A Half-Century of Productivity Growth and Structural Change in Canadian Agriculture: An Overview

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ABSTRACT

The primary agriculture sector in Canada experienced impressive productivity growth over the 1961-2007 period, outperforming by far productivity growth seen in the Canadian business sector as a whole. In the period in question, the agriculture sector also experienced profound structural changes, from the massive decline in the use of labour input due to mechanization, to the increased use of intermediate inputs (such as fertilizers and pesticides) in the production process. The objective of this article is to highlight some of the most important structural changes observed by Canadian agriculture over the past 50 years, and link them to the robust productivity growth in the sector.

RÉSUMÉ

Le secteur de l'agriculture primaire au Canada a connu une croissance marquée de sa productivité pour la période de 1961 à 2007, devançant de beaucoup la croissance de la productivité du secteur canadien des entreprises dans son ensemble. Au cours de cette période, le secteur de l'agriculture a également vécu des changements structurels profonds allant de la chute massive de l'utilisation de l'apport de travail causée par la mécanisation à l'emploi accru d'intrants intermédiaires (comme les engrais et les pesticides) dans le processus de production. Cet article a pour objet de mettre en évidence certains des changements structurels les plus importants dans le secteur de l'agriculture au Canada au cours du dernier demi-siècle et d'établir des liens entre ces changements et la solide croissance de la productivité du secteur.

AGRICULTURAL PRODUCTIVITY HAS BEEN increasing at a much faster pace than aggregate productivity in Canada over the past decades. In particular, while business sector productivity growth in Canada saw a significant slowdown after 2000, productivity growth in the primary agriculture sector remained strong. The purpose of this article is to highlight some of the key structural changes experienced by Canadian agriculture over the past 50 years, and link them to the robust productivity growth in the sector.

This article is divided into five sections. The first section defines the data sources and con-

1 The author is an economist at the Centre for the Study of Living Standards (CSLS). This article is a summary of a report on agricultural productivity in Canada commissioned by Agriculture and Agri-Food Canada from the CSLS (de Avillez, 2011a). A second report was comissioned on the productivity of the Canadian food processing sector (Ross, 2011). The CSLS would like to thank Agriculture and Agri-Food Canada for their financial support. Email: ricardo.avillez@csls.ca.

cepts used. Section two analyzes output and price trends observed in the Canadian agriculture sector. Section three details labour, capital, and intermediate input trends. Section four looks into the productivity performance of the primary agriculture sector, comparing it to that of the Canadian business sector as a whole. Labour and multifactor productivity estimates are discussed. The fifth section concludes.

Data Sources and Definitions

Data Sources

The main data source for this article is Statistics Canada's Canadian Productivity Accounts (CPA). The CPA provides detailed data on output, input use, and productivity for the primary agriculture sector, as well as for the business sector as a whole.[2] The advantages of using the CPA data are two-fold: 1) methodological consistency when comparing different sectors in the Canadian economy; 2) its long-run appeal, with most of its data series encompassing the 1961-2007 period.

This article also makes extensive use of Statistics Canada's agricultural data. In particular, data on agricultural land area, fertilizer use, and pesticide use were taken from the Census of Agriculture, while farm cash receipt data was taken from Statistics Canada's Net Farm Income survey.

The Primary Agriculture Sector

At the two-digit level, the North American Industry Classification System (NAICS) groups agriculture along with forestry, fishing and hunting (NAICS code 11). In this article, the primary agriculture sector is defined as the sum of the crop production (NAICS code 111) and animal production (NAICS code 112) subsectors. These two subsectors have always represented the bulk of the agriculture, forestry, fishing and hunting sector in Canada.

Even though crop production and animal production are two very distinct subsectors, this article focuses on the primary agriculture sector as a whole. The reason for this is that a significant number of farms in Canada have a mixed nature, engaging in both crop production and animal production, and Statistics Canada has no way to allocate inputs and outputs perfectly between the two subsectors. It is important to keep in mind, however, that the primary agriculture sector is quite heterogeneous in terms of production processes, and there might be different forces driving productivity in the two subsectors. An important example of this can be seen in Stewart *et al.* (2009), where the authors find that the effects of scale economies in Canadian Prairie agriculture are much larger in animal production than in crop production.

Productivity Concepts

Two sets of labour and multifactor productivity estimates calculated by Statistics Canada are presented: one uses a value added approach (VA); the other uses a gross output approach (GO).

- **Labour productivity (VA)** is defined as real GDP per hour worked;
- **Labour productivity (GO)** is defined as real gross output per hour worked;
- **Multifactor productivity (VA)** is the difference between real GDP growth and combined labour-capital input growth. MFP thus reflects output growth that is not accounted for by input growth.
- **Multifactor productivity (GO)** is the ratio between real gross output and combined input growth, which, in this case, includes not only labour and capital, but also intermediate inputs such as fertilizers, pesticides, etc.

2 The methodology used by Statistics Canada to calculate the CPA's productivity estimates can be found in Baldwin *et al.* (2007).

Table 1: Real GDP in the Primary Agriculture Sector, Canada, 1961-2007
(compound annual growth rates, per cent)

	1961-2007	1961-2000	2000-2007
Business Sector	3.81	4.04	2.59
Primary Agriculture Sector	1.80	1.83	1.60

Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 379-0027, 383-0021/22).

Gross output consists of all goods and services produced by an economy, sector, industry or establishment during a certain period of time. Value added (or GDP at basic prices), on the other hand, measures the contribution of primary inputs (labour and capital) to the production process. While gross output refers to an actual physical quantity, there is no physical representation of value added.

When dealing with the economy as a whole, the value added approach is the natural choice, because it avoids double counting of intermediate inputs in the aggregate output. In practice, the value added approach is also the standard choice of most sectoral productivity analysis. Trueblood and Ruttan (1992) argue, however, that when investigating the productivity performance of a particular sector, the focus should be on the total input-output relationship in order to evaluate the overall gains in both primary and intermediate input use. This is particularly true in the case of sectors that experienced significant shifts in the use of inputs through time, such as the primary agriculture sector, where intermediate inputs (feed, fertilizers, pesticides, etc.) play a much more prominent role nowadays than they did in the past.

Output and Price Trends

In this section, we highlight the most important output trends seen in the primary agriculture sector over the 1961-2007 period.

Real GDP growth in Canadian primary agriculture lagged behind overall business sector growth

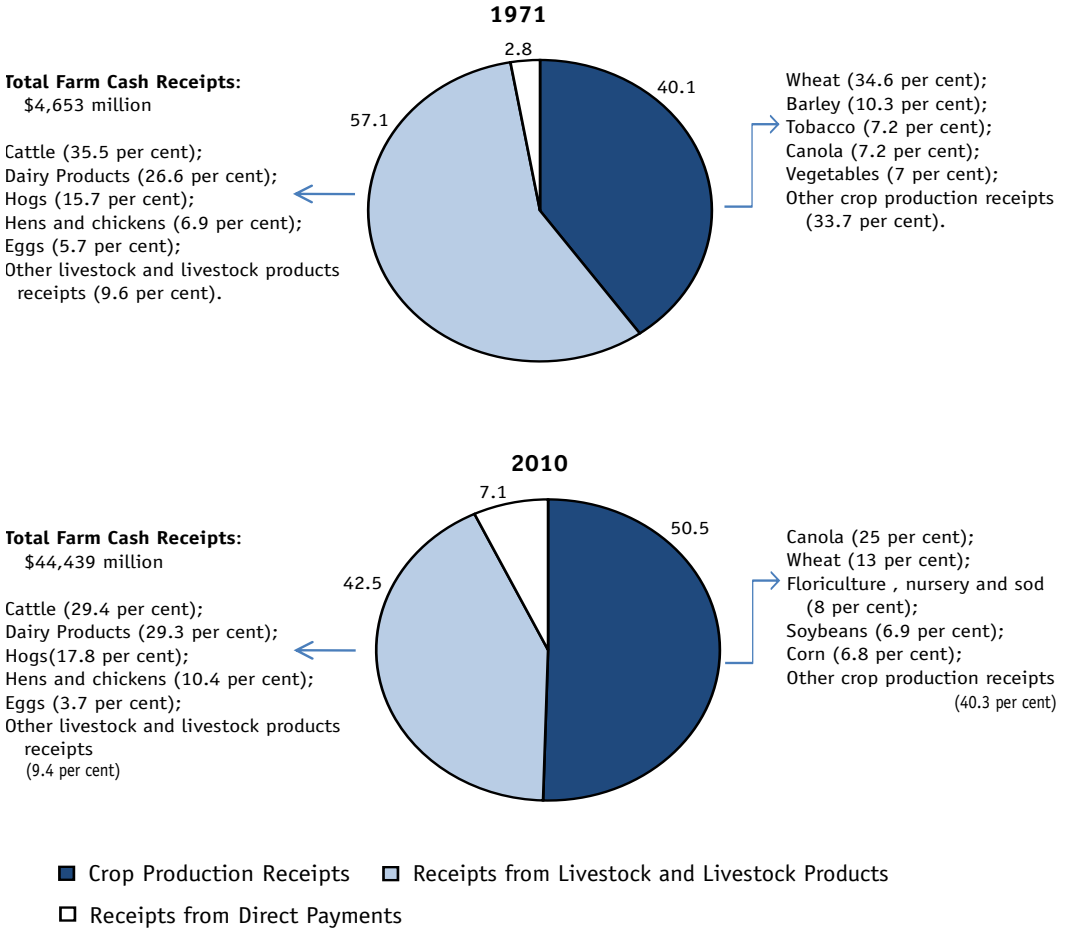
In 2007, real GDP in the primary agriculture sector was $20,135 million (chained 2002 dollars), 2.3 times its 1961 level. It grew at an average annual rate of 1.80 per cent during the 1961-2007 period, only half of the real GDP growth experienced by the Canadian business sector over the same period, 3.81 per cent per year (Table 1). These results are not surprising. In general, agricultural output grows at a much slower pace than business sector output because food products tend to have low income elasticities of demand (i.e. they are necessity goods). For exactly the same reason, when real GDP growth in the business sector faltered in the 2000-2007 period, decreasing from 4.04 per cent per year in the 1961-2000 period to 2.59 per cent, real GDP growth in primary agriculture experienced only a very small drop, from 1.83 per cent to 1.60 per cent.

Important shifts in the mix of agricultural commodities produced

Perhaps the best way of mapping changes in the mix of commodities produced by the Canadian farm sector over the past decades is to look at farm cash receipt data from Statistics Canada's Net Farm Income survey.

In 2010, total farm cash receipts reached $44,439 million, up from $4,653 million in 1971, with crop receipts accounting for $22,425 million (or 50.5 per cent of the total), livestock and livestock products receipts responsible for $18,879 million (42.5 per cent of the total), and

Chart 1
Total Farm Cash Receipts, Canada, 1971 and 2010



direct payments accounting for $3,133 million (7.0 per cent of the total) (Chart 1). Crop production was dominated by canola (25.0 per cent of total crop receipts), which was followed in importance by wheat (13.0 per cent), and floriculture, nursery and sod (8.0 per cent). In livestock production, the three categories that accounted for the lion's share of livestock receipts were: cattle (29.4 per cent of total livestock and livestock products receipts), dairy products (29.3 per cent), and hogs (17.8 per cent).

Comparing total farm receipt data from 1971 and 2010, we can see a number of interesting trends. It becomes clear that the relative importance of the crop production subsector increased over time. In 1971 it was responsible for only 40.1 per cent of total farm receipts, but by 2010 it accounted for 50.5 per cent of receipts. Not only that, the composition of crop production receipts changed much more between the two periods than that of livestock and livestock production receipts, which remained fairly stable during the period. The most important change in crop production receipts is undoubtedly the decline in importance of wheat, which represented 34.6 per cent of total crop production receipts in 1971, but by 2010 accounted for only 13.0 per cent. Conversely, the importance of canola increased dramatically, and by 2010 this

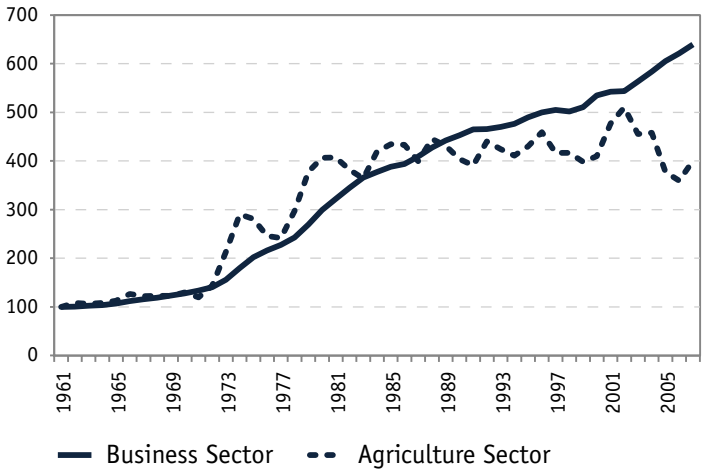
Table 2
Implicit Price Deflators for the Primary Agriculture Sector, Canada, 1961-2007
(compound annual growth rates, per cent)

	1961-2007	1961-2000	1961-1971	1971-1981	1981-1989	1989-2000	2000-2007
Business Sector	4.11	4.39	2.93	9.18	4.04	1.76	2.59
Primary Agriculture Sector	3.06	3.68	1.78	13.05	0.72	-0.46	-0.33

Source: CSLS calculations based on Statistics Canada data. (CANSIM Tables 379-0027, 383-0021/22, and 381-0015).

field crop accounted for 25.0 per cent of total crop production receipts.[3] One last thing that should be highlighted is the increasing diversification of Canadian crop production, which can be seen by the increase in other crop production receipts between the two periods (i.e. the five most important commodities in terms of cash receipts now account for a smaller share of total crop receipts than they did in 1971).

Chart 2
Implicit Price Deflators for the Primary Agriculture Sector, Canada, 1961-2007
(Index 1961=100)



Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 379-0027, 381-0015, and 383-0021/22).

Despite high volatility, relative prices in the primary agriculture sector saw a substantial decline during the 1961-2007 period

The implicit price deflators for the business sector and for the primary agriculture sector during the 1961-2007 period tell very different stories (Table 2). Business sector prices grew at an average annual rate of 4.11 per cent during those years, while agricultural prices grew only 3.06 per cent per year. For the business sector, even though the bulk of price increases came in the 1971-1989 period, the subsequent periods still saw positive growth rates. In the case of primary agriculture, however, most of the price increases came in the 1971-1981 period, when prices more than tripled, after which the rate of price increases first fell sharply in the 1981-1989 period, and then became negative in subsequent periods. The differences between the two series become clearer when we look at Chart 2, where we can see that, although prices in the business sector have been consistently growing over the 1961-2007 period, prices in the primary agriculture sector have been stagnant since the early 1980s, fluctuating around the same level since. According to the implicit price deflator, agricultural prices in 2007 were below the 1989 level, and at about the same level as in 1979.

3 It is also interesting to that 93 per cent of canola crops in 2009 were genetically modified (GM). For a detailed discussion of the contribution of biotechnology activities to the Canadian economy, see de Avillez (2011b).

Input Trends

This section analyzes the most significant input use trends in Canadian primary agriculture during the 1961-2007 period.

Due in large part to increasing mechanization, the primary agriculture sector saw a massive decline in the use of labour input

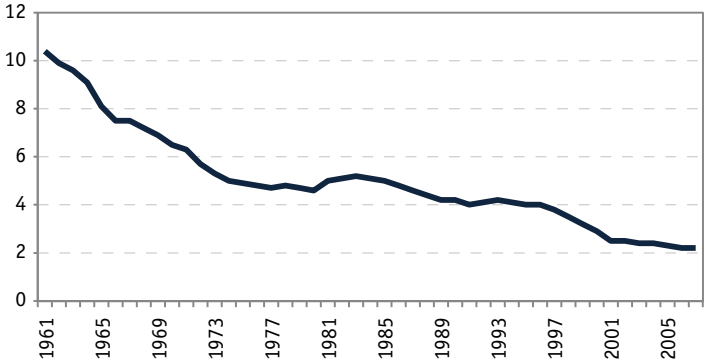
There were 302 thousand jobs in the primary agriculture sector in 2007, 46 per cent less than the number observed in 1961, 557 thousand. The decline in the absolute number of jobs in primary agriculture, coupled with the increase in the total number of jobs available in the Canadian business sector over the past 50 years, led to a steep fall in the primary agriculture sector's share of employment in the Canadian economy. More specifically, it accounted for 10.4 per cent of Canadian business sector jobs in 1961, but only 2.2 per cent in 2007 (Chart 3).[4]

According to data from Statistics Canada's Labour Force Survey, the majority of workers in the primary agriculture sector were self-employed in 2007. It should be noted, however, that the share of self-employed workers in the sector has been falling over time, from 68.2 per cent of total agricultural workers in 1987 to 62.5 per cent in 2007. Another interesting development is the decline in the number of unpaid family workers in primary agriculture, which accounted for 18.9 per cent of self-employed workers in 1987, but by 2007 represented only 6.0 per cent.

Total hours worked in primary agriculture fell even more than the number of jobs in the sector (again, both in absolute and real terms). In 2007, total hours worked in primary agriculture represented 2.7 per cent of total hours worked in the Canadian business sector, down from 14.3 per cent in 1961, a drop of 11.6 percentage points. Total hours worked in primary agriculture declined at a rate of 1.90 per cent per year during the 1961-2007 period, while in the business sector it increased by 1.72 per cent per year.

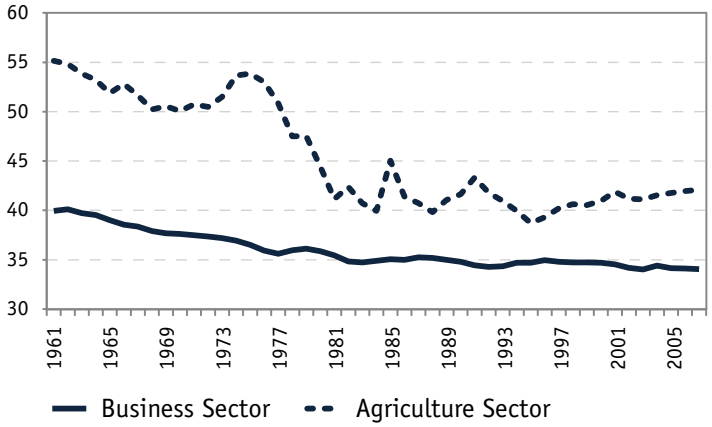
The fall in total hours worked in primary agriculture reflected a reduction not only in the

Chart 3
Number of Jobs in the Primary Agriculture Sector as a Share of the Business Sector, Canada, 1961-2007
(per cent)



Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0003, 383-0009/10).

Chart 4
Average Weekly Hours Worked per Worker in the Primary Agriculture Sector, Canada, 1961-2007



Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0003, 383-0009/10).

4 Looking at the total economy (instead of the business sector), employment in primary agriculture accounted for 1.8 per cent of employment in Canada in 2007.

BOX 1 – The Limits of Mechanization

The increasing mechanization in crop production allowed for a massive boost in agricultural productivity. However, not all types of crops benefited equally from mechanization. Calvin and Martin (2010) have identified U.S. fruit and vegetable industries that are still labour-intensive, with either no mechanization or only partial mechanization. These include the production of apples, oranges (fresh-market), strawberries, and asparagus, which are not mechanized at all, as well as that of oranges (processing), raisins, and lettuce, which are partially mechanized. One of the main problems of using harvesting machines in farms that supply fresh-market fruits and vegetables is that they can damage the skin of the fruits/vegetables, making them unacceptable by fresh-market standards. An example of this is the harvester used by orange growers in Florida, which "shakes the tree canopy to dislodge the fruit" (p. 16), but by doing so frequently damages the skin of the oranges. Consequently, these harvesters are used only for oranges that will be processed, not for oranges that are sold to the fresh market. According to Calvin and Martin (2010:29):

> Growers may mechanize to replace costly labor if an economical mechanical alternative is available. However, mechanization often presents complex technical challenges. A machine cannot easily mimic the judgment and dexterity of experienced farm workers, particularly when crops do not mature evenly, and workers must determine what can be harvested during multiple passes through fields and orchards. Research and development (R&D) can be both expensive and time consuming, with success of mechanization difficult to predict. Developing a viable mechanized harvest system often depends on breakthroughs in three areas: machinery, varieties, and agricultural practices. Results from all three lines of research may not emerge at the same time.

number of jobs in the sector, but also in the duration of the average working week. Chart 4 shows that average hours worked in a week in the sector fell from 55.2 hours in 1961 to 42.1 hours in 2007, a 24 per cent drop. This series reached an all time low in 1995, 38.7 hours, after which it started to increase gradually. Note that, throughout the entire period, workers in the primary agriculture sector worked considerably more in a week than the average Canadian worker. This weekly hours differential, however, has fallen over time, from 15.2 hours in 1961 to 8.0 hours in 2007.

Another important issue related to the use of labour input in primary agriculture has to do with how much of nominal GDP goes to labour compensation (as opposed to capital compensation). In 1961, the labour compensation share of GDP was the same in the primary agriculture sector and the business sector, 62.4 per cent (Chart 5).[5] By 2006, the labour share of GDP in the business sector had a slight fall, to 56.8 percent, while the labour share of GDP in the agriculture sector plummeted to only 37.7 per cent, a 24.7 percentage point drop.[6]

5 According to Baldwin *et al.* (2007), "income data for all paid employment originate directly from the estimates of employment income produced by the Income and Expenditure Accounts. In the case of self-employed workers, the combined labour income was obtained by imputation in the past, using the assumption that the value of an hour worked by a self-employed worker was equal to the value of an hour worked by a paid worker (at the average rate) in the same industry. The same imputation approach is used to produce data for unpaid family workers. In addition, employment income for certain professionals (physicians, lawyers, dentists, accountants and engineers) is derived from income tax statistics" (p. 39).

6 Currently, the CPA's labour compensation for the Canadian business sector series ends in 2006.

Table 3
Real Capital Stock per Hour Worked in the Primary Agriculture Sector, Canada, 1961-2007

	1961-2007	1961-2000	2000-2007
	(compound annual growth rates, per cent)		
Business Sector	1.46	1.57	0.79
Primary Agriculture Sector	2.52	2.74	1.32
	1961	**2000**	**2007**
	(chained 2002 dollars of capital stock per hour worked)		
Business Sector	20.51	37.72	39.87
Primary Agriculture Sector	15.02	43.11	47.27

Source: CSLS calculations based on Statistics Canada data (CANSIM Table 383-0021, and 383-0022).

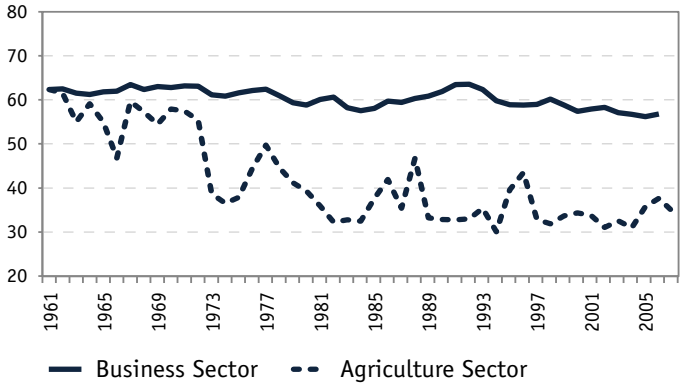
Agricultural workers in Canada nowadays have, on average, 3.0 times as much capital to work with as they did in 1961

The relationship between physical capital and productivity is relatively direct. With more capital to work with, each worker can produce more output per hour. If, through investment, capital input increases at a faster pace than labour input, then the amount of capital per labour input increases, i.e. there is capital deepening. The main point to understand here is that what matters to productivity is not capital input in absolute terms, but capital per worker or, better yet, capital per hour worked.

Another reason why investment in physical capital is relevant is because it is the primary means by which technical change is introduced into the production process. Spending on R&D often leads to the creation of better quality machinery and equipment. With investment, these quality gains are gradually embodied in the capital stock.

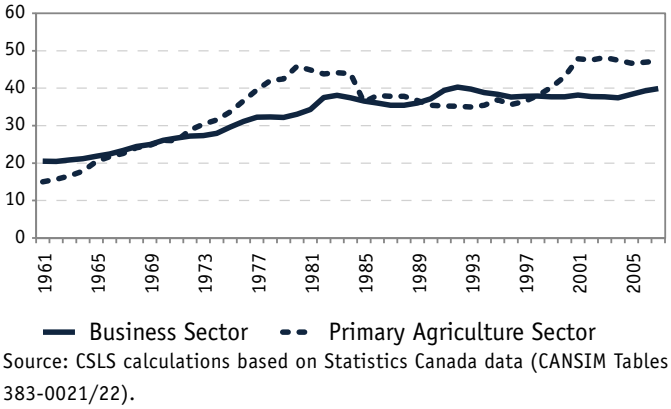
Capital stock intensity, defined here as real capital stock (fixed, non-residential) per hour worked in the primary agriculture sector increased at a faster rate than in the business sector during the 1961-2007 period (2.52 versus 1.46 per cent per year) (Table 3, Chart 6). In terms of levels, capital stock intensity in primary agriculture increased from $15.02 (chained 2002 dollars) per hour in

Chart 5
Labour Compensation as a Share of Nominal GDP in the Primary Agriculture Sector, Canada, 1961-2007
(per cent)



Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0021/22).

Chart 6
Capital Intensity in the Primary Agriculture Sector, Canada, Chained 2002 Dollars per Hour Worked, 1961-2007



Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0021/22).

BOX 2 – Robotic Farmhands

A recent trend that is helping farmers reduce labour costs and increase productivity is the use of robotics in daily farm operations. Once restricted to large operations due to high fixed costs, robotic farmhands are starting to be incorporated by medium sized operations as well. This is happening not only because of falling prices of capital goods, which make this type of high-tech machinery more accessible, but also because of the current macroeconomic conditions (low interest rates coupled with a strong Canadian dollar), an ideal occasion for machinery to be imported from the United States and Europe.

Two examples of robotic farmhands used in dairy farming are feed-pushing robots, and computerized milking parlours. Feed pushing robots let cows feed on demand, independent of the time of day and without human assistance. Since the quantity of milk produced depends on how well fed the cow is, the use of feed pushing robots tends to increase milk production significantly. A computerized milking parlour functions like a slowly rotating carousel where cows, equipped with transponders, get on and off in order to be milked. It can identify cows that are sick or in heat based on their movement patterns, and can even clean a cow's udder prior to milking. Furthermore, it allows for as much as 50 cows at a time, which means that up to 300 cows can be milked per hour.

Source: Trichur (2011).

1961 to $47.27 per hour in 2007, while business sector capital stock intensity increased from $20.51 per hour to $39.87 per hour.

An intuitive way to picture how the increase in capital intensity has affected the primary agriculture sector is to look at the number of trucks and tractors per farm unit, which has increased considerably over the 1971-2006 period. In 1971, the average farm unit had only 1 truck and 1.6 tractors, but in 2006 these numbers had jumped to 2 and 3.2, respectively. Not only that, the average size (and quality) of trucks and tractors also increased dramatically over the period.

Increased reliance on intermediate inputs

In addition to labour and capital, it is also important to keep track of how intermediate input use has changed over time. This is particularly true in the case of primary agriculture, where seed, feed, fertilizers, and pesticides play an essential role in the productive process.

Statistics Canada divides intermediate inputs into three broad categories: energy, material, and services. The energy input category includes different types of fuels used in economic activities, such as fuel oil, natural gas, coal, and electricity. The material input category takes into account all commodity inputs that are not included in the energy category (such as seed, feed, fertilizers, pesticides), while the services input category aggregates nine subcategories of services.[7]

The value of intermediate inputs in the primary agriculture sector was $31,966 million (current dollars) in 2007, of which $22,813 million refer to material input costs (71.4 per cent of total input costs), $5,471 million to services input costs (18.0 per cent), and $3,412 million to energy input costs (10.6 per cent).

Chart 7 shows the contributions of labour, capital, and intermediate inputs to gross output in the agriculture sector. As can be seen, the value of intermediate inputs represented 66.9

7 The nine services input categories are: communications, finance and insurance, real estate rental, hotel services, repair services, business services, vehicle repair, medical and educational services, and purchases from government enterprises.

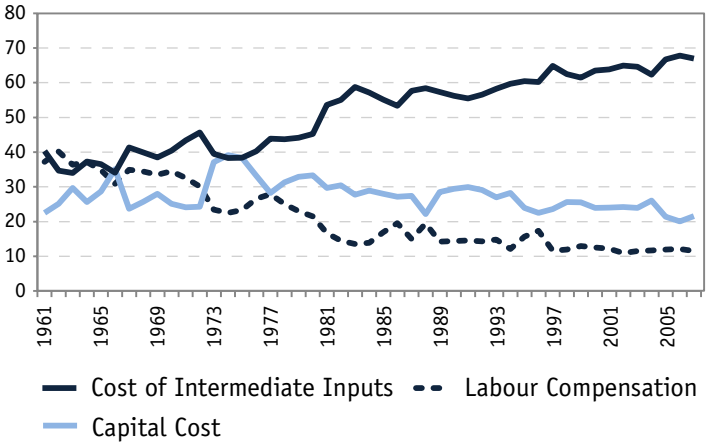
per cent of gross output in the sector in 2007, up from 40.3 per cent in 1961. The importance of labour compensation in the sector's gross output fell markedly in the period, from 37.2 per cent in 1961 to 11.5 per cent in 2007, a drop of 25.8 percentage points, while the importance of capital compensation remained practically stable (22.5 per cent of the sector's gross output in 1961 to 21.6 per cent in 2007).

During the 1961-2007 period, real intermediate input use in the primary agriculture sector grew at a robust pace of 4.63 per cent per year. Although all three input groups saw significant growth over the period, the energy input grew the most, 5.97 per cent per year (Table 4). Note that the 2000-2007 period observed a sharp decline in real intermediate input growth in primary agriculture, from 5.23 per cent per year in the 1961-2000 period to only 1.33 in 2000-2007, which explains why the sector's real gross output and real GDP were almost the same during the period (1.41 versus 1.60 per cent per year, respectively).

In concrete terms, fertilized land area in Canada increased from 6,928 thousand hectares in 1971 (approximately 10.0 per cent of total agricultural land area in the country) to 25,348 thousand hectares (37.5 per cent of total agricultural land area). Real expenses in fertilizer use in Canada grew at a rapid rate of 3.75 per cent per year during the 1971-2006 period (Table 5, Panel A). In 1971, fertilizer expenses totaled $392 million (constant 1992 dollars), but by 2006 they had reached $1,422 million (constant 1992 dollars), nearly four times the original amount. Since agricultural land area remained roughly constant throughout the entire period, fertilizer expenses per hectare of agricultural land area practically quadrupled also, jumping from $5.71 in 1971 to $21.04 (constant 1992 dollars) in 2006.

Pesticide use also increased considerably during the period. Real expenses in pesticide use in

Chart 7
Cost of Intermediate Inputs as a Share of Nominal Gross Output in the Primary Agriculture Sector, 1961-2007
(per cent)



Source: CSLS calculations based on Statistics Canada data (CANSIM Table 383-0022).

Canada increased from $224 million (constant 1992 dollars) in 1971 to $1,228 million (constant 1992 dollars) in 2006, more than five times the original amount (Table 5, Panel B), which entails a growth rate of 4.98 per cent per year during the 1971-2006 period. Since agricultural land area remained almost constant throughout this entire period, pesticide expenses per hectare of agricultural land area increased at practically the same rate as overall pesticide expenses, 5.03 per cent per year, from $3.26 in 1971 to $18.17 in 2006.

Pesticide use expenses per hour worked in the primary agriculture sector (which is a component of intermediate input intensity) increased at an average annual growth rate of 6.61 per cent during the 1971-2006 period, from $0.20 (constant 1992 dollars) in 1971 to $1.87 (constant 1992 dollars) in 2006.

Productivity Trends

During the 1961-2007 period, the Canadian primary agriculture sector outperformed the business sector by far in terms of productivity

Table 4

Real Intermediate Input Use in the Primary Agriculture Sector, Canada, 1961-2007

(compound annual growth rates, per cent)

	1961-2007	1961-2000	2000-2007
Intermediate Inputs	4.63	5.23	1.33
Energy Input	5.97	7.07	0.00
Material Input	4.27	4.79	1.38
Services Input	4.72	5.25	1.84

Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0021, and 383-0022).

Table 5

Fertilizer and Pesticide Use in Canada, 1971-2006

a) Fertilizer Use

	1971	2001	2006
	(millions, constant 1992 dollars)		
Fertilizer Use Expenses	392.07	1,615.69	1,422.32
	(thousands, hectares)		
Fertilized Land Area	6,928	24,015	25,348
	1971-2006	1971-2001	2001-2006
	(compound annual growth rates, per cent)		
Fertilizer Use Expenses	3.75	4.83	-2.52
Fertilized Land Area	3.78	4.23	1.09

b) Pesticide Use

	1971	2001	2006
	(millions, constant 1992 dollars)		
Pesticide Use Expenses	223.95	1,289.20	1,228.38
	1971-2006	1971-2001	2001-2006
	(compound annual growth rates, per cent)		
Pesticide Use Expenses	4.98	6.01	-0.96

Source: CSLS calculations based on Statistics Canada data, Census of Agriculture (CANSIM Table 153-0039).

growth. In this section, we detail the agriculture sector's productivity performance, discussing the most imporant trends observed during the period.

Labour Productivity (VA)

Labour productivity in the primary agriculture sector grew at an average annual rate of 3.77 per cent during the 1961-2007 period, much faster than the rate of growth observed in the business sector as a whole, which was only 2.06 per cent per year (Table 6). Growth rates in primary agriculture exhibited little change over the 1961-2000 period and 2000-2007 period (3.79 versus 3.62 per cent, respectively). Business sector growth rates, on the other hand, experienced a significant slowdown in the latter period (1.08 versus 2.24 per cent per year), which implies a widening of the performance gap between the agriculture sector and the Canadian business sector in recent years.

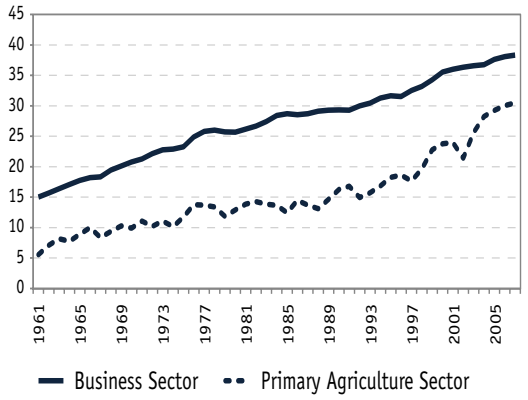
The labour productivity level (expressed in chained 2002 dollars) in primary agriculture remained below the business sector average during the entire period (Chart 8). However, the gap between labour productivity levels in the agriculture sector and the business sector reduced considerably over the last 50 years. The labour productivity (VA) level in primary agriculture was $5.55 per hour (chained 2002

Table 6
Labour Productivity (VA) in the Primary Agriculture Sector, Canada, 1961-2007

	1961-2007	1961-2000	2000-2007
	(compound annual growth rates, per cent)		
Business Sector	2.06	2.24	1.08
Primary Agriculture Sector	3.77	3.79	3.62
	1961	**2000**	**2007**
	(chained 2002 dollars per hour worked)		
Business Sector	15.01	35.56	38.35
Primary Agriculture Sector	5.55	23.78	30.50
	(as a share of the business sector, per cent)		
Primary Agriculture Sector	37.0	66.9	79.5

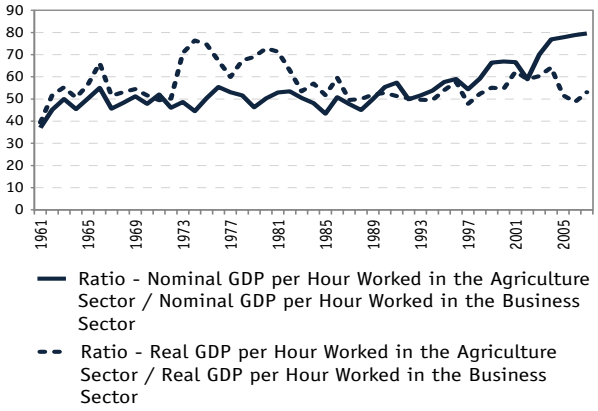
Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0022).

Chart 8
Labour Productivity (VA) in the Primary Agriculture Sector, Canada, Chained 2002 Dollars, 1961-2007



Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0022).

Chart 9
GDP per Hour Worked in the Primary Agriculture Sector as a Share of GDP per Hour Worked in the Business Sector, Canada, 1961-2007



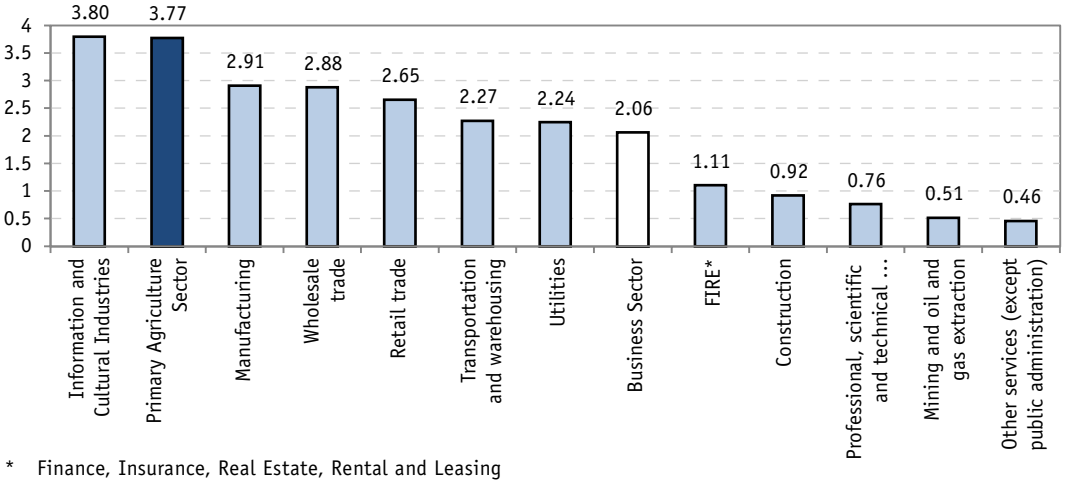
Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0022).

dollars) in 1961, only 37 per cent of the Canadian average. By 2007, the sector's labour productivity (VA) had risen to $30.50 per hour, representing 79.5 per cent of the business sector level.

Although real GDP per hour worked, i.e. labour productivity (VA), in primary agriculture grew quickly, the sector's levels of nominal output per hour worked were notably low when compared to other sectors or the Canadian business sector as a whole (Chart 9). In 2007, nominal GDP per hour worked in the agriculture sector represented only 53.1 per cent of the business sector level, up from 39.4 per cent in 1961. In other words, primary agriculture had a (seemingly) paradoxical performance in terms of labour productivity: strong real GDP per hour growth rates, but low nominal GDP per hour levels.

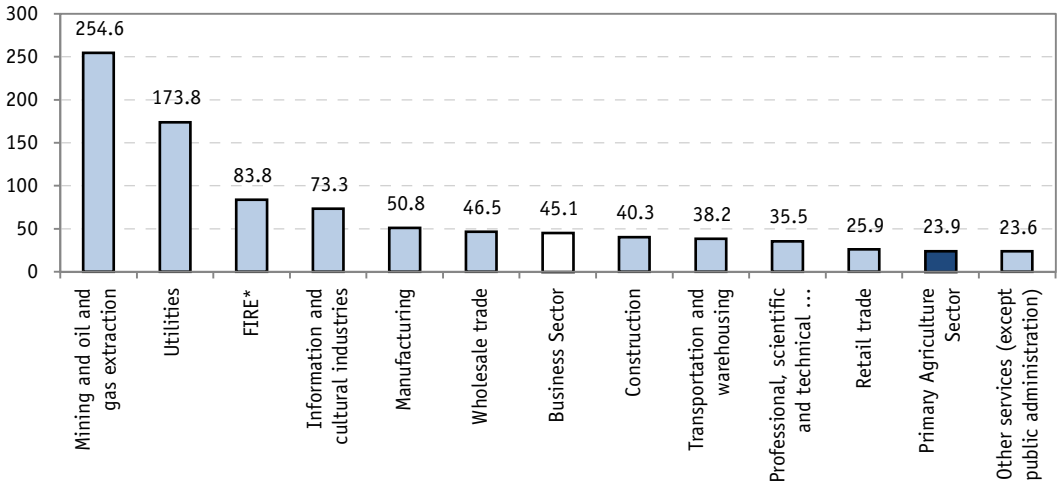
This point becomes clear when we compare the labour productivity performance of the primary agriculture sector to that of other sectors

Chart 10
Real GDP per Hour Worked, Sectoral Comparison, 1961-2007
(compound annual growth rates, per cent)



* Finance, Insurance, Real Estate, Rental and Leasing
Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0022).

Chart 11
Nominal GDP per Hour Worked, Sectoral Comparison, Levels, 2007



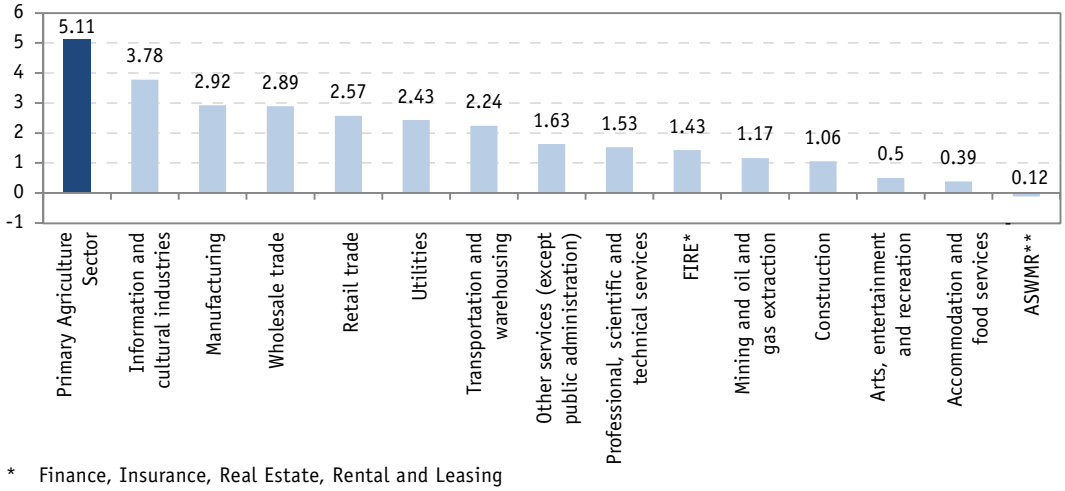
* Finance, Insurance, Real Estate, Rental and Leasing
Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0022).

(Chart 10, Chart 11). As discussed previously, labour productivity in the agriculture sector grew at a much faster pace than in the business sector during the overall period. Looking at more detailed data, it can be seen that the sector outperformed all of the two-digit NAICS sectors, with the exception of information and cultural industries, which grew at only a slightly faster pace (3.80 vs. 3.77 per cent per year during the 1961-2007 period). In terms of nominal GDP per hour worked, however, the agriculture sector had the second lowest level in 2007, $23.92 per hour, only above other services,

Chart 12

Real Gross Output per Hour Worked, Sectoral Comparison, 1961-2007

(compound annual growth rates, per cent)



* Finance, Insurance, Real Estate, Rental and Leasing

** Administrative and Support, Waste Management and Remediation Services

Source: CSLS calculations based on Statistics Canada data (CANSIM Table 383-0022).

which had a marginally lower level at $23.64 per hour.

Labour Productivity (GO)

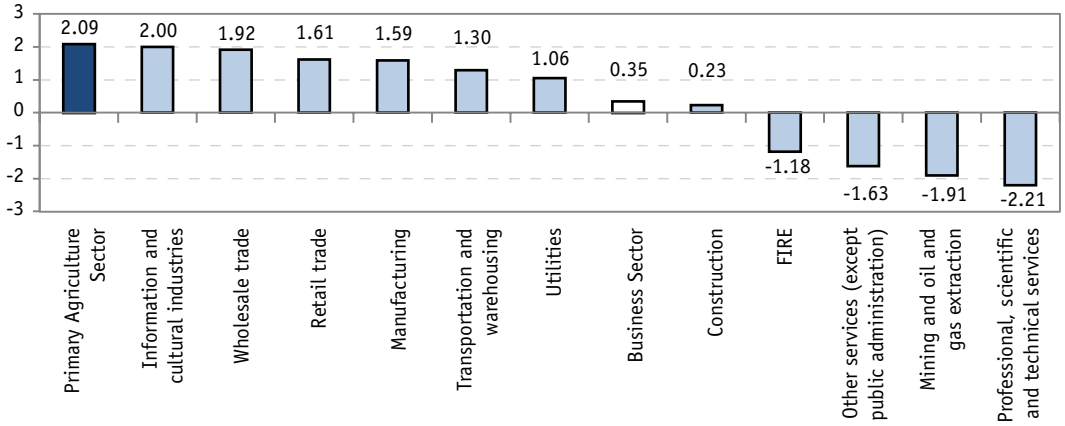
Using a gross output approach, labour productivity (now defined as gross output per hour worked) in the Canadian primary agriculture sector grew at an average annual rate of 5.11 per cent during the 1961-2007 period (Chart 12). Note that this figure is higher than the growth rate observed when we measure labour productivity using a value added approach, 3.77 per cent. The reason for this difference is clear: the more intensive use of intermediate inputs in the agriculture sector, which, as we have seen, represented 66.9 per cent of the sector's gross output in 2007, up from 40.3 per cent in 1961.

Multifactor productivity (VA)

Multifactor productivity (MFP) is a residual term that encompasses all productivity growth that is not explained by the growth in labour and capital inputs – as well as intermediate inputs, if productivity is being calculated on a gross output basis. This subsection focuses on MFP growth measured using a value added basis. Estimates for MFP growth calculated using a gross output approach are discussed in the next subsection.

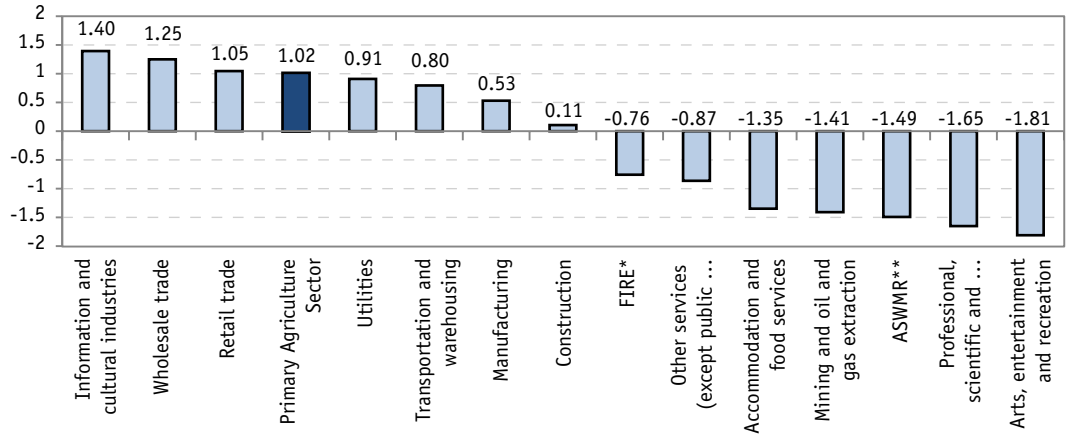
MFP in primary agriculture increased by 2.09 per cent per year over the 1961-2007 period, six times the growth experienced by the Canadian business sector, which was only 0.35 per cent per year. While MFP growth in the business sector slowed significantly in the 2000-2007 period, declining from 0.46 per cent per year during the 1961-2000 period to -0.30 per cent (a drop of 0.76 percentage points), MFP (VA) growth in primary agriculture remained practically constant throughout the entire period, 2.14 per cent in 1961-2000 and 1.79 per cent in 2000-2007 (a drop of only 0.35 percentage points). Chart 13 shows that, in terms of MFP (VA) growth, the primary agriculture sector outperformed all other sectors in the Canadian business sector during the 1961-2007 period, with information and cultural industries coming close second

Chart 13
MFP (VA) Growth, Sectoral Comparison,1961-2007
(compound annual growth rates, per cent)



Source: CSLS Calculations based on Statistics Canada data (CANSIM Tables 383-0021, and 383-0022).

Chart 14
Multifactor Productivity (GO), Sectoral Comparison, 1961-2007
(compound annual growth rates, per cent)



* Finance, Insurance, Real Estate, Rental and Leasing

** Administrative and Support, Waste Management and Remediation Services

Source: CSLS calculations based on Statistics Canada data (CANSIM Table 383-0022).

(2.00 per cent per year), followed by wholesale trade (1.92 per cent).

Multifactor productivity (GO)

Using a gross output approach, MFP in the Canadian agriculture sector grew at an average annual rate of 1.02 per cent during the 1961-2007 period (Chart 14). Note that this figure is substantially lower than the growth rate observed when we measure multifactor productivity using a value added approach. Again, the reason for this difference is clear: the more intensive use of intermediate inputs in primary agriculture over time, which caused the GO

BOX 3 – The Land Productivity of Organic Agriculture

Organic agriculture has experienced impressive growth over the past decade. This growth is driven by several reasons, including: 1) health concerns over chemical, hormonal, and transgenic contamination of conventional agricultural products; 2) minimizing the environmental impact of agricultural activities; 3) claims of higher efficiency in input use; 4) claims of higher nutritional value and overall quality over regular agricultural products. Although some of these claims have not yet been confirmed by the scientific community, the growing importance of organic agriculture raises the question as to whether a widespread substitution of organic practices for non-organic agricultural methods would be feasible.

Savage (2011) compared acreage and yields of organic crops to those of "conventionally" grown crops in the United States using data from the U.S. Department of Agriculture's 2008 Survey of Organic Agriculture, which encompassed 14,500 certified organic farms. He had two major findings: 1) In 2008, there were 1.6 millions of acres of harvested organic cropland in the United States, which represented only 0.52 per cent of total crop acreage; 2) Despite a few exceptions, organic crop yields were substantially lower than the yields of their conventional counterparts. Crop yields for organic winter wheat, for example, were only 60 per cent that of non-organic winter wheat. The only exceptions to this trend were organic sweet potatoes, canola, and hay, all of which had higher yields than non-organic crops.

According to Savage, the overall lower yields of organic crops imply that a complete switch to organic production in the U.S. would require an additional 121.7 million acres of cropland, almost the same land area as Spain. This would represent an increase of 39 per cent in current U.S. cropland area.

It should be noted, however, that the higher crop yields in traditional agriculture (when compared to its organic counterpart) do not necessarily imply that it is more efficient. Crop yields are a partial productivity measure, and, as such, do not control for the use of other inputs (such as labour, capital or intermediate inputs) in the production process. To accurately measure which type of agriculture is more efficient, multifactor productivity estimates would be more appropriate.

input aggregate to grow faster than the VA input aggregate. The agriculture sector's performance in terms of MFP growth during the 1961-2007 period remains impressive if we use a gross output approach, with only three sectors growing faster: information and cultural industries (1.40 per cent per year), wholesale trade (1.25 per cent), and retail trade (1.05 per cent).

Conclusion

The productivity performance of the Canadian primary agriculture sector is a success story. Labour productivity (VA) in Canadian primary agriculture increased at an average annual rate of 3.77 per cent during the 1961-2007 period, while MFP (VA) in the sector grew 2.09 per cent per year. Whether we look at labour productivity (VA) or MFP (VA), the sector outperformed the Canadian business sector, which observed growth rates of 2.06 and 0.35 per cent per year (respectively) during the period in question. Focusing on gross output productivity measures, we find similar results, with labour productivity (GO) and MFP (GO) in primary agriculture growing at average annual rates of 5.11 and 1.02 per cent (respectively), significantly faster than most other sectors in the Canadian economy.

BOX 4 – Livestock Productivity

In addition to labour, land, intermediate inputs, and multifactor productivity, one can analyze improvements of livestock productivity over time. Has the amount of beef production per cow increased over the years? What about milk? Or the number of eggs per hen?

According to Veeman and Gray (2010), livestock yields have increased considerably in Canada over the past 20-30 years, as a result of "improved genetics, feed conversion, and management practices, as well as the exploitation of economies of scale in production" (p. 135).The growth in livestock yield becomes abundantly clear when we look at some of the numbers:

Cattle

- In 1972, beef production per cow was 170 kilograms. By 2006, it had jumped to 272 kilograms, a 60 per cent increase.
- Between 1980 and 2003, the weight of cattle carcasses rose by 34 per cent.
- In the 1991-1992 period, the average dairy cow produced 5,456 kilograms of milk. This number had increased to 9,538 kilograms of milk by 2007-2008, a 75 per cent increase.

Hogs

- The age at which Ontario hogs reached 100 kilograms in 1980 was 183 days. By 2006, it had dropped to 157 days.

Poultry

- Although no estimates are given, Veeman and Gray (2010) state that changes in feed conversion rates reduced dramatically the number of days a broiler needed to reach market weight.
- After significant increases prior to 1990, the number of eggs per layer remained relatively stable at around 265-270 eggs per year.

Source: Veeman and Gray (2010).

The difference in the sector's productivity performance when we use value added or gross output measures is caused by the increasingly important role of intermediate inputs in agricultural production. In 2007, intermediate inputs accounted for 66.9 per cent of the sector's gross output, up from 40.3 per cent in 1961. The strong intermediate input growth in the period boosted gross output growth, which in turn contributed to increase labour productivity (GO) well above labour productivity (VA) growth. At the same time, the fact that intermediate inputs grew at a faster pace than gross output in the sector during the period (4.63 versus 3.11 per cent per year) cause MFP (GO) growth to be lower than MFP (VA) growth.

The excellent productivity performance in Canadian primary agriculture during the 1961-2007 period was caused in large part by the increasing level of mechanization in the sector, as well as by the role played by R&D, which allowed farmers to incorporate important labour saving technologies into the production process. This led to a major contraction in labour input use, and explains why the sector's total hours worked declined not only as a share of the business sector (from 14.3 per cent in 1961, to 2.7 per cent in 2007), but also in absolute terms. It also explains why the average capital share of GDP in primary agriculture has been roughly 60 per cent during the 1961-2007, well above the business sector average of 40 per cent.

However, there is no guarantee that, *ceteris paribus*, the productivity growth rates that were attained in the past will be attainable in the future. In particular, would it be reasonable to

expect unlimited productivity gains from mechanization in the long-run?

Trend productivity is the outcome of complex interactions of actions of farmers, their suppliers and customers, universities and governments. Nevertheless, the longer-term productivity performance of the sector is mainly determined by investments in innovation and innovation adoption, and the size and pace of economic adjustment by producers to rapidly changing environment and market conditions. Of course, federal and provincial governments can play an important role in improving the sector's productivity performance and competitiveness by supporting and fostering innovation and innovation adoption, improving access to export markets, removing inter-provincial barriers to trade, reducing regulatory burden, providing adequate and state-of the art transportation and telecommunication infrastructure and facilitating the market driven structural changes and economic adjustment.

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