wheat have been introduced over time, with each wheat class made up of varieties that can be visually distinguished from other wheat classes. Durum wheat now includes extra-high-gluten varieties. Even hard red spring wheat has seen some quality attributes such as protein levels reflected in payment premiums. Canola was transformed from rapeseed in the early 1970s by reducing the level of glucosinolates and erucic acid. Since 2000, new canola varieties high in oleic acid have been introduced. The pulse industry has introduced a wide variety of new types of lentils, chickpeas, and field peas, in some cases targeting high-value niche markets. While feed is the primary use of barley, plantings continue to be dominated by two-row malting varieties, which replaced earlier six-row malting varieties.[4]

The balance of types of crops grown has shifted significantly since 1960. In particular, farmers in Western Canada have moved from a wheat, oats, and barley cereal monoculture to more robust rotations that include broadleaf crops such as canola and pulse crops, while farmers in Ontario and Quebec have introduced soybeans into their rotations. The magnitude of these changes is illustrated in Figure 6.6, using the percentage of acres seeded to non-cereal crops as a measure of diversification.

Discussion of productivity enhancement in cropping systems would be incomplete without mention of the dramatic change in tillage systems (Zentner et al. 2002). In the 1960s, fields were tilled extensively during the summer-fallow period in much of Western Canada and tilled again prior to seeding. In the more-humid regions of Central Canada, land was tilled with a moldboard plough to bury the stubble residue from the previous crop. While these intensive tillage practices

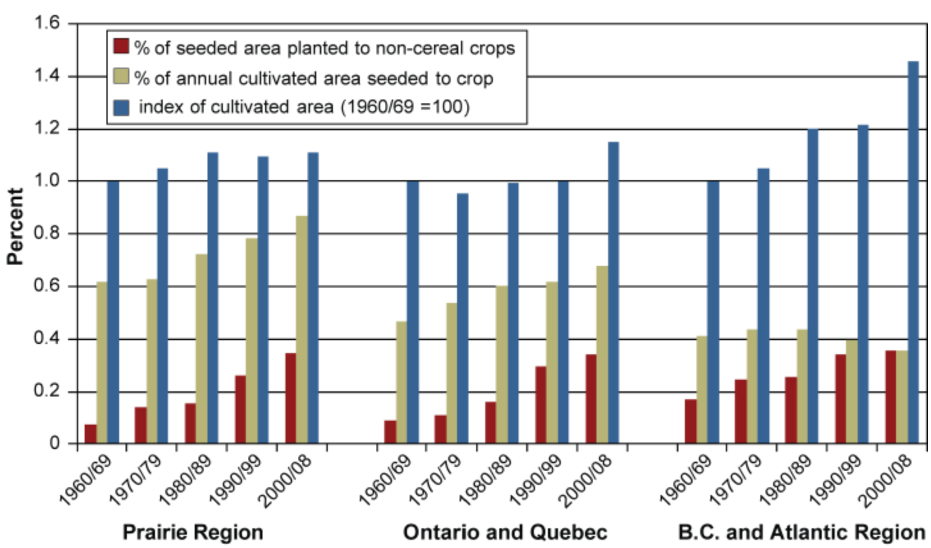


**Figure 6.6. Land use cultivated and seeded area and diversity of crops, selected regions of Canada by decade, 1960-2007**

*Source:* Authors' calculations from CANSIM Database.

[4]Farmer and research preoccupation with malting varieties has often been alleged as a reason why barley yields have not advanced as rapidly as they might have, had more attention been placed on the breeding and growing of superior feed barley varieties (see Ulrich, Furtan, and Schmitz 1986).

controlled weeds, they also contributed to soil erosion and a general loss of soil organic matter. Beginning in the 1970s, some farmers and industry groups began developing seeding systems and weed control systems that required less tillage. By the 1990s, very effective low-disturbance seeding systems had been developed, and they were rapidly adopted, as illustrated in Figure 6.7. All areas of Canada are adopting reduced-tillage systems, with the highest adoption rates occurring in Saskatchewan. These cropping systems reduce the demand for diesel, fuel, and labor, while increasing the demand for glyphosate herbicide and nitrogen fertilizer.

The adoption of low-disturbance seeding systems and the introduction of more intensive, and diverse crop rotations have also had a significant impact on the environment. These systems have reversed the long-term decline in soil organic matter and have resulted in a significant amount of carbon sequestration in the growing pool of organic matter. The reduction in tillage has significantly reduced both water and wind erosion. To the extent these environmental benefits are excluded in productivity measurement, the recent gains in productivity are understated.

Finally, it is important to note that the impact of changes in yield, cropping intensity, cropping diversity and tillage systems on productivity cannot be easily separated from one another. Each of these aspects of the cropping system has complemented the others. Similarly, a better use of available moisture has reduced the need to summerfallow, while increasing the demand and opportunity

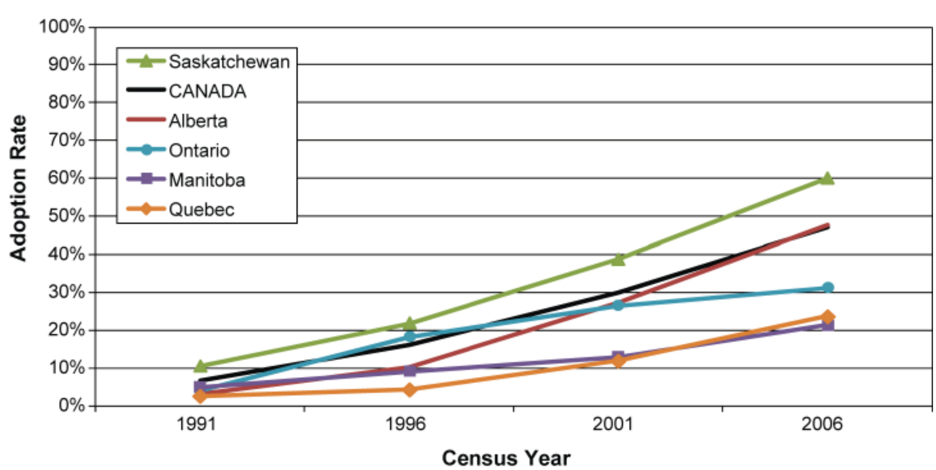


**Figure 6.7. Adoption of low-disturbance seeding as a percentage of seeded area, Canada and selected provinces**

*Source:* Statistics Canada, Census of Agriculture, 1991, 1996, 2001, 2006.

for growing other crops in the rotation. The access to higher-yielding pulse and canola crops has made these rotations more attractive.

### 2.2. Livestock Partial Productivity Measures

Livestock yields have risen over time as a result of improved genetics, feed conversion, and management practices, as well as the exploitation of economies of scale in production. In recent years, as noted, Canada's livestock industry has shifted toward more intensive livestock operations with a much smaller number of farms (except for the supply-managed poultry sector), an increase in the number of animals per farm, and many productivity-related improvements. For example, in Ontario, the efficiency of feed conversion for most livestock operations is estimated to have tripled between 1950 and 2000. Given that the yields per acre of feed grains doubled in Ontario in this period, each acre could effectively support six times as much livestock production in 2000 as in 1950 (White, Dalrymple, and Hume 2007).

In the case of cattle, beef production per cow has risen from about 170 kilograms in 1972 to approximately 272 kilograms in 2006. As well, during the 23-year period from 1980 to 2003, cattle carcass weights increased by 34% (AAFC 2005). Hybrid vigor from crossing traditional with newer European breeds was a major factor in this improvement. There are no Brahma or Cebu breeds in Canada's beef herd, unlike arid regions of Australia or the United States, so Canada has no concerns about reduced meat tenderness from this factor.

The Canadian hog industry has experienced notable productivity improvements arising from new genetics, new technologies, and economies of scale. Following the trend in other nations, Canada has seen the benefits of increased production from monogastric animals, such as hogs, which can utilize concentrated feeds very efficiently and which have shorter life cycles that foster faster genetic advance. From 1990 to 2003, larger litter sizes, more litters per year, and heavier carcass weights resulted in a 38% rise in production per sow (AAFC 2005). Genetic improvement in swine is reflected in the reduction in age at which hogs in Ontario reach 100 kg, which fell from 183 days in 1980 to 157 days in 2006 (White, Dalrymple, and Hume 2007). Despite the major advances in Canadian hog production and productivity up to 2006, the hog industry has been struggling economically since then, citing problems with global demand, trade barriers, and environmental constraints.

The Canadian dairy industry has also experienced some structural change and productivity increases. Increases in milk production per dairy cow have accompanied the increase in herd size. In 1991-92, milk production per cow was 5,456 kg whereas by 2007-08, average milk production per cow was 9,538 kg, representing almost a 43% increase in productivity from 1991 to 2007, an increase of 2.5% per year during this period (Canadian Dairy Commission 2009).

The poultry industry also changed structurally, with farm size increasing 35% from 1990 to 2007. In contrast to other sectors, the number of chicken producers increased slightly during this time period (Chicken Farmers of Canada 2009). Broiler chicken production experienced remarkable changes in productivity, as feed conversion rates improved sharply and the number of days for a broiler to reach market weight fell dramatically. Despite significant prior gains, the average number of eggs per layer has remained fairly stable since 1990, ranging from 265 to 270 eggs per year.

## 3. TOTAL FACTOR PRODUCTIVITY MEASURES AND GROWTH RATES FOR CANADIAN AND PRAIRIE AGRICULTURE

Partial productivity measures such as yield per unit of land can certainly be informative and useful, as we have seen in the preceding section. However, a better indicator of productivity performance, if it is available, is total factor productivity (TFP), particularly where substantial input substitution is occurring over time. TFP or multifactor productivity is the ratio of aggregate output to aggregate input, wherein as many inputs in the production process as possible, and not just a single input, are counted in evaluating productivity performance. TFP growth, then, is the growth in aggregate output that is not explained by growth in all measured inputs (for example, land, labor, capital, and materials).

### 3.1. Total Factor Productivity Growth in Canadian Agriculture

There is modest historical literature on productivity growth in Canadian agriculture. However, the extensive body of agricultural-specific productivity analyses undertaken in the United States has not been replicated in Canada at the national level. Some useful empirical information on TFP in Canadian agriculture does exist as an ancillary product of the extensive work on productivity in the Canadian economy and its sectors undertaken by Statistics Canada, especially in the past decade.

In CANSIM Table 383-0022, Statistics Canada provides time-series data relating to agriculture, from 1961 to 2005, on TFP based on gross output, TFP based on value added, and labor productivity. The most appropriate agriculture-related output variable available for our analysis is the combined crop and livestock production index. Over the period 1961 to 2005, TFP (based on gross output) for crop and animal production in Canada increased by 0.6% per year. Over the same time period, TFP (based on value added) for crop and animal production grew somewhat more rapidly, at some 1.4% per year. Following Christensen (1975), we prefer TFP measures based on gross output rather than on value added. However, the productivity growth rate estimate based on the preferred measure is appreciably lower than the estimates of agricultural productivity found in prior studies of the United States, the Canadian Prairies, or Australia. One possible reason why the growth rate in TFP reported by Statistics Canada based on gross output is comparatively low is that the annual compound growth rate for all inputs combined in crop and livestock production based on Statistics Canada's evidence is 2.4%, a rate considerably higher than in comparable American and Australian studies for aggregate input use in agriculture.

Finally, labor productivity in Canadian crop and animal production grew even more rapidly from 1961 to 2005, at 4.7% per year. Indeed, labor productivity growth in agriculture has tended to be considerably faster than in other sectors of the Canadian economy. However, the concern is that labor productivity growth considerably overstates the total overall productivity gains in agriculture, given the substantive increases in the use of material inputs and the historical capital-for-labor substitution in production.

### 3.2. Productivity (TFP) Growth: The Case of Prairie Agriculture in Western Canada

The Prairie provinces of Alberta, Saskatchewan, and Manitoba are the "bread basket" of Canadian agriculture, comprising nearly half of Canada's farms and much larger shares of its cropland and grassland base. A lengthy time-series study of productivity growth in Prairie agriculture, using TFP measures based on Tornqvist-Theil indexing procedures, was recently completed (Stewart 2006). Using this detailed case study, we can focus on the estimates of output, input, and productivity growth for Prairie agriculture from 1940 to 2004, including the disaggregation of the analysis to the crop and livestock sectors (Stewart, Veeman, and Unterschultz 2009; Veeman, Stewart, and Unterschultz 2006). We can also assess how and why productivity growth has occurred.

*3.2.1. Prairie Agricultural Production over Time*

The measurement of productivity growth in Prairie agriculture requires the construction of a comprehensive and lengthy data set of both quantities and prices for agricultural inputs and outputs. Beyond its use in measuring productivity growth, the data set also points to overarching trends in Prairie agricultural production over 65 years. In terms of input use, technological change in Prairie agriculture has been strongly labor saving and materials using. This is a reflection of the rapid mechanization of agriculture, gains in labor productivity, and the increasing use of pesticide, fertilizer, and energy inputs.

Agricultural outputs have also changed substantially over time. The Prairie crops sector typically produces in excess of 60% of the total value of Prairie agricultural production, although the livestock sector increased its share of total agricultural production from the 1980s onward. As evident in Figure 6.6, there has been a decline in the share of cereal crops being produced (e.g., wheat, barley, and rye) and an increase in production of canola and specialty crops (e.g., lentils, peas). Barley, until lately, nearly retained its share, and tame hay increased its share, principally as feed for the growing Prairie livestock sector.

Cattle's share in total Prairie livestock production increased from 1940 until 1980, as a feed lot industry was established in southern Alberta. By 1980 cattle's share began to stabilize, and then it declined somewhat as swine production expanded rapidly (principally in Manitoba). The cattle share also declined substantially following the 2003 finding of BSE in an Alberta cow and subsequent international trade restrictions. Poultry and dairy's share of livestock production declined relatively steadily from 1940 to 2004.

*3.2.2. Prairie Productivity Growth and Its Measurement*

Törnqvist-Theil indexes were employed to obtain the estimates of output growth, input growth, and TFP growth presented in Table 6.1. This "superlative" indexing methodology has been widely used since the 1970s (Christensen 1975), subject to the availability of data (notably input price data).

Considering average growth rates, computed as compound annual rates of growth by fitting trends to the respective underlying index numbers, Prairie agriculture displayed relatively strong overall productivity and output growth of 1.56% and 2.43% per annum, respectively, over the period 1940 to 2004 (see Table 6.1). Aggregate input growth is more modest at only 0.86% a year. Accordingly, productivity growth (on a gross output basis) accounts for the lion's

**Table 6.1. Average annual compound percentage growth rates for Prairie aggregate agricultural inputs, outputs, and productivity (TFP), 1940-2004**

| | 1940-2004 | 1940-1959 | 1960-1979 | 1980-2004 | 1990-2004 |
|---|---|---|---|---|---|
| TFP growth | 1.56 | 1.25 | 1.48 | 1.80 | 1.46 |
| Input growth | 0.86 | -0.03 | 1.45 | 0.57 | 0.21 |
| Output growth | 2.43 | 1.22 | 2.95 | 2.38 | 1.67 |

*Source:* Stewart 2006.

share of the considerable growth in Prairie agricultural output over this 65-year period. However, growth rates measured over various subperiods indicate substantial variation over time. Of particular significance is the decline in productivity growth over the 15 years prior to 2005, and the associated decline in output growth, partly but not solely due to the bad drought years of 2001 and 2002. Other factors may include the emergence of new disease and pest pressure such as fusarium head blight and wheat midge, and major cultural changes such as the widespread adoption of zero tillage. The historical trends of Prairie agricultural output, input, and productivity growth over time are shown in Figure 6.8. The considerable year-to-year variations in output and productivity growth are largely associated with weather and climatic factors, chiefly summer (June and July) rainfall and temperature, as was noted in the prior discussion of crop yield variation.

To assess the aggregate productivity growth measures in more detail, estimates are also obtained at the provincial and sectoral (i.e., crops and livestock) levels. Census data information is used to allocate shared inputs between the crops and livestock sectors, with shares being interpolated for intercensal years. A number of noteworthy trends can be discerned from Table 6.2. First, productivity growth in the crops sector over the 65-year period is substantially (some two to three times) higher than that in the livestock sector, a result also found in the United States (Huffman and Evenson 1993). The stronger growth path of productivity in the Prairie crops sector relative to the livestock sector is also evidenced in Figures 6.9 and 6.10. Second, productivity growth in Manitoba agriculture was considerably higher than in Alberta or Saskatchewan agriculture, and productivity growth in Saskatchewan agriculture was slightly higher than in Alberta agriculture (see Stewart 2006). Third, while crop productivity growth declined considerably over the final 15 years of the study, livestock productivity growth accelerated (at least in Manitoba and Saskatchewan). The slight decline in aggregate Prairie agricultural productivity growth then was the result of slower

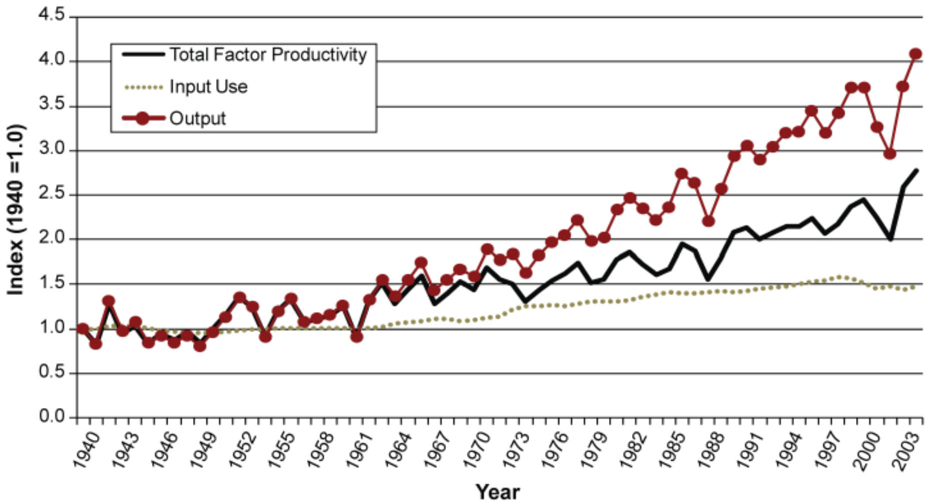


**Figure 6.8. Törnqvist-Theil Indexes of Prairie aggregate agricultural inputs, outputs, and productivity, 1940-2004**

*Source:* Stewart 2006.

**Table 6.2. Average annual compound productivity percentage growth rates for Prairie provinces by crops and livestock sectors**

| | Crops | | Livestock | |
|---|---|---|---|---|
| | 1940-2004 | 1990-2004 | 1940-2004 | 1990-2004 |
| Alberta | 1.65 | -0.33 | 0.54 | 0.58 |
| Saskatchewan | 1.76 | 0.39 | 0.59 | 4.28 |
| Manitoba | 2.12 | 2.70 | 0.97 | 5.33 |
| Prairies | 1.77 | 0.51 | 0.65 | 2.27 |

*Source:* Stewart 2006.

productivity growth for crops, while the acceleration of livestock productivity growth moderated the slowdown in aggregate Prairie productivity.

The stronger productivity performance in the Prairie crops sector from 1940 to 2004 does not mean, however, that the sectoral profitability of the crops sector has been better than that in the Prairie livestock sector. A crude measure of change in sectoral profitably is provided by change in its returns-to-cost ratio (*Py.Y/Px.X*) which, in turn, is the product of TFP (*Y/X*) and the sector's terms of trade (*Py/Px*) where *Y* is aggregate output, *X* is aggregate input, *Py* is the aggregate output price index, and *Px* is the aggregate input price index (Krishna 1982). Because the sectoral terms of trade facing the crops sector has deteriorated more rapidly over time (at –2.57% per annum versus only –0.29% for the livestock sector), the returns-to-

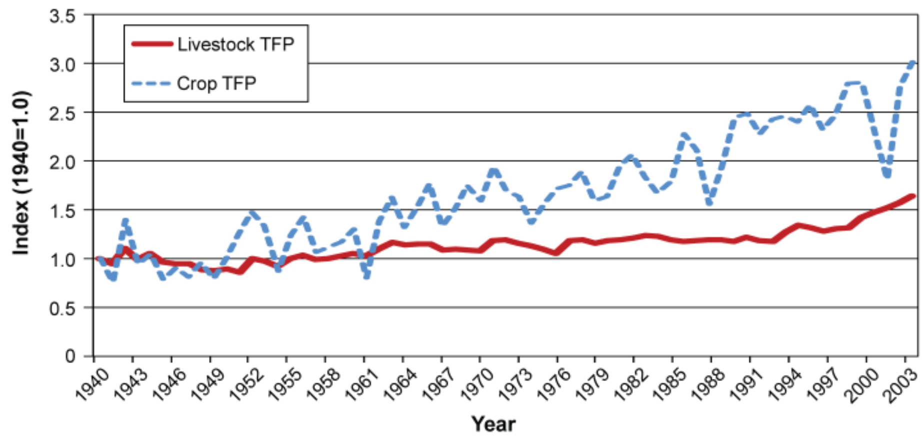


**Figure 6.9. Törnqvist-Theil Indexes of crops and livestock total factor productivity for the Prairies, 1940-2004**

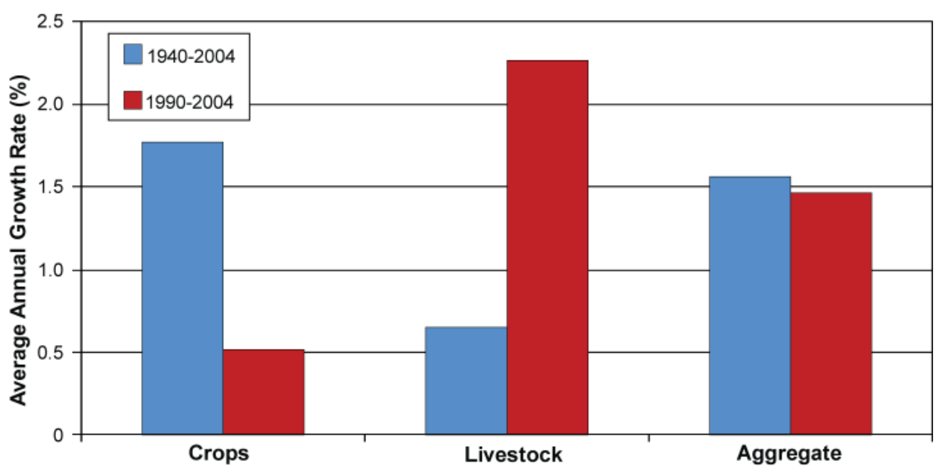


**Figure 6.10. Productivity growth rates for the Prairies, 1940-2004 and 1990-2004**

*Source:* Stewart 2006.

cost ratio for the crops sector has declined by 0.85% per year while the same ratio has actually increased somewhat in the Prairie livestock sector, at 0.36% per year over the 1940 to 2004 time period (Stewart 2006). In short, historically, productivity advance has slightly outpaced cost-price squeeze pressures in the livestock sector but has fallen behind in the crops sector on the Canadian prairies. It must be recognized that the terms of trade for prairie farmers is largely influenced by productivity growth outside Canada, which drives relative prices globally, rather than the smaller influence of productivity growth inside Canada.

The relative agricultural productivity growth performance of the three Canadian Prairie Provinces is quite consistent with that of the 10 Great Plains states in the United States, as reported by the U.S. Department of Agriculture online in 2007 (Stewart, Veeman, and Unterschultz 2009). For the comparable period of 1960 to 1999, the average productivity advance in the Canadian prairie provinces of 1.6% per year is only slightly higher than the annual average 1.4% growth rate in TFP in the Great Plains states. Moreover, for the more immediate and shorter time period of 1980 to 1999, the average Great Plains rate of 2.0% per year is very slightly higher than the Canadian prairie rate of 1.9%. A major caveat, however, to this bilateral comparison is that some of the input data, such as labor, are quality adjusted in the work by the U.S. Department of Agriculture for the United States, an adjustment that would lead to somewhat lower productivity growth rates for the Great Plains states.

**3.3. How Prairie Productivity Growth Happened**

In this section, the empirical results of decomposing estimated productivity growth in the crops and livestock sectors into their constituent parts are very briefly summarized (Stewart 2006; Stewart, Veeman, and Unterschultz 2009). Productivity growth can be ascribed to one of three influences: technical change, increases in the degree of technical efficiency, or greater economies of scale in production. By using a translog cost function, productivity growth can be econometrically decomposed to reveal the respective roles of technology and economies of scale in productivity growth (Capalbo 1988). Efficiency changes are reflected along with measurement errors in the reported residual.

In the case of Prairie agriculture, the crops sector has been better able to leverage productivity growth from technological advances, since for Alberta, Saskatchewan, and Manitoba, respectively, 94.7%, 84.5%, and 80.4% of the recorded productivity growth since 1940 has been generated by technical change (Stewart, Veeman, and Unterschultz 2009). In contrast, the livestock sector has been more effective in generating increasing returns to scale over time, with about half of its productivity advance attributable to scale impacts historically. Accordingly, the recent slowdown in crops productivity growth can be largely attributed to limited technological advances in this sector. The accelerating livestock productivity growth can be attributed in part to technological gains accruing to the sector, but more importantly to the economies of scale realized from the rapid increase in livestock output over the 15 years to 2005 and the increasing shift to intensive livestock operations.

## 4. PRODUCTIVITY GROWTH SLOWDOWN AND LINKS TO RESEARCH

In this section, we briefly assess whether there has been a recent slowdown in agricultural productivity growth in Canada and in the Prairie region of Western Canada. Linkages of productivity change in primary agriculture to expenditures on agricultural research and development (R&D) are also explored. Whether agricultural productivity growth has slowed down or not in the past two decades is an open question in many nations, Canada included.

Although crop yields are only a partial productivity measure, changes in crop yields provide the most readily available and long-standing measures of productivity gains in Canadian agriculture. As we have noted, aggregate crop yields have followed a linear pattern of growth since the early 1960s such that the proportional rates of growth of the yields of the major Canadian grain and oilseed crops—wheat, canola, corn, and peas—declined over time.

The TFP growth estimates available for agriculture that are most convincing are those for the Prairie region of Western Canada. Structural change (Chow) tests were undertaken for each of the crop, livestock, and aggregate (multioutput) agricultural productivity growth for this region to see if a structural break occurred in 1990. Such a structural break is statistically confirmed for livestock productivity growth, with the rate of growth being faster after 1990. For crops productivity, the rate of growth is lower after 1990, but this is not statistically significant. It is possible that the shift to zero-till and greater cropping intensity partially compensated for the declining yield growth rates in crops. For crops and livestock taken together, the rate of productivity growth is actually higher after 1990, but the structural break is not statistically significant.

If a productivity slowdown has occurred in the past two decades in Canadian agriculture, this has occurred in the crops sector. The evidence for this is most convincing from the crop yield trends, and somewhat less so for TFP growth in crops grown in Prairie agriculture. Complicating the assessment overall of recent productivity trends is that the year 2008 saw record or near-record crop production levels and yields in Canada but continuing poor economic and financial conditions for the red meat sectors.

There is reasonable qualitative evidence and some econometric evidence to support the view that lagging agricultural R&D is adversely influencing agricultural productivity growth, especially in crops. Real public agricultural research expenditures in Canada for both crops and livestock declined between 1996 and 2004 (Gray 2008). The impact of variety improvement is most apparent in wheat, for which there has been little private research activity. The extent that canola and pea variety improvement may have recently accelerated has been offset by other factors in production, as historical average yields follow strikingly similar linear growth patterns across all major crops. Specific explanations for productivity growth and its variability over time among provinces and between the livestock and crop sectors can be advanced for Prairie agriculture (Stewart 2006). Following Huffman and Evenson's methodology (1993 and 2001), Stewart (2006) estimated a three-equation SUR (seemingly unrelated regression) model, using indexes of aggregate agricultural, crop, and livestock productivity (TFP) as dependent variables. Explanatory variables tested included measures of domestic prairie agricultural research and development, terms of trade (following Cochrane 1958), farm specialization, farm size, education, extension, off-farm labor, farm/manufacturing wage ratio, and support payments.

Domestic research and development, a "knowledge stock" variable, is calculated as a 20-year stock of federal, provincial, and private sector research and development expenditures. This "knowledge stock" variable leveled off for both crops and livestock in Prairie agriculture since 1990 (Stewart 2006). For both livestock and crops, domestic research and development displayed a positive relationship and was the largest absolute value among the reported coefficients. This finding points to the fundamental role that previous domestic research and development investments have played in productivity growth in both the crop and livestock sectors.

## 5. SUMMARY AND CONCLUSION

With increasing consolidation and specialization, Canadian primary agriculture has evolved over time to a sector dominated by fewer and larger farms, which account for most agricultural production, although a number of smaller farms continue to operate. As in many developed nations, large farms in Canada account for most of the agricultural production. In terms of farm receipts, red meats, grains and oilseeds (led by wheat and canola, respectively), and dairy are Canada's most important agricultural commodities. However, Canadian farmers have been diversifying their production mix to reach niche markets, increase value added, and spread risk.

Since the early 1960s, the yields of several major crops have increased by approximately 60%. Yield trends for corn, wheat, canola, and peas are remarkably similar, exhibiting consistent absolute growth but declining proportional rates of growth over the period. The assessment of yield changes, however, is complicated by increased cropping intensity (reduced summer fallow), more cropping diversity, and ongoing changes in cropping technology (reduced tillage and low-disturbance seeding systems), particularly in Western Canada. Interesting evidence from crop field trials shows that trial yields for canola and peas have grown more rapidly than for wheat since 1960. This raises the perplexing question of why actual realized yield growth trends have been so similar across these crops.

An assessment of partial productivity measures for the Canadian livestock sector indicates many areas in which production efficiency has improved substantially: higher carcass weight for beef animals, much more production per sow, and major increases in milk production per dairy cow. These "yield" improvements have occurred as Canada's livestock production has become concentrated, in more intensive operations, on many fewer but generally much larger farms.

Based on national time-series data reported by Statistics Canada, labor productivity in crop and animal production in Canada grew rapidly, at 4.7% per year from 1961 to 2005, reflecting, at least in part, the considerable substitution of capital for labor that continued during this period. It is possible to infer from Statistics Canada's national accounts data that TFP growth for crops and livestock, considered together, was considerably slower, ranging from less than 1.0% per year (based on gross output measures) to some 1.4% per year (based on value added measures). More research on productivity estimation and analysis that is directed explicitly to the agricultural sector could clarify these differences and strengthen understanding of agricultural productivity in Canada.

There are major advantages and insights in more detailed assessment of production structure, its evolution, and productivity performance for a major agricultural region such as Western Canada's Prairies over a lengthy time span (Stewart 2006). Productivity growth, exceeding 1.5% per year, has been very important historically in Prairie agriculture, generating nearly two-thirds of output growth. Crop productivity growth outpaced that of livestock, but not in the past 10 or 15 years. The decomposition of estimated productivity growth suggests that technical change has been critical in the crops sector, whereas the roles of technical change and scale impacts have been roughly equal in the livestock sector. R&D expenditures have been a key causal factor underpinning productivity growth in agriculture.

Slower growth in agricultural R&D in Canada seemingly underlies slower productivity growth in the past 10 to 15 years. It is possible that the upswing in livestock productivity, relative to slower growth in crop productivity in the last decade, may be associated, at least in part, with elimination of the Crow

Rate subsidy on grain moving to export position. This change in policy provided more economic incentives for livestock feeding in Western Canada, but more work is needed on this front to fully ascertain the full impact of this policy change. Similarly, more research is needed on whether agriculture in Alberta and western Saskatchewan has suffered from the recent energy/oil boom and adverse "Dutch disease" impacts. A final caveat is that the TFP growth measures reported here are "private" and not "social" or environmentally adjusted productivity measures (Hailu and Veeman 2001). The incorporation of environmental externalities such as nitrate leaching, pesticide damage, and air and water pollution from agricultural production poses difficulties but would provide a better indication of productivity performance from a social perspective.

In summary, overall the study of Canadian crop yields (a partial productivity measure) and, to a lesser degree, the analysis of total factor productivity growth in the crops sector in the Prairie region of Western Canada indicates a slowdown of productivity growth in crop production in the past two decades. Increased funding for agricultural research would help to counter the productivity slowdown in crops and to ensure that future productivity growth in the livestock sector could be based relatively more on technical change and less on scale economies associated with output expansion. Improved productivity performance, led by increased funding for R&D, is critical to the future competitiveness and economic sustainability of Canada's primary agriculture.

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