August 2011

151 Slater Street, Suite 710
Ottawa, Ontario K1P 5H3
613-233-8891, Fax 613-233-8250
csls@csls.ca

Centre for the Study of Living Standards

A Detailed Analysis of the Productivity Performance of the Canadian Primary Agriculture Sector

CSLS Research Report 2011-06

August 2011

Prepared for Agriculture and Agri-Food Canada | By the Centre for the Study of Living Standards

A Detailed Analysis of the Productivity Performance of the Canadian Primary Agriculture Sector

Abstract

In contrast to the significant slowdown in aggregate productivity growth in Canada since 2000, the labour productivity performance of the primary agriculture sector has been strong. The objective of this study is to shed light on the factors behind the sector's success. This report provides an overview of the productivity performance of the Canadian agriculture sector over the 1961-2007 period, discussing both long-term trends and recent developments. Labour productivity and MFP estimates for the period are analyzed, as well as land and intermediate input productivity. The main drivers of productivity growth in the sector are identified and examined. Finally, policy suggestions are discussed.

A Detailed Analysis of the Productivity Performance of the Canadian Primary Agriculture Sector

Table of Contents

List of Charts and Summary Tables

Charts

Summary Tables

A Detailed Analysis of the Productivity Performance of the Canadian Primary Agriculture Sector

Executive Summary

Labour productivity is the key factor that determines living standards in the long run. Since 2000, Canada's labour productivity growth has been abysmal, both from an historical and an international perspective. Labour productivity in the Canadian agriculture sector, however, was unaffected by this slowdown, continuing to grow at a very robust pace in the post-2000 period. The objective of this report is to provide an overview of the productivity performance of the Canadian agriculture sector over the 1961-2007 period, highlighting both long-term trends and recent developments. The report identifies the main drivers behind the sector's success, and makes general policy suggestions that might help improve the sector's productivity performance even more.

Output Trends

Real GDP in the Canadian primary agriculture sector grew at less than half the rate experienced by the business sector during the overall 1961-2007 period (1.80 versus 3.81 per cent per year). 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. For exactly the same reason, when real GDP 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.

Real gross output in the primary agriculture sector grew at an average annual rate of 3.11 per cent during the 1961-2007 period, significantly faster than the sector's real GDP growth. The reason for this is the more intensive use of intermediate goods in primary agriculture over time. In fact, the cost of intermediate inputs represented 66.9 per cent of the sector's gross output in 2007, up from 40.3 per cent in 1961.

Input Use Trends

By far the most important development in terms of input use in the primary agriculture sector during the 1961-2007 period was the massive contraction in total hours worked. 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.

Another important trend was the growing importance of intermediate inputs in the primary agriculture sector. In 2007, intermediate input use accounted for 66.9 per cent of the sector's nominal gross output, up from 40.3 per cent in 1961. In real terms, intermediate input use in the sector increased 4.63 per cent per year during the 1961-2007 period. More recently, however, intermediate input growth has fallen considerably, from 5.23 per cent in the 1961-2000 period to 1.33 per cent in the 2000-2007 period.

Productivity Trends

This report analyzes several partial productivity measures, including labour, land, and intermediate input productivity, as well as multifactor productivity (MFP). Two sets of labour productivity and MFP estimates are presented: one calculated using a **value added approach (VA)**, the other calculated using a **gross output approach (GO)**.

Labour Productivity (VA)

Labour productivity (VA) in primary agriculture increased at almost double the rate of the Canadian business sector during the 1961-2007 period (3.77 versus 2.06 per cent per year). 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 (1.07 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 (VA) level in primary agriculture was $5.55 per hour (chained 2002 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 the agriculture sector grew quickly, the levels of nominal output per hour worked were notably low when compared to other sectors or the Canadian business sector as a whole. 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.

Nominal productivity levels are affected by both physical productivity growth and trends in output price. This seemingly paradoxical performance of the agriculture sector was due to the fact that the increase in agricultural labour productivity was accompanied by an overall fall of agricultural prices relative to economy-wide prices. In Canada, prices of most agricultural commodities are determined in competitive markets, which means that the average agricultural producer is a price taker, not a price maker, and prices reflect the underlying cost structures. The cost structures, in turn, are affected by several factors, one of the most important being productivity growth. In this context, changes in relative prices are driven by productivity developments at an industry level. As agriculture has enjoyed above average productivity growth, the relative price of its products have fallen. Falling relative prices indicate that an important share of the sector's productivity gains during the 1961-2007 period was passed on to consumers.

Labour Productivity (GO)

Labour productivity (GO) in primary agriculture grew at an average annual rate of 5.11 per cent during the 1961-2007 period, considerably higher than the rate observed using the value added measure, 3.77 per cent. The difference between the two growth rates was caused by the more intensive use of intermediate inputs in the sector over time, which boosted gross output growth well above GDP growth, and led GO labour productivity growth to be stronger than that of VA labour productivity.

Multifactor Productivity (VA)

MFP (VA) 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, 0.35 per cent per year. While MFP (VA) growth in the business sector slowed significantly in the 2000-2007, declining from 0.46 per cent per year during the 1961-2000 period to -0.30 per cent, 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.

Multifactor Productivity (GO)

MFP (GO) in the primary agriculture sector grew at an average annual rate of 1.02 per cent per year in the 1961-2007 period, slower than the rate observed when the value added measure is used. Again, the reason for this difference is the more intensive use of intermediate inputs over time, which implies a higher rate of growth for the input aggregate, and thus a slower MFP growth.

The Contribution of Labour Productivity Growth in the Primary Agriculture Sector to Aggregate Labour Productivity Growth

A country's aggregate labour productivity is approximately equal to the weighted sum of the different sectors' labour productivity, with the weight of each sector being equal to its labour input share. This is the mechanism whereby the primary agriculture sector plays a role in contributing to overall labour productivity growth. According to CSLS calculations, the primary agriculture sector accounted for 19.2 per cent of aggregate labour productivity (VA) growth in Canada (business sector) during the 1961-2007 period. This may seem surprising, given that the importance of the primary agriculture sector as a share of business sector GDP and employment has fallen over time, representing 1.4 per cent of GDP, and 2.2 per cent of total employment in 2007. However, the sector accounted for 5.6 per cent of business sector GDP and 10.4 per cent of business sector employment in 1961. Furthermore, it experienced exceptional labour productivity growth throughout the entire period, well above most other sectors in the Canadian economy, which contributed to increase its role in overall labour productivity growth.

Sources of Labour Productivity Growth in the Primary Agriculture Sector

Value Added

Using the standard neo-classical growth accounting framework, labour productivity (VA) growth can be decomposed into three sources: capital intensity growth, MFP growth, and labour quality growth. During the 1961-2007 period, the primary agriculture sector's labour productivity (VA) growth was driven almost entirely by MFP (VA) and capital intensity growth, which were responsible for 2.09 and 1.51 percentage points of the overall labour productivity (VA) growth (or 55.5 and 40.2 per cent, respectively). The rest of labour productivity growth was driven by increases in labour quality.

The picture in the business sector is quite different. First, labour productivity (VA) growth in the Canadian business sector was considerably slower than in the agriculture sector, 2.07 per cent per year during the 1961-2007 period. Second, most of this growth came from increases in capital intensity, which accounted for 62.6 per cent of total labour productivity (VA) growth. Labour quality growth also played a very relevant role, accounting for 20.8 per cent of total growth, significantly more than its role in the agriculture sector. In contrast to the major role of MFP (VA) growth in primary agriculture, MFP (VA) growth in the business sector accounted for only 16.8 per cent of total labour productivity (VA) growth.

Gross Output

Labour productivity (GO) can be decomposed into four components: capital intensity, intermediate input intensity, labour quality, and MFP growth. During the 1961-2007 period, the primary agriculture sector's labour productivity (GO) growth was driven mostly by increases in intermediate input intensity (which accounted for 61.5 per cent of total growth), followed by MFP growth (20.0 per cent), capital intensity growth (15.5 per cent), and labour composition growth (1.8 per cent).

Drivers of Labour Productivity Growth in the Primary Agriculture Sector

Each of the four sources of labour productivity growth discussed above is determined by a variety of factors. The agricultural productivity literature identifies several of those factors, which are, ultimately, the real drivers behind labour productivity growth. Below, we highlight our key findings regarding the drivers of labour productivity growth in primary agriculture.

Capital Intensity

During the 1961-2007 period, capital services intensity in the agriculture sector grew at an average annual rate of 2.82 per cent, still slower than capital services intensity growth in the business sector (3.27 per cent per year), but by no means a poor performance. One of the main reasons why the primary agriculture sector is still lagging the business sector in terms of capital services intensity seems to be the low use of ICT related capital in the sector. When we calculate capital stock intensity, the picture changes, with the primary agriculture sector outpacing the business sector during the 1961-2007 period (2.52 versus 1.46 per cent per year). Overall, both figures are a clear indication that the sector has seen considerable capital deepening over the years due to increasing levels of mechanization.

Intermediate Input Intensity

Intermediate input use in Canadian primary agriculture increased at an average annual rate of 4.63 per cent during the 1961-2007 period. Coupled with the steep decline in hours worked, this implies an increase of intermediate input intensity of 6.65 per cent per year.

- Fertilized land area in Canada increased from 6,928 thousand hectares in 1971 (which represented 10 per cent of total agricultural land area in the country) to 25,348 thousand hectares in 2006 (37.5 per cent of agricultural land area).

- Fertilizer use expenses per hour worked in the primary agriculture sector increased at an average annual growth rate of 5.35 per cent during the 1971-2006 period, from $0.35 (constant 1992 dollars) in 1971 to $2.16 (constant 1992 dollars) 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.

Multifactor Productivity (MFP)

MFP reflects output growth that is not accounted for by input growth. Thus, MFP captures the residual effects of several elements of the production process, such as improvements in technology and organizations, capacity utilization, increasing returns to scale, among other factors. It also embeds errors due to the mismeasurement of inputs and output.

- The main factor identified by the agricultural productivity literature as driving MFP growth is R&D expenditures. For most sectors, business enterprise research and development intramural expenditures (BERD) are a good measure of R&D efforts. However, much of the business expenditures on agricultural R&D takes place off farm, and thus is not captured by BERD estimates. An example of this would be seed research done by companies such as Monsanto. Second, BERD represents only a small fraction of R&D spending in Canadian agriculture. The federal and provincial governments play a vital role in fostering innovation and research in the sector. Thus, even though BERD in primary agriculture has tripled between 1994 to 2007, from $32 million to $94 million, it still represents only a small portion of total R&D expenditures in the sector.

- During the 2002-2008 period, federal expenditures on agricultural R&D (intramural and extramural) averaged $420 million per year, approximately 7 per cent of total federal expenditures on R&D. Federal expenditures on agricultural R&D grew 4.29 per cent per year during the period, slightly slower than overall federal expenditures on R&D, which grew 5.14 per cent per year.

- In general, scale economies are relevant to productivity growth. Advantages enjoyed by large production units over small production units can include lower cost of capital, greater scale economies in the use of resources and production, and more efficient risk management. However, the existence and extent of scale economies in primary agriculture varies according to the commodity produced. A recent study has found, for instance, that economies of scale in Canadian Prairie agriculture are much larger in animal production than in crop production.

- In order to ascertain to what extent scale economies exist in Canadian agriculture, and in which of its subsectors they are more relevant, one has to estimate a cost function for agricultural production, which is beyond the scope of this paper. We can suggest, however, that the importance of scale economies in the primary agriculture sector can be seen in the movement towards larger, and fewer farms that has been taking place in Canada over the last 30 years. According to Statistics Canada's Census of Agriculture, there were 336 thousand farm units in Canada in 1971, and the average farm unit size was 1.88 square kilometres. By 2006, the number of farm units had dropped by 37 per cent, to 229 thousand, and average farm size had increased by more than 50 per cent, to 2.95 square kilometres. It is important to keep in mind that even though the existence of scale economies constitutes an important rationale for consolidation, it is not the only one. Thus, as we mentioned before, while the trend towards larger, and fewer farms is suggestive of scale economies, by no means it should be seen as definitive evidence.

Labour Quality

Economists have emphasized the importance of human capital in driving economic progress. In general, the higher the education level and the greater the experience of workers, the more output they can produce per hour of labour.

- According to Statistics Canada's Canadian Productivity Accounts (CPA), labour quality in primary agriculture grew at an average annual rate of 0.55 per cent during the 1961-2007 period, slightly less than the growth of 0.71 per cent observed in the business sector. The 2000-2007 period saw a change in this long-term trend, with labour composition in agriculture increasing by 0.69 per cent, more than in the business sector, which saw an increase of 0.54 per cent.

- In line with the CPA's labour quality measure, average years of schooling in the agriculture sector has been increasing at a slightly faster pace than the national average in recent years (0.51 versus 0.39 per cent per year, respectively). This has led to a small narrowing in the schooling gap between the agriculture sector and the national average, with average years of schooling in primary agriculture at 89.5 per cent of the national level in 2007, up from 87.8 per cent in 1990. In absolute terms, average years of schooling in the agriculture sector rose from 11.4 years in 1990 to 12.4 years in 2007.

- The proportion of workers with post-secondary certificate or diplomas in the agriculture sector increased considerably, jumping from only 17.7 per cent of total workers in the sector in 1990 to 28.2 per cent in 2007. This number was still below the national average, which reached 35.0 per cent of total workers (all industries) in 2007, but the gap is clearly closing. In 1990 the proportion of workers in the agriculture sector that had a post-secondary certificate or diploma was only 67.2 per cent of national average, but in 2007 this number had gone up to 80.5 per cent.

Summing Up…

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 to the production process. This led to a major contraction in labour input use in primary agriculture, and explains why the sector's total hours worked as a share of the business sector consistently declined from 14.3 per cent in 1961, to 2.7 per cent in 2007. 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?

Policy Directions

Productivity growth in the primary agriculture sector 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 the private sector investments in innovation and innovation adoption, and the size and pace of economic adjustment by producers to rapidly changing environment and market conditions. 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.

A Detailed Analysis of the Productivity Performance of the Canadian Primary Agriculture Sector[1]

I. Introduction

Labour productivity is the key factor that determines living standards in the long run. If the amount of real output per hour worked does not increase, real wages and incomes cannot rise (Sharpe, 2010a). Since 2000, Canada's labour productivity growth has been abysmal, both from an historical and an international perspective (Sharpe and Thomson, 2010b).[2] Labour productivity in the Canadian primary agriculture sector, however, was unaffected by this slowdown, continuing to grow at a very robust pace during the 2000-2007 period. Despite strong growth rates in terms of *real* output per hour worked, the level of *nominal* output per hour worked in primary agriculture was notably low when compared to the Canadian business sector, representing only 53.1 per cent of the business sector's level in 2007.

This (seemingly) paradoxical performance of the primary agriculture sector's labour productivity raises a number of important questions regarding real output growth, relative prices of agricultural goods, and labour input use. This report seeks to understand these and other productivity trends in primary agriculture over the last 50 years, identifying the main sources and drivers that influence agricultural productivity. Understanding the nature of productivity growth in agriculture is a necessary first step towards improving policies that affect this sector. Although our analysis emphasizes developments in labour productivity, other productivity measures are also discussed, such as intermediate inputs, land, and multifactor productivity.

The report is organized as follows. Section two defines the primary agriculture sector, overviews the recent literature on measuring agricultural productivity, and explains the link between labour productivity and living standards. This section also details the data sources used in the report, and possible measurement issues. Section three discusses trends in labour, intermediate input, land, and multifactor productivity in primary agriculture during the1961-2007 period, at both the national level and at the provincial level. The fourth section compares the

---

[1] This report was prepared by Ricardo de Avillez, under the supervision of Andrew Sharpe. The section on policy directions received major input from Someshwar Rao. The views presented in this report are the views of the CSLS. The CSLS would like to thank the participants of the AAFC discussion session on agricultural productivity on Feb 25, 2011, and the participants of the CEA Session on June 4, 2011, at the University of Ottawa for their feedback. Special thanks go to Professor Erwin Diewert (UBC) and Bruce Phillips (AAFC). The CSLS would like to thank Agriculture and Agri-Food Canada for the financial support. For comments, Ricardo de Avillez can be contacted at ricardo.avillez@csls.ca.

[2] From 1981 to 2000, labour productivity in Canada's business sector grew at an average annual rate of 1.59 per cent. In the 2000-2010 period, labour productivity growth dropped sharply to a mere 0.73 per cent per year in Canada. This slowdown in labour productivity growth in Canada was not experienced in the United States, which grew at an average annual rate of 2.69 per cent during the same period (up from 1.96 per cent during the 1981-2000 period).

primary agriculture sector in Canada to that of other countries. Section five identifies and discusses the fundamental factors that influence productivity growth in primary agriculture. Section six delineates possible policy implications of the previous analysis, section seven suggests topics that would benefit from further research, and section eight concludes.

II. Definitions, Concepts, Measurement Issues, and Data Sources

In this part of the report, we first define the main activities included in the primary agriculture sector. We then review some of the key issues related to measuring agricultural productivity, and how (and why) this report deviates from the established literature. Next, the link between labour productivity and living standards is explained. This is followed by a brief discussion on data sources used in the report, and measurement issues.[3]

A. The Primary Agriculture Sector

Statistics Canada classifies establishments[4] according to the North American Industry Classification System (NAICS). NAICS categorizes establishments into industries based on the similarity of their production processes. It has a hierarchical structure that divides the economy into 20 sectors, which are identified by two-digit codes. Below the sector level, establishments are classified into three-digit subsectors, four-digit industry groups, and five-digit industries. At all levels the first two digits always indicate the sector, the third digit the subsector, the fourth digit the industry group, and the fifth digit the industry.

At the two-digit level, NAICS code 11 groups agriculture along with forestry, fishing and hunting. In this report, the primary agriculture sector is defined as the sum of the crop production (NAICS code 111) and animal production (NAICS code 112) subsectors (Exhibit 1). These two subsectors have always represented the bulk of the agriculture, forestry, fishing and hunting sector in Canada. In 2007, for example, nominal GDP in agriculture, forestry, fishing and hunting amounted to $23,344 million, $15,790 million (or 67.6 per cent) of which were due to crop and animal production (Chart 1).

Crop production is a subsector composed of establishments involved in growing crops, plants, vines, trees and their seeds. Examples of such establishments are farms, orchards and greenhouses. The typical production cycle in this sub-sector is completed when the commodity reaches the "farm gate" for market (or, in other words, the point of price determination) (Statistics Canada, 2007). The length of the production cycle distinguishes the crop production subsector from the forestry and logging subsector, where output might be similar, but production cycles are longer. For example, the production of Christmas trees is classified as crop production because the production cycle is less than 10 years.

---

[3] For definitions of the main concepts used throughout this report, refer to Appendix 1.

[4] "The establishment is the level at which all accounting data required to measure production are available. The establishment, as a statistical unit, is defined as the most homogeneous unit of production for which the business maintains accounting records from which it is possible to assemble all the data elements required to compile the full structure of the gross value of production (total sales or shipments, and inventories), the cost of materials and services, and labour and capital used in production. Provided that the necessary accounts are available, the statistical structure replicates the operating structure of the business. In delineating the establishment, however, producing units may be grouped. An establishment comprises at least one location but it can also be composed of many. Establishments may also be referred to as profit centres" (Statistics Canada, 2007).

Animal production is a subsector that includes establishments engaged in raising animals, producing animal products and fattening animals. Examples of such establishments are farms, ranches and feedlots.

Exhibit 1: The Primary Agriculture Sector, Subsectors and Industry Groups According to the North American Industry Classification System

111 Crop Production

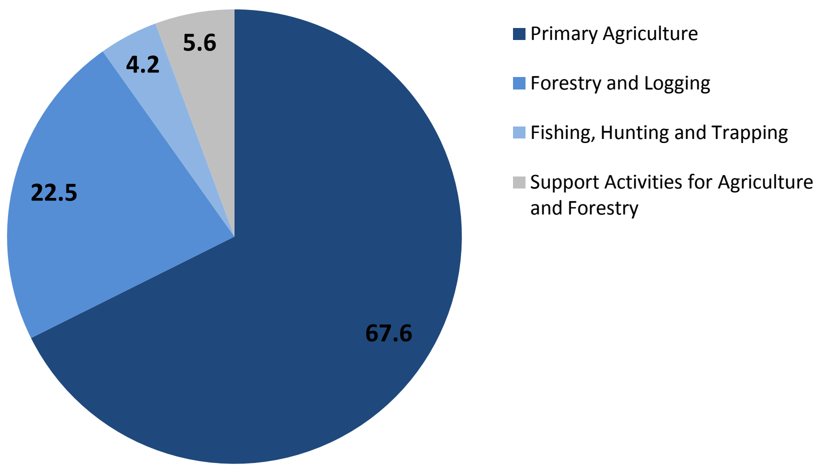
- 1111 Oilseed and Grain Farming
- 1112 Vegetable and Melon Farming
- 1113 Fruit and Tree Nut Farming
- 1114 Greenhouse, Nursery, and Floriculture Production
- 1119 Other Crop Farming

112 Animal Production

- 1121 Cattle Ranching and Farming
- 1122 Hog and Pig Farming
- 1123 Poultry and Egg Production
- 1124 Sheep and Goat Farming
- 1125 Animal Aquaculture
- 1129 Other Animal Production

Source: Statistics Canada, 2007.

Chart 1: Nominal GDP in Primary Agriculture as a Share of Agriculture, Forestry, Fishing and Hunting, Canada, 2007



Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0021 and 38309922).

B. Measuring Agricultural Productivity

Productivity is, broadly speaking, a measure of how much output is produced per unit of input used. Although there are several measures of productivity, the existing body of literature on agricultural productivity favours one specific measure: multifactor productivity (MFP) calculated on a gross output basis (see Christensen, 1975, Ball, 1985, Trueblood and Ruttan, 1992, and Ball *et al.*, 1997). That is not to say that other productivity measures are not used to analyze agricultural productivity, far from it. Rayner *et al.* (1986), for example, calculate estimates of labour productivity for the agriculture sector in the United Kingdom; Alston *et al.* (2010) look at global trends of land and labour productivity in primary agriculture; Veeman and Gray (2010) discuss land productivity and livestock productivity in Canadian agriculture, etc. These other productivity measures (especially land and labour productivity) are often regarded by the agricultural productivity literature as informative, but not as comprehensive as MFP calculated using a gross output approach. In this section, we explain some of the key issues of agricultural productivity analysis, including the reasons why MFP on a gross output basis is the most widely used measure of productivity in primary agriculture, and how (and why) this report differs from the established literature. Special emphasis is given to explaining the importance of analyzing labour productivity, since its use in studies on agricultural productivity is perhaps not as well established as that of MFP or land productivity (crop yields, in particular).

Economists distinguish between partial and multifactor productivity measures. Partial productivity measures refer to the relationship between output and a single input, such as labour, capital, or land. Multifactor productivity (MFP), on the other hand, attempts to measure how efficiently a number of factors of production are used in the production process. In other words, MFP reflects output growth that is not accounted for by measured input growth. As mentioned in the previous paragraph, the literature on agricultural productivity clearly favours the use of MFP over other productivity measures. Christensen (1975) states that "(…) U.S. agricultural economists recognized early the inadequacy of partial productivity indexes such as output per man or yield per acre (…)" (p. 910). Trueblood and Ruttan (1992) argue that

> MFP is considered superior to partial productivity measurements because it does not lend itself as easily to misinterpretation. For example, when one compares labor productivity and MFP of U.S. agriculture (…), one immediately notices how much more rapidly labor productivity has grown relative to MFP; this phenomenon can be attributed to the substitution of capital for labor associated with increased mechanization (p. 2).

In other words, the authors are arguing that labour productivity does not control for variations in the use of other inputs (such as capital), and these variations might be responsible for the changes in labour productivity, which is why this productivity measure could be potentially misleading.

Strictly speaking, the above argument is correct: labour productivity tells us nothing about using inputs other than labour more efficiently or how technology impacts the use of inputs in general. In our opinion, however, this type of argument misses the mark for two reasons. First, it is questionable whether or not MFP "does not lend itself to misinterpretation" as easily as labour productivity. By definition, MFP growth can be explained by a number of very different factors such as improvements in technology and organization, capacity utilization, increasing returns to scale, among other factors. It also embeds errors due to the mismeasurement of inputs. In practice, however, the actual contribution of these factors can be very hard to disentangle, which led Moses Abramovitz to famously say that MFP is "a measure of our ignorance about the causes of economic growth" (Abramovitz, 1956). Moreover, as a residual, MFP is only as good as the aggregate input measure it is based on, and calculating changes in input quality is no trivial task.

Second, the fact that labour productivity growth might be driven by mechanization (which reflects itself in increased capital intensity) or other factors is not necessarily misleading. Using the neoclassical growth-accounting framework first developed by Solow (1957), labour productivity growth (measured as output per hour worked) can be decomposed into the contributions of three main factors: 1) capital intensity (capital per hour worked); 2) labour quality; 3) and MFP. Therefore, labour productivity growth should not be understood as an "autonomous" force; instead it is driven by several components, one of which is MFP.

This report is not arguing that MFP is not an important measure of productivity growth, as it clearly is; rather, it is arguing that, as any productivity measure, it has limitations. MFP can capture efficiency improvements, i.e. shifts in the production possibility frontier, much better than other productivity measures because it captures the effects of substitution between inputs. Labour productivity, however, is a better tool for understanding improvements in overall living standards (the next section explores the link between labour productivity and living standards in more detail). As Headley *et al.* (2010) note, labour productivity in primary agriculture is "intimately linked to agricultural wages and poverty reduction" (p. 1). Furthermore, the OECD (2001) recommends the use of value added labour productivity for "analysis of micro-macro links, such as the industry contribution to economy-wide labour productivity and economic growth" (p. 15), arguing that "value-added based labour productivity forms a direct link to a widely used measure of living standards, income per capita" (p. 15). Overall, it is essential to keep in mind that productivity is a multi-dimensional concept, and different productivity measures capture different aspects of reality. Thus, this report focuses its discussion not only on MFP, but also on labour productivity, with the link between these two productivity measures being provided by the neoclassical growth-accounting framework.

Another fundamental issue is whether agricultural productivity measures should be calculated using a gross output or a value added approach. Again, we will see that there are advantages and disadvantages to both approaches. Gross output consists of all goods and services produced by an economy, sector, industry or establishment during a certain period of time. Value added, on the other hand, measures the contribution of primary inputs (labour, capital, and land) 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 efficiency gains in both primary and intermediate input use. This is particularly true in the case of primary agriculture, where seed, feed, fertilizers, pesticides, etc. play an essential role. Christensen (1975) shares this view, and cites arguments used by Arrow and Hulten on the limits of the value added approach.

According to Arrow (1985), the use of the value-added approach would only make sense if intermediate inputs were separable from primary inputs (which, as Christensen notes, would require unrealistic restrictions on the marginal rates of substitution):

> Without the separability assumption, however, it is hard to assign any definite meaning to real value added, and probably the best thing to say is that the concept should not be used when capital and labor are not separable from materials in production (p. 458).

Diewert and Morrison (1986) and Diewert and Fox (2008) disagree with this view. In these two papers, the authors develop a framework for measuring MFP growth on a value added basis using a flexible functional form, and assuming competitive pricing and constant returns to scale, where there are no separability restrictions on technology.

On a different front, Hulten (1978) argues that if intermediate inputs are excluded, then all technical progress would be accrued to either labour or capital, which would rule out increased efficiency of intermediate goods. As Domar (in Christensen, 1975) ironically remarked: “It seems to me that a production function is supposed to explain a productive process, such as the making of potato chips from potatoes (and other ingredients), labor, and capital. It must take some ingenuity to make potato chips without potatoes” (p. 912).

In this report, we use both the gross output approach and the value added approach. Each approach is used with different objectives in mind. Whenever data is available, the gross output approach is used to compare the primary agriculture sector in Canada with that of other countries. The value added approach is employed to compare productivity trends in the primary agriculture sector in Canada to other sectors and to the Canadian economy as a whole. As Trueblood and Ruttan (1992) argue:

> As for the specification of the explicit or implicit production function, we favor the gross approach because it is more consistent with the idea of a production function where output is a function of all of the inputs. However, we understand that the net (value added) approach is widely used for other industries, so we would like to see this methodology continued for the sake of being able to consistently compare the agricultural sector against other sectors (p.21-22).

One last issue that needs to be tackled is whether agricultural productivity performance should be analyzed always in terms of the aggregate primary agriculture sector, or if the crop and animal production subsectors can (and should) also be treated separately. This is a contentious point because 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. At the same time, it is important to acknowledge 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.

The main data source for this report is Statistics Canada's Canadian Productivity Accounts (CPA), which uses the North American Industry Classification System (NAICS) to classify establishments into different categories. According to NAICS, an establishment is engaged in crop production if more than 50 per cent of its revenue comes from growing crops, plants, vines, trees and their seeds. Conversely, an establishment is classified under animal production if more than 50 per cent of its revenue comes from raising animals, producing animal products and fattening animals. Thus, a mixed farm where 60 per cent of its revenue is classified under crop production and 40 per cent under animal production would have all its inputs and output categorized as crop production. This can potentially distort both productivity growth rates and levels (in the case of partial productivity measures).

Continuing with our example of a farm with a 60-40 division of output between crop production and animal production, and assuming (as our data indicates) that value added labour productivity levels are much higher in crop production than in animal production, the classification of the entire value added of this farm as a crop production establishment would be understating the true level of the farm's crop production value added labour productivity. Furthermore, output movements from crop production to animal production would negatively impact the growth rate of the farm's value added labour productivity through the reallocation level effect, i.e. shifts in the share of hours worked from a sector with high labour productivity level to a sector with low labour productivity level (see Sharpe and Thomson, 2010).

The magnitude of this potential distortion is not known, and may impose a limitation on the accuracy of subsector data. A detailed analysis of farm micro-level data, which is beyond the scope of this paper, would be necessary to estimate the exact magnitude of this distortion. Since it is not possible to know how accurate the subsector data are, this report focuses on the primary agriculture sector as a whole.

C. Labour Productivity and Living Standards

In the previous section, we noted that there is a link between labour productivity and living standards. In this section, we explain the nature of this link.

Labour productivity is a measure of how much output is produced per unit of labour input, i.e. output per worker or output per hour worked. If the output per farmer increases, fewer farmers are necessary to feed the Canadian population as a whole. The analysis of labour productivity can thus help answer important questions such as: how many farmers were required to feed the Canadian population in the past? How many are needed now? What explains the differences between periods?

A simple calculation (dividing the total Canadian population by the number of workers in primary agriculture), reveals that in the 1960s, one farmer could feed *at least* 33 people in Canada. In 2010, this number had gone up to 109 people, which represents an increase of 230 per cent. This calculation does not take into account the role of international trade and does not control for factors such as changes in daily calorie intake over time. However, since Canada is a net exporter of agricultural goods, the numbers above understate the number of people fed by a single farmer. What these numbers clearly show, however, is the significant increase of output per farmer, i.e. labour productivity.[5]

According to van Ark (2002), labour productivity affects social progress through two fronts:

> The first and more obvious reason is that, together with a greater use of labour, productivity positively contributes to per capita income, which is a reasonable proxy for living standards in a country. The second reason is that labour productivity growth often reflects the accumulation of intangible capital, which itself contributes to social progress, as workers become equipped with more human capital, more knowledge and access to networks, and which may ultimately even lead to the creation of more social capital (p. 69).

Our main focus here is the first reason highlighted by van Ark, the relationship between GDP per capita and labour productivity.[6] Using a simple growth accounting framework, GDP per capita can be decomposed into a number of determinants:

---

[5] The American Farm Bureau Federation (AFBF) has data on how many people a farmer feeds in the United States. According to the AFBF, a U.S. farmer fed 46 people in the 1960s. In 2011, this number had jumped to 155 people, an increase of 237 per cent (Source: AFBF, http://www.fb.org/index.php?action=yourag.facts).

[6] For a detailed discussion on how labour productivity affects the accumulation of intangible capital, refer to van Ark (2002).

Exhibit 2: Decomposition of GDP per Capita into Labour Productivity and Labour Supply Components

$$\frac{GDP}{Population}=\frac{GDP}{Hours\ Worked}\times\frac{Hours\ Worked}{Employment}\times\frac{Employment}{Labour\ Force}\times\frac{Labour\ Force}{Working\ Age\ Population}\times\frac{Working\ Age\ Population}{Total\ Population}$$

↑	↑	↑	↑	↑	↑
GDP per Capita	**Labour Productivity (LP)**	**Hours Worked per Person Employed (HWPE)**	**1-Unemployment Rate (1-UR)**	**Labour Force Participation Rate (LFPR)**	**Working Age Population Share (WAPS)**

Note: The definition of working age population used here encompasses persons fifteen years and older.
Source: Adapted from The Conference Board of Canada, 2009.

According to Exhibit 2, GDP per capita is driven by labour productivity (LP) and labour supply, which affects GDP per capita through four different terms (HWPE, UR, LFPR, and WAPS).[7] Exhibit 2 shows the factors that contribute to the *levels* of GDP per capita. To see how each of these factors contribute to the *growth rate* of GDP per capita, we take the log of both sides and differentiate with respect to time, which leads to:

$$\Delta GDP\ per\ Capita = \Delta LP + \Delta HWPE + \Delta(1-UR) + \Delta LFPR + \Delta WAPS$$

where Δ denotes percentage point changes.

Note that four of the five factors shown above have an upper bound, i.e. there is a clear limit as to how much hours worked per person employed, per cent employed in the labour force, labour force participation rate, and working age population share can rise. Labour productivity, on the other hand, can grow indefinitely, driven on the long-run by innovation and technological change, and therefore plays a vital role in increasing GDP per capita.

We estimated the contribution of the different factors to GDP per capita in Canada over the 1981-2010 period.[8] In 2010, Canada had a GDP per capita of $38,849 (chained 2002 dollars), up from $26,081 (chained 2002 dollars) in 1981, which entails an average growth rate of 1.37 per cent per year.[9] As Summary Table 1 and Chart 2 show, labour productivity growth accounted for 1.19 percentage points of GDP per capita growth over the entire period, 87 per cent of total growth. Of the four labour supply terms, hours worked per person employed and the unemployment rate had slightly negative contributions (-0.14 and -0.02 per cent per year, respectively), while the labour force participation rate and working age share of population rate

[7] The reader should bear in mind that this is one of many possible GDP per capita decompositions. In the end, GDP per capita is determined by a number of different factors that are not highlighted here, such as terms of trade.
[8] The numbers in this section refer to total economy, not business sector, and hence are slightly different than the numbers used in the rest of the report, which refer to the Canadian business sector.
[9] In order to be consistent with Exhibit 2, continuous time growth rates were calculated (as opposed to growth rates that are compounded in discrete time periods).

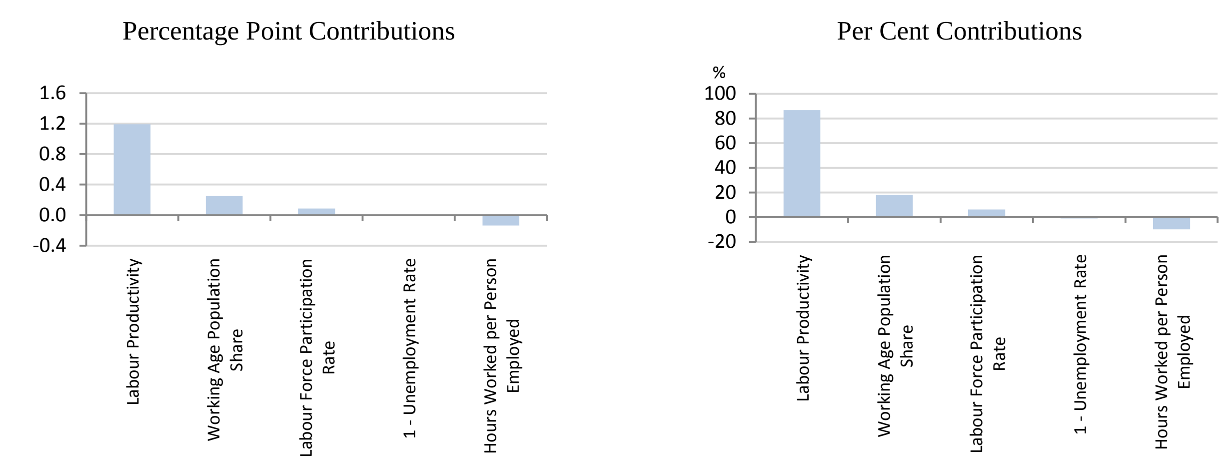
had positive contributions (0.08 and 0.25 per cent per year, respectively). In the 2000-2010 period, labor productivity in Canada increased by 0.96 per cent, representing 120.4 per cent of GDP per capita growth, while the labour supply variables had a net negative contribution of 20.4 per cent.

Summary Table 1: Sources of GDP per Capita Growth in Canada, 1981-2010

	1981-2010	1981-2000	2000-2010
	(percentage point contribution)		
GDP per Capita	1.37	1.68	0.80
Labour Productivity	1.19	1.31	0.96
Hours Worked per Person Employed	-0.14	0.08	-0.54
1 - Unemployment Rate	-0.02	0.04	-0.13
Labour Force Participation Rate	0.08	0.04	0.18
Demographic Participation Rate	0.25	0.21	0.33
	(per cent contribution)		
GDP per Capita	100.0	100.0	100.0
Labour Productivity	86.8	78.4	120.4
Hours Worked per Person Employed	-10.0	4.5	-67.9
1 - Unemployment Rate	-1.1	2.6	-16.0
Labour Force Participation Rate	6.2	2.1	22.2
Demographic Participation Rate	18.1	12.3	41.2

Source: CSLS calculations based on Statistics Canada data.

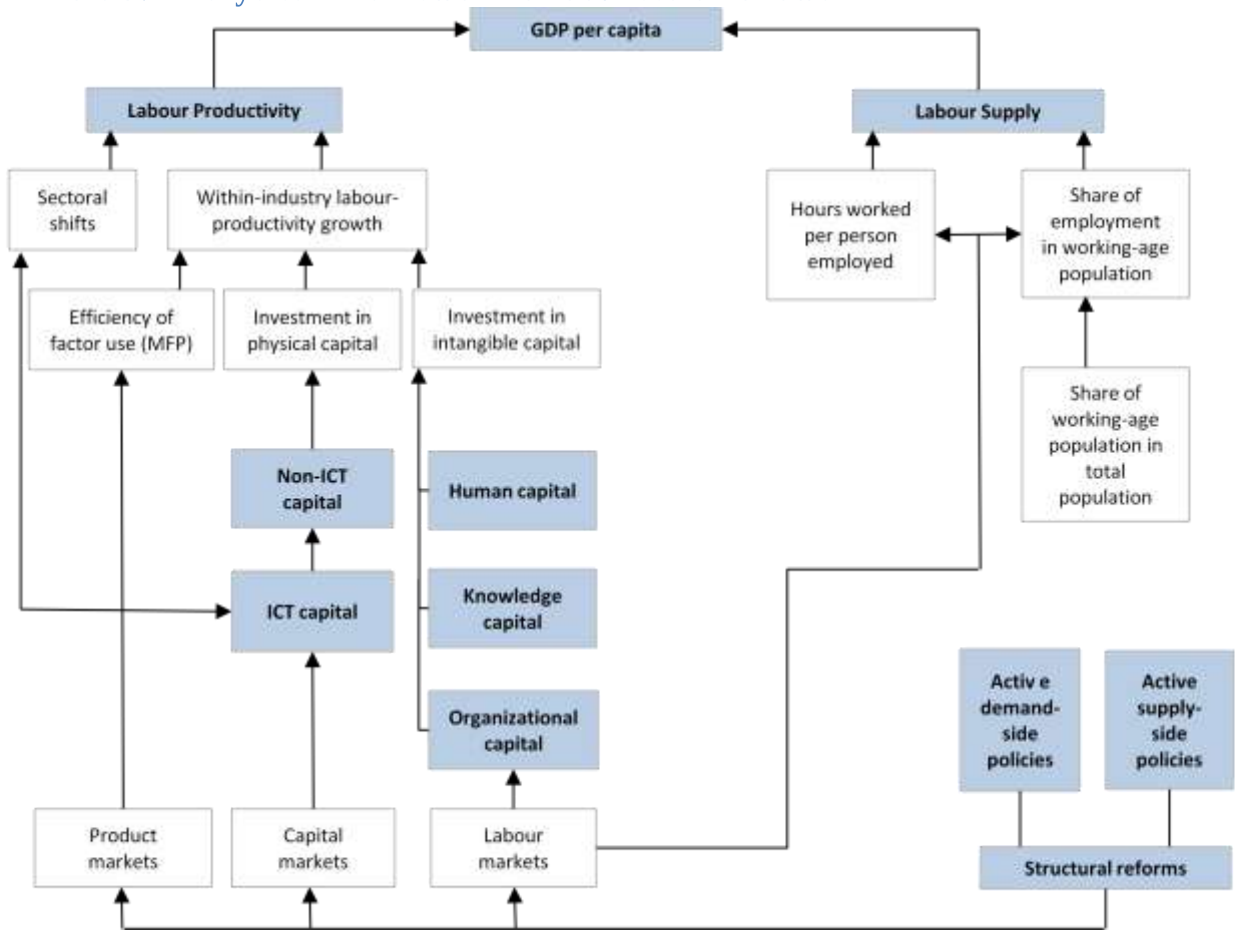
Chart 2: Sources of GDP per Capita Growth in Canada, 1981-2010



Source: CSLS calculations based on Statistics Canada data.

Although the basic structure of this growth accounting framework is quite straightforward, what happens underneath its surface is not. Exhibit 3 shows how the determinants of GDP per capita, both from the labour productivity side and from the labour supply side, are interconnected. Labour productivity levels and growth rates are determined by the interrelations of labour, capital, and product markets. Furthermore, Exhibit 3 makes it clear that MFP growth, in this framework, is also a source of labour productivity growth.

Exhibit 3: Analytical Framework of Sources of Growth



Source: van Ark (2002), p.71.

A country's aggregate labour productivity is approximately equal to the sum of the different sectors' labour productivity, with each sector being weighted by its respective labour input share. This is the mechanism whereby the primary agriculture sector plays a role in contributing to overall labour productivity growth. Using the framework developed by Sharpe and Thomson (2010b), we can decompose the contributions of different sectors to aggregate labour productivity growth in Canada.[10] According to CSLS calculations, the agriculture sector accounted for 19.2 per cent of aggregate labour productivity growth in Canada (business sector) during the 1961-2007 period Summary Table 2. This may seem surprising, given that the importance of the primary agriculture sector as a share of national GDP and as a share of national employment has fallen over time (representing 1.4 per cent of GDP, and 2.2 per cent of total employment in 2007). However, the sector experienced exceptional labour productivity growth during the entire period, well above most other sectors in the Canadian economy, which contributed to increase its role in overall labour productivity growth. More specifically, the

[10] For a brief explanation of this framework, see Appendix 2.

agriculture sector's labour productivity increased by 3.77 per cent per year during the 1961-2007 period, well above the business sector average of 2.07 per cent per year.

Summary Table 2: Sectoral Contribution to Business Sector Labour Productivity Growth in Canada, 1961-2007

	Hours Share, 1961	Hours Share, 2007	Δ Hours Share	Labour Productivity Level, 1961	Labour Productivity Level, 2007	Δ Labour Productivity Level	Absolute Sectoral Contribution to Overall Labour Productivity Growth	Per Cent Sectoral Contribution to Overall Labour Productivity Growth
Business Sector	**100.0**	**100.0**	**0.00**	**15.01**	**38.35**	**23.33**	**23.33**	**100.0**
Primary Agriculture	14.3	2.7	-11.63	5.55	30.50	24.95	4.49	19.2
Forestry and Logging	1.8	0.4	-1.41	12.82	51.12	38.29	0.52	2.2
Fishing, Hunting and Trapping	0.5	0.1	-0.41	20.58	40.73	20.15	0.09	0.4
Support Activities for Agriculture and Forestry	0.2	0.2	0.04	15.89	21.47	5.57	0.00	0.0
Mining and oil and gas extraction	1.6	1.9	0.33	95.76	121.20	25.44	0.68	2.9
Utilities	0.7	0.8	0.15	56.90	157.99	101.08	0.88	3.8
Construction	9.5	10.0	0.48	19.29	29.38	10.09	0.91	3.9
Manufacturing	26.3	14.9	-11.38	13.42	50.16	36.74	8.31	35.6
Wholesale trade	4.8	6.9	2.13	11.43	42.10	30.68	1.56	6.7
Retail trade	11.9	12.8	0.96	6.89	22.98	16.09	1.76	7.6
Transportation and warehousing	7.1	6.6	-0.53	12.14	34.11	21.97	1.59	6.8
Information and cultural industries	1.9	2.7	0.79	11.92	66.11	54.19	1.27	5.5
FIRE	4.3	7.8	3.56	44.78	74.26	29.47	2.54	10.9
Professional, scientific and technical services	1.7	7.9	6.19	21.69	30.74	9.05	-0.32	-1.4
Other services (except public administration)	13.3	24.1	10.73	16.22	20.00	3.78	-1.46	-6.3

Note: The sum of the sectoral contributions to overall labour productivity growth is slightly smaller than the total change experienced by business sector labour productivity (22.83 versus 23.33). This difference is caused by the aggregation method used by Statistics Canada to calculate real GDP in the Canadian business sector, i.e. the chained Fisher quantity index formula. Unlike the fixed base Laspeyres quantity index formula, where aggregate real GDP is the *exact* sum of sectoral GDP, in the Fisher formula aggregate GDP is *approximately* the sum of sectoral GDP. The difference between the Fisher aggregate and the Laspeyres aggregate is a function of how far away from the reference year a particular observation is).
Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0021 and 383-0022).

D. Data

The main data source for this report is Statistics Canada's Canadian Productivity Accounts (CPA). The CPA provides detailed data on GDP, input use, and productivity for the primary agriculture sector, as well as for the business sector as a whole.[11] 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, and some of them going even further, to 2009.

Exhibit 4 summarizes the official data sources and data availability for the output, input, and productivity estimates used in this report.

Exhibit 4: Official Data Availability for Canada

	SURVEY	Index or Level	Business Sector	Primary Agriculture Sector	Primary Agriculture Subsectors
GDP					
Nominal	Productivity Measures and Related Variables - National (CPA)	L	1961-2006	1961-2007	..
	GDP by Industry - Provincial and Territorial (Annual)	L	..	1997-2007	1997-2007
	Input-Output Structure of the Canadian Economy in Current Prices	L	1961-2007	1961-2007	..
Real, Chained	GDP by Industry - National (Monthly)	L	1997-2010	1997-2010	1997-2010
	Productivity Measures and Related Variables - National (CPA)	I	1961-2009	1961-2007	..
Real, Constant	GDP by Industry - National (Monthly)	L	1981-2010	1986-2010	1997-2010
Gross Output					
Nominal	Productivity Measures and Related Variables - National (CPA)	L	..	1961-2007	..
Real, Chained	Productivity Measures and Related Variables - National (CPA)	I	..	1961-2007	..
Employment	Labour Productivity Measures - Provinces and Territories (Annual) (CPA)	L	1997-2009	1997-2009	..
	Labour Productivity and Related Variables, by Industry according to the CSNA (Old CPA)	L	1961-2001	1961-2000	..
	Labour Force Survey	L	..	1987-2010	1987-2010
Hours	Productivity Measures and Related Variables - National (CPA)	L	1961-2006	1961-2007	..
	Labour Productivity Measures - Provinces and Territories (Annual) (CPA)	L	1997-2009	1997-2009	..
	Labour Productivity and Related Variables, by Industry according to the CSNA (Old CPA)	L	1961-2001	1961-2000	..
	Labour Force Survey	L	..	1987-2010	1987-2010
Capital Stock					
Nominal	Fixed Capital Flows and Stocks	L	1961-2010	1961-2010	1961-2010
Real, Chained	Fixed Capital Flows and Stocks	L	1961-2010	1961-2010	1961-2010
Real, Constant	Fixed Capital Flows and Stocks	L	1961-2010	1961-2010	1961-2010
Capital Services	Productivity Measures and Related Variables - National (CPA)	I	1961-2009	1961-2007	..
Intermediate Inputs	Productivity Measures and Related Variables - National (CPA)	I	..	1961-2007	..
Labour Productivity	Productivity Measures and Related Variables - National (CPA)	I	1961-2009	1961-2007	..
Multifactor Productivity	Productivity Measures and Related Variables - National (CPA)	I	1961-2009	1961-2007	..

Note: CPA – Canadian Productivity Accounts.
Old CPA – Refers to series from the Canadian Productivity Accounts that have been terminated and are no longer updated.

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

Whenever official productivity estimates were not available from Statistics Canada, we constructed our own measures using either the above data sources or the CSLS Provincial Productivity Database.

This report makes extensive use of Statistics Canada's agricultural data. In particular, data on agricultural land area, number of farm units, average farm size, etc. were taken from the Census of Agriculture, while data for crop yields were obtained from the Field Crop Reporting Series.

Productivity data for the U.S. primary agriculture sector was taken from the USDA's Economic Research Service website (http://www.ers.usda.gov/Data/AgProductivity/), and spans the 1948-2008 period. For other OECD countries, productivity data from the 60-Industry Database were used (http://www.ggdc.net/databases/60_industry.htm). This database, maintained by the Groeningen Growth and Development Centre (GGDC), provides detailed labour productivity estimates which span the 1979-2003 period for most OECD countries.

E. Measurement Issues

The quality of productivity estimates can be no better than the quality of the data on which they are based. Productivity estimates are constructed from data on nominal output (either gross output or value added), price deflators, labour input, capital input, and intermediate inputs.

Statistics Canada rates the quality of GDP, output, and input data from their input-output tables for each NAICS industry. The highest quality rating of "A" or "most reliable" is assigned to data sets with the largest sample size and smallest under-coverage requiring indirect estimation of missing data. A rating of "B" or "reliable" is assigned to data sets that had some, but not all, of the attributes of an "A" rating. The lowest quality rating, "C" or "acceptable", is assigned to data sets that required significant indirect estimation techniques and relied on source data from small samples.

According to the latest input-output tables (Statistics Canada, 2010), which refer to the 2006-2007 period, gross output data for the agriculture sector are rated A, or most reliable, while intermediate inputs and GDP data are rated B, or reliable.[12] Given these ratings, this report assumes that data for the agriculture sector are generally reliable.

i. Current Dollar Output

Since the agriculture sector produces output that is sold in the market there is little ambiguity concerning the appropriate measure of value of the sector's nominal output as there often is in non-market industries such as health care and national defence.

ii. Price Deflators

Productivity growth over time is a real or physical concept; it captures the amount of real output that is produced per unit of input. For example, labour productivity is meant to capture how many kilograms of wheat per hour can be farmed by one agricultural worker. However, current-dollar output measures are affected by the fact that prices may change over time for reasons that have nothing to do with the production process (for example, general price inflation). Since measures of productivity growth should not reflect such price changes, it is necessary to adjust the nominal output data by a price deflator to ensure that what is being measured is *real* productivity growth.

A subtle point related to prices and productivity is the issue of output (and input) quality. Prices and quality change over time, and indeed, some price changes are driven by quality changes. It is necessary to disentangle quality-driven price changes from pure price changes

[12] All the ratings refer to current dollar estimates.

such as general inflation. To continue with the chair factory example, suppose that the quality of the chair produced increased by 10 per cent and so did the price, with no change in the number of hours of work necessary to produce it. Statisticians will consider that the real price of chairs has remained constant (that is, the price increase was entirely due to an increase in quality), and productivity will have increased by 10 per cent. In this case, the entire increase in current dollar output (number of chairs times the price per chair) will be accounted for by productivity increases. If, however, the 10 per cent price increase was not accompanied by a change in quality, productivity will remain unchanged even though the revenue obtained for each chair increased 10 per cent. In the latter case, the entire increase in current dollar output is accounted for by pure price changes. It is this sort of change in current-dollar output that is eliminated through the use of a price deflator.

Price data for the agriculture sector is relatively reliable due to the physical nature of the sector's output, and also due to the relatively small (although far from negligible) changes in the quality of agricultural.

iii. Labour Input

In the Canadian Productivity Accounts (CPA), Statistics Canada estimates hours worked by first estimating average annual hours per job and the number of jobs by province, industry, and class of workers. The volume of hours worked is then obtained by multiplying these two estimates (Maynard, 2005). Establishments are surveyed using the Survey of Employment, Payroll and Hours (SEPH), while households are surveyed using the Labour Force Survey (LFS).[13] Because the coverage of the LFS is more comprehensive (e.g. it includes self-employed workers), the CPA uses this source as the main indicator of the number of jobs in the economy. However, Statistics Canada believes that the SEPH provides a more accurate classification of jobs according to industry, because firms responding to the SEPH tend to be more knowledgeable about their industry classification than workers responding to the LFS. As a result, SEPH data are used to allocate hours worked to specific industries.

For several reasons, measuring the use of labour input in the agriculture sector is not a trivial task. A significant number of persons working in primary agriculture do so on a part-time basis or on a seasonal basis, and many farmers rely on other sources of income.[14] Another issue is that unpaid family labour plays an important role in several agricultural activities, but it is not easy to measure its contribution precisely.

[13] The LFS excludes the Armed Forces, Indian Reserves, and, in the past, the Territories. The CPA hours worked estimates make adjustments for these exclusions.

[14] According to Statistics Canada's Census of Agriculture, the share of farm operators that rely on non-farm activities as a source of income has increased consistently from 37.1 per cent of all farm operators in 1991, to 48.4 per cent in 2006 (http://www.statcan.gc.ca/pub/95-632-x/2007000/t/4129760-eng.htm).

The LFS controls for many possible sources of distortions. Its questionnaire includes questions on unpaid family labour, differentiates hours worked in a person's main job and other jobs, etc. Of course, the fact that it is mainly a phone survey raises some issues regarding the accuracy of their estimates. In particular, proxy responses,[15] which account for around 65 per cent of all LFS responses (Statistics Canada, 2008, p. 40), are found to have a negative impact in data quality, especially in the case of quasicontinuous variables such as wage rates (Lemaitre, 1988). Thus, it is important to keep in mind that these difficulties in measuring labour input use can affect the accuracy of the sector's productivity estimates.

iv. Capital Input

The quality and quantity of capital that firms use in the production process is a key determinant of productivity. Capital stock can be estimated over long time periods using data on investment. Statistics Canada takes into account the fact that different types of capital provide services at different rates. This report makes use of capital stock, capital services, and investment data. Gross real investment estimates shed light on how much new capital is entering a sector, whereas net real investment data (net of depreciation) show whether a sector's capital stock is growing or shrinking.

[15] Proxy responses happen when a single, well-informed member of the household answers for the entire household. According to Statistics Canada (2008), this is done "when it would be too time-consuming and costly to make several visits or calls to obtain the information directly from each household member" (p. 40).

III. Productivity Trends in the Canadian Primary Agriculture Sector

This part of the report is divided into two sections. The first reviews trends in the primary agriculture sector at the national level, while the second analyzes provincial trends. Both long-term trends and recent developments in the agriculture sector are discussed.

A. Agriculture Sector Productivity Trends at the National Level

This section explores productivity output, input, and productivity trends in the Canadian primary agriculture sector. The performance of primary agriculture is compared to that of the Canadian **business sector**, which is defined here as "the whole economy less public administration, non-profit institutions and the rental value of owner-occupied dwellings" (Statistics Canada, 2007). The discussion focuses on the 1961-2007 period, in order to highlight long-term trends. Data for the 1961-2000 period and 2000-2007 period are also presented to show how the recent performance in the sector compares to its historical performance. The reader should note that the choice of 2007 as the end year was driven solely by data availability issues, as most series from the Canadian Productivity Accounts (CPA), which is the main data source for this report, end in 2007.

i. Output Measures

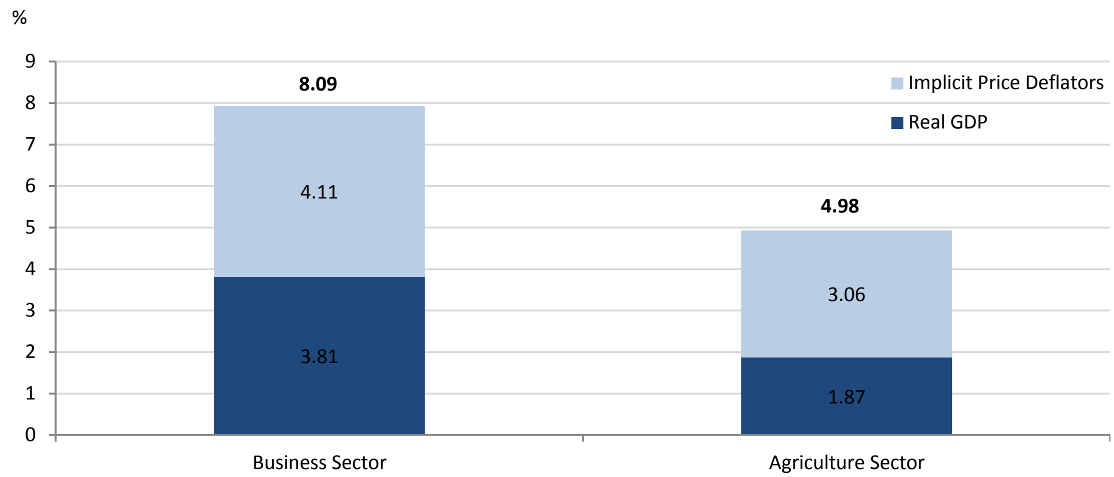
In this subsection, we outline long-run trends in the output of the Canadian primary agriculture sector. GDP (nominal and real), gross output (nominal and real), and implicit price deflator figures for the 1961-2007 period are discussed.

a. Nominal Output

In 2007, nominal GDP in the primary agriculture sector was $15,790 million, nine times its value in 1961, $1,685 million. During the 1961-2007 period, nominal GDP grew at an average annual rate of 4.98 per cent in the primary agriculture sector, while it grew by 8.09 per cent per year in the Canadian business sector (Chart 3).

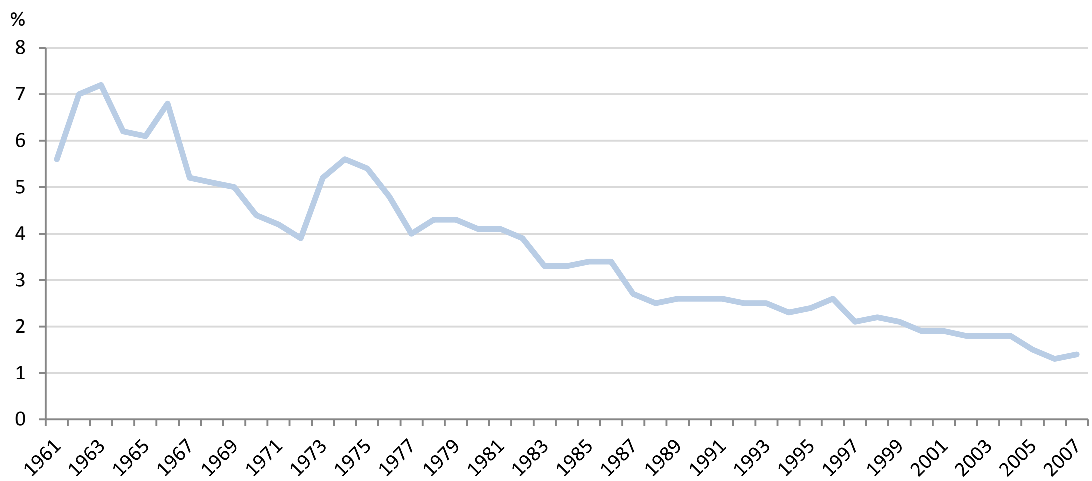
Since primary agriculture lagged the business sector in terms of nominal GDP growth, the importance of primary agriculture as a share of business sector GDP has declined considerably over the past decades, from 5.6 per cent in 1961 to 1.4 per cent in 2007. Chart 4 shows that the sector's size as a share of GDP experienced strong fluctuations during the 1960s and 1970s. Beginning in the late-1970s, however, these sizable fluctuations gave way to a slow, but steady decline in the sector's share in the economy. One important factor contributing to this decline is the overall fall in the relative prices of agricultural products. According to Agriculture and Agri-Food Canada, even though the share of primary agriculture in aggregate GDP has fallen over time, the agriculture and agri-food sector as a whole continues to represent a significant share of the Canadian economy, contributing with 8.2 per cent of the country's GDP in 2009 (AAFC, 2011).[16]

Chart 3: Nominal GDP in the Primary Agriculture Sector and Business Sector, Canada, Compound Annual Growth Rates, 1961-2007



Note: Contributions do not sum to the total growth rates because of rounding.
Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0021 and 383-0022).

Chart 4: Nominal GDP in the Primary Agriculture Sector as a Share of the Business Sector, Canada, per cent, 1961-2007



Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 381-0015, 383-0021, and 383-0022).

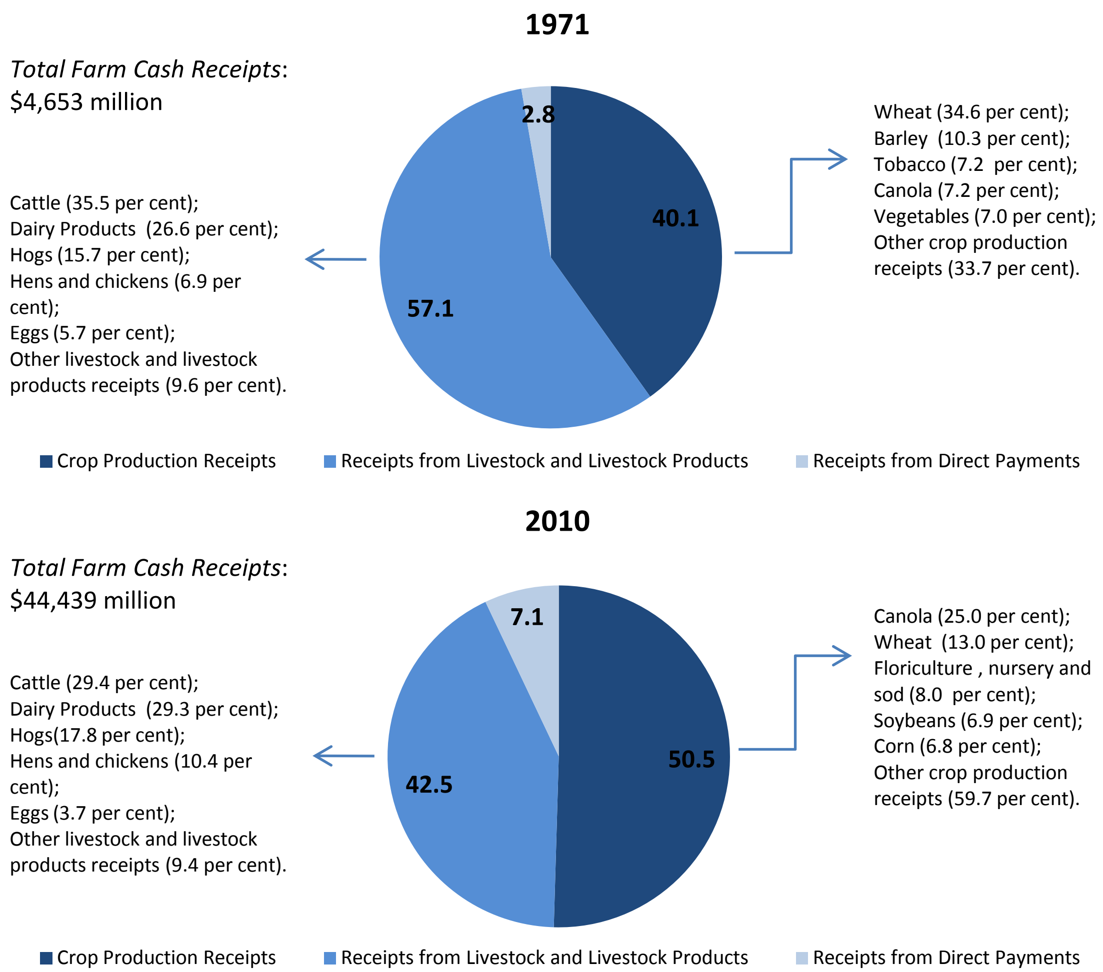
In 2007, nominal gross output in the Canadian agriculture sector was $47,756 million, 17 times its value in 1961, $2,823 million. Gross output in the sector grew at an average annual rate of 6.34 per cent during the 1961-2007 period, considerably faster than the sector's nominal GDP

[16] The agriculture and agri-food sector is composed by "farm input and service supplier industries, primary agriculture, food and beverage processing, food distribution, retail, wholesale and foodservice industries" (AAFC, 2011).

growth, 4.98 per cent per year. As will be seen in the next sections, this was due to the more intensive use of intermediate goods over time.

Before moving on to the next subsection, we briefly discuss the composition of the Canadian farm sector. The best way to do this is using farm cash receipt data from Statistics Canada's Net Farm Income survey.

Chart 5: Total Farm Cash Receipts, Canada, 1971 and 2010



Source: Statistics Canada, Net Farm Income (CANSIM Table 20001).

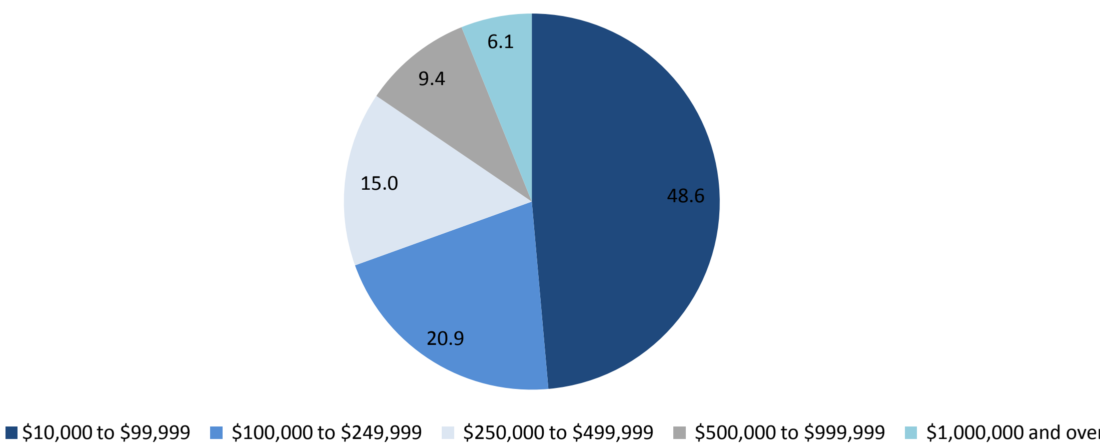
In 2010, total farm cash receipts reached $44,439 million, up from $4,653 million in 1971, with crop receipts accounting for $22,425 million (or 50.5 per cent of the total), livestock and livestock products receipts responsible for $18,879 million (42.5 per cent of the total), and direct payments accounting for $3,133 million (7.0 per cent of the total) (Chart 5). 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 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 the two years, we can see a number of interesting trends. Looking at Chart 5, it becomes clear that the crop production subsector gained importance 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 field crop accounted for 25 per cent of total crop production receipts. 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).

According to Statistics Canada's Farm Financial Survey, almost half of the farms in Canada (48.6 per cent) had sales between $10,000 and $99,999 in 2009. Only a small number of farms (6.1 per cent) had sales greater than $1,000,000 (Chart 6).[17]

Chart 6: Farm Size by Sales, Canada, 2009



Source: Statistics Canada, Farm Financial Survey (CANSIM Table 20066).

[17] It is interesting to note that smaller farms rely much more on income from non-farm activities than larger farms. A recent article in the Globe and Mail based on Statistics Canada data and on the work of David Sparling and Pamela Laughland (from the Richard Ivey School of Business) shows that 62 per cent of the income from farms that have sales between $10,000-$99,999 are obtained from non-farming activities. Meanwhile, non-farm income accounts for only 17 per cent of the income of farms in the $100,000-$249,000 category, 10 per cent in the case of farms in the $250,000-$499,999 category, 6 per cent in the case of farms in the $500,000-$999,999 category, 4 per cent in the case of farms in the $1,000,000-$2,499,999 category, and 1 per cent in the case of farms in the $2,500,000 or more category (Leeder, 2011).

b. Real GDP

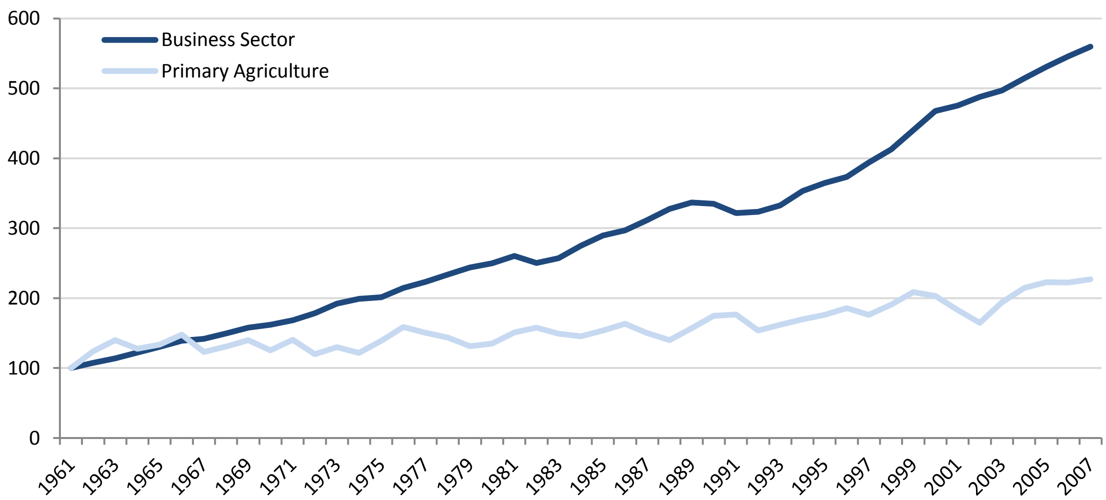
In 2007, real GDP in the primary agriculture sector was $20,135 million (chained 2002 dollars), 2.3 times its 1961 level. It grew at an average annual rate of 1.80 per cent during the 1961-2007 period, only half of the real GDP growth experienced by the Canadian business sector over the same period, 3.81 per cent per year (Summary Table 3, Chart 7). 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 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.

Summary Table 3: Real Output in the Primary Agriculture Sector, Canada, Compound Annual Growth Rates, per cent, 1961-2007

	1961-2007	1961-2000	2000-2007
	(real GDP, chained 2002 dollars, CAGR)		
Business Sector	3.81	4.04	2.59
Primary Agriculture Sector	1.80	1.83	1.60
	(real gross output, chained 2002 dollars, CAGR)		
Business Sector	..	..	..
Primary Agriculture Sector	3.11	3.42	1.41

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

Chart 7: Real GDP in the Primary Agriculture Sector, Canada, Index 1961=100, 1961-2010



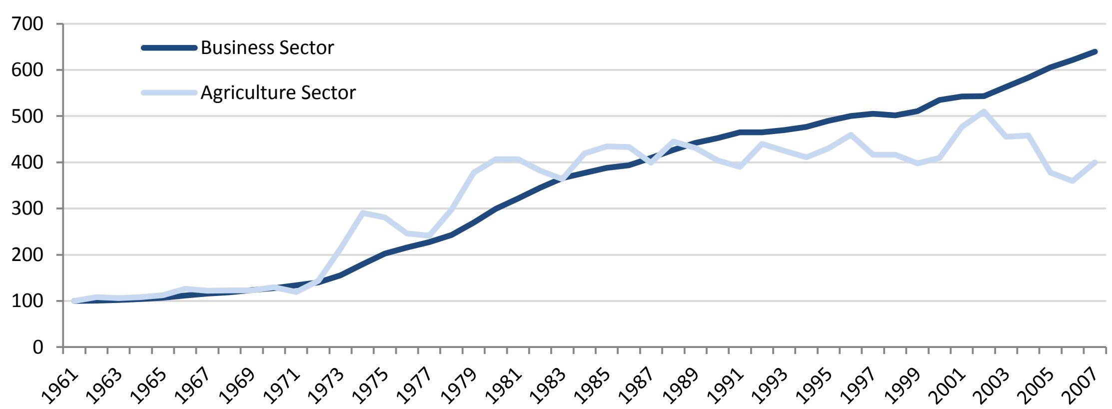
Source: Statistics Canada (CANSIM Tables 379-0027, and 383-0021/22).

In 2007, real gross output in the Canadian primary agriculture sector was $50,225 million (chained 2002 dollars), 4 times its value in 1961, $12,275 million (chained 2002 dollars). Gross output in the sector grew at an average annual rate of 3.11 per cent during the 1961-2007 period, again significantly faster than the sector's real GDP growth, 1.80 per cent per year, because of the more intensive use of intermediate goods over time. Note, however, that real gross output and real GDP growth during the 2000-2007 period were practically the same (1.41 versus 1.60 per cent per year, respectively). This is due to a significant decline in the growth rate of intermediate input use in the beginning of the 2000s.

c. Price Levels in the Agriculture Sector

The implicit price deflators for the business sector and for the primary agriculture sector during the 1961-2007 period tell very different stories (Summary Table 4, Chart 8). 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 8, 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.

Chart 8: Implicit Price Deflators for the Primary Agriculture Sector, Canada, Index 1961=100, 1961-2007



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

Summary Table 4: Implicit Price Deflators for the Primary Agriculture Sector, Canada, 1961-2007

	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).

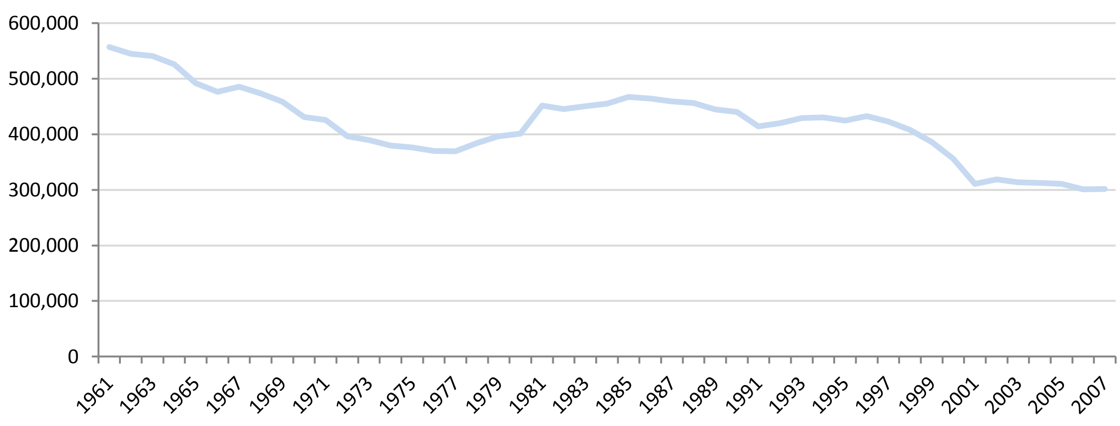
ii. Input Measures

In this subsection, we examine how labour, capital, land, and intermediate inputs have been used in the Canadian primary agriculture sector during the 1961-2007 period.

a. 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 (Summary Table 5, Chart 9). 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 10).[18]

Chart 9: Number of Jobs in the Primary Agriculture Sector, Canada, 1961-2007

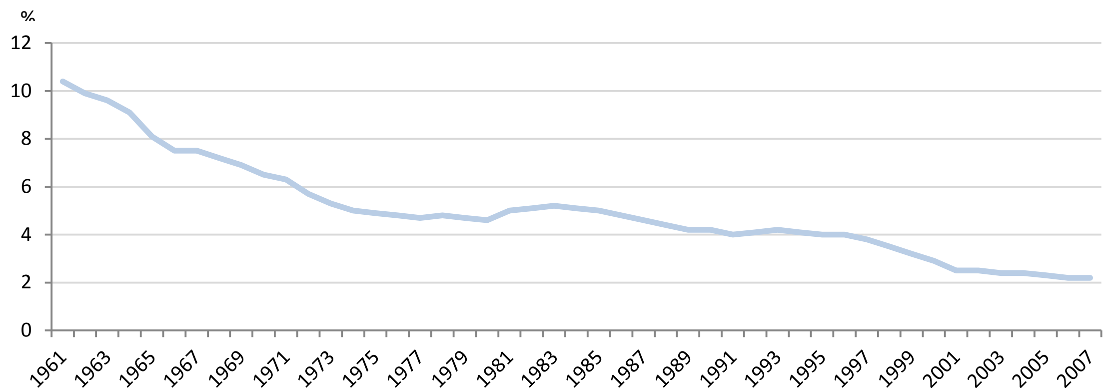


Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0003, 383-0010).
Note: Growth rates from employment in Agricultural and related service industries in CANSIM Table 383-0003, which spans the 1961-2000 period, were linked to employment data for Crop and animal production in CANSIM Table 383-0010, which spans the 1997-2010 period, to obtain employment estimates for the overall 1961-2007 period.

---

[18] 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.

Chart 10: Number of Jobs in the Primary Agriculture Sector as a Share of the Business Sector, Canada, 1961-2007



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

Summary Table 5: Total Number of Jobs in the Primary Agriculture Sector, Canada, Compound Annual Growth Rates, per cent, 1961-2007

	1961-2007	1961-2000	2000-2007
	(compound annual growth rate, per cent)		
Business Sector	2.07	2.13	1.77
Primary Agriculture Sector	-1.32	-1.14	-2.34
	1961	**2000**	**2007**
	(total number of jobs, thousands)		
Business Sector	5,360	12,191	13,783
Primary Agriculture Sector	557	356	302

Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0003, 383-0010).
Note: Growth rates from employment in Agricultural and related service industries in CANSIM Table 383-0003, which spans the 1961-2000 period, were linked to employment data for Crop and animal production in CANSIM Table 383-0010, which spans the 1997-2010 period, to obtain employment estimates for the overall 1961-2007 period.

The rate of decline was faster over the 1961-1981 period, when the agriculture sector's share of business sector employment decreased by 5.4 percentage points. After this period, the rate of decline slowed down considerably. According to Agriculture and Agri-Food Canada, even though the share of primary agriculture in total employment has fallen over time, the agriculture and agri-food sector as a whole was responsible for approximately 12 per cent of total employment in Canada in 2007 (AAFC, 2009).

According to data from Statistics Canada's Labour Force Survey, about two thirds of the workers in the primary agriculture sector were self-employed. It is interesting to note, however, that the number of self-employed workers in the sector has been falling over time, from 68.2 per cent 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.

The number of total hours worked in primary agriculture also dropped considerably over the last 50 years, at an average annual rate of 1.90 per cent (Summary Table 6). In 2007, the number of total hours worked in the agriculture sector was only 41.3 per cent of the hours worked in 1961 (or, in other words, hours worked experienced a 58.7 per cent drop since 1961).

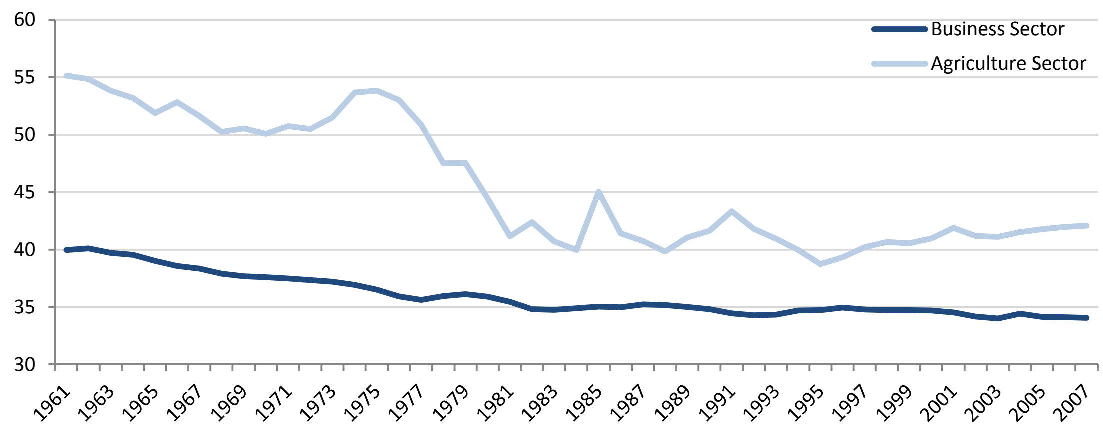
Summary Table 6: Total Hours Worked in the Primary Agriculture Sector, Canada, Compound Annual Growth Rates, per cent, 1961-2007

	1961-2007	1961-2000	2000-2007
Business Sector	1.72	1.76	1.49
Primary Agriculture Sector	-1.90	-1.89	-1.96

Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0009/10; unpublished Labour Force Survey data).

The fall in total hours worked in primary agriculture reflected a reduction not only in the number of jobs in the sector, but also in the duration of the average working week. Chart 11 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, which represents a 47 per cent drop.[19]

Chart 11: 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).

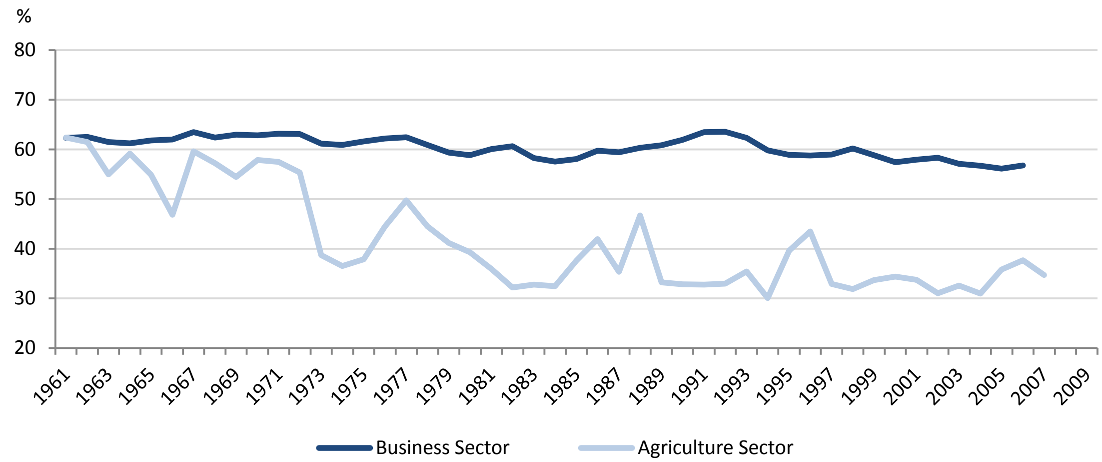
Another important issue related to the use of labour input in primary agriculture has to do with how much of nominal GDP goes to labour compensation (as opposed to capital compensation). In 1961, the labour compensation share of GDP was the same in the primary agriculture sector and the business sector, 62.4 per cent (Chart 12). By 2006,[20] the labour share

[19] In 2007, total hours worked in primary agriculture represented 2.7 per cent of total hours worked in the Canadian business sector, more than the primary agriculture sector's share in total employment, 2.2 per cent. However, the hours worked share observed a greater fall since 1961, when it was 14.3 per cent, while the employment share was only 10.4 per cent.

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

of GDP in the business sector had fallen a little, 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. As will be seen in Part V, this is a direct consequence of the increasing mechanization in primary agriculture.

Chart 12: Labour Compensation as a Share of Nominal GDP in the Primary Agriculture Sector, Canada, 1961-2007[21]



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

b. Capital Input

Three Statistics Canada surveys are used as the main sources of agricultural capital data in this report: the Canadian Productivity Accounts (CPA), the Fixed Capital Flows and Stocks, and the Value of Farm Capital. Although we discuss each of the above sources in details below, it should be emphasized that the agricultural productivity estimates for Canada presented in this report are consistent with capital data from the CPA.

There are two main measures of capital input: capital stock and capital services. Capital stock, as the name implies, is the stock of physical capital that is used in the production process. The capital stock measures calculated by Statistics Canada's CPA include fixed reproducible business assets (which, in turn, encompass equipment and machinery, buildings, and engineering structures), inventories, and land. They are estimated assuming that investments follow geometric depreciation patterns, which assign more depreciation to a capital asset in the early years of its service life than later in its service life.

[21] 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).

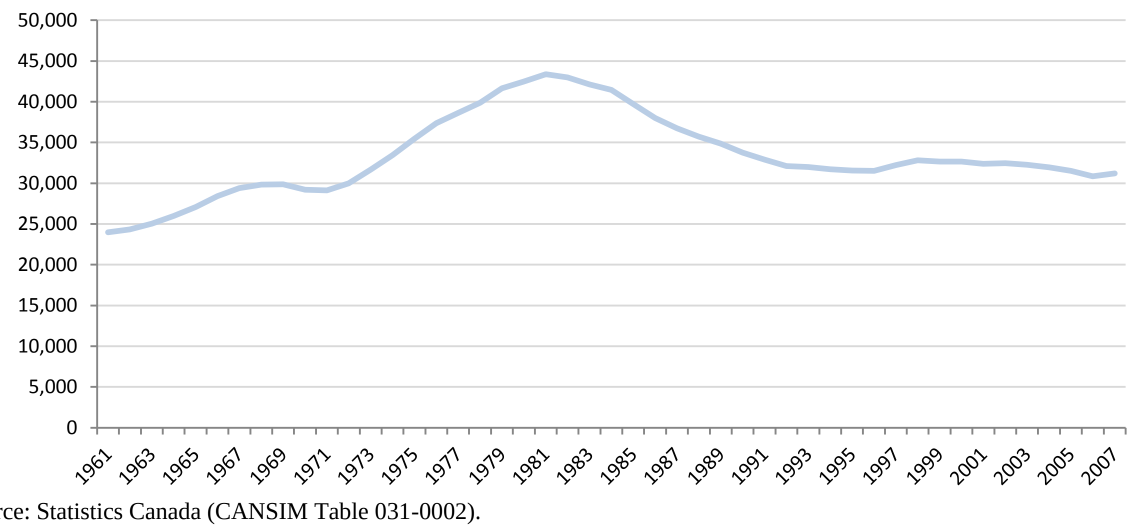
The capital services input, on the other hand, represents the flow of services provided by the capital stock during a certain time period. It is calculated by aggregating the capital stock of different types of capital goods using the relative cost of capital as weights. Capital services growth is driven by: 1) increases in the level of capital stock; and 2) shifts in the capital composition towards assets that provide relatively more services per dollar of capital stock (i.e. short lived assets). In this subsection, we discuss the evolution of both capital stock and capital services in the agriculture sector over the last 50 years.

Fixed Capital Flows and Stocks

Statistics Canada's Fixed Capital Flows and Stocks survey focuses on the evolution of the capital stock of fixed, non-residential, reproducible business assets, which include machinery and equipment, buildings, and engineering structures. In 1961, the primary agriculture sector's capital stock of fixed reproducible business assets was equal to $24 billion (chained 2002 dollars), which represented 10.5 per cent of the total capital stock in the business sector. By 2007, the agriculture sector's capital stock had increased to $31 billion (chained 2002 dollars), but as a share of total real capital stock in the business sector it had fallen to 3.2 per cent, less than one-third of its 1961 share (Chart 13, Chart 14).

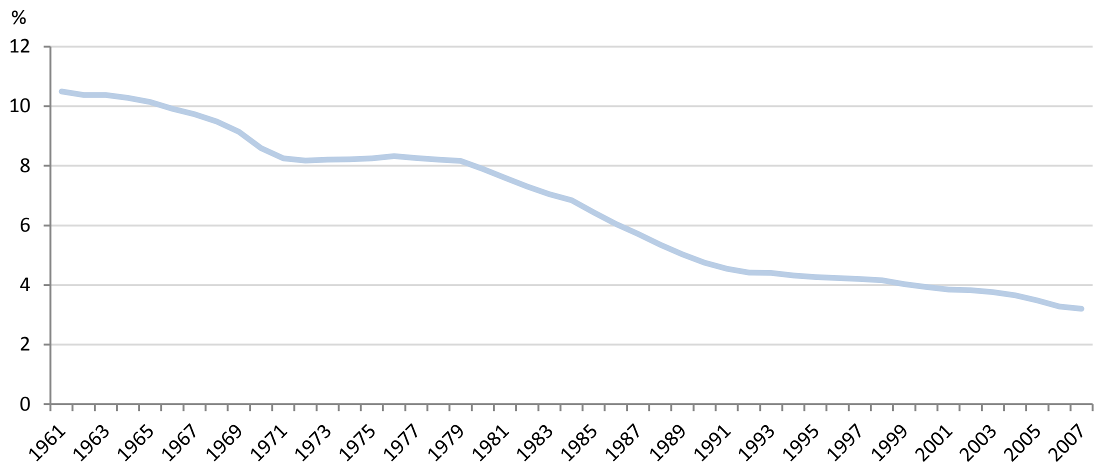
Real capital stock of fixed business assets in the Canadian primary agriculture sector grew by only 0.57 per cent per year over the 1961-2007 period (Summary Table 7). This weak, but positive, growth rate for the overall period is a consequence of the relatively strong growth experienced during the 1961-1981 period, after which capital stock growth in the sector turned negative.

Chart 13: Fixed Non-Residential Net Capital Stock in the Primary Agriculture Sector, Canada, Millions of 2002 Chained Dollars, 1961-2007



Source: Statistics Canada (CANSIM Table 031-0002).

Chart 14: Fixed Non-Residential Net Capital Stock in the Primary Agriculture Sector as a Share of the Business Sector, Canada, 1961-2007



Source: CSLS calculations based on Statistics Canada data (CANSIM Table 031-0002).

Summary Table 7: Real Net Capital Stock in the Primary Agriculture Sector, Canada, Compound Annual Growth Rates, per cent, 1961-2007

	1961-2007	1961-2000	1961-1981	1981-2000	2000-2007
Business Sector	3.20	3.36	4.69	1.99	2.30
Primary Agriculture Sector	0.57	0.80	3.01	-1.48	-0.65

Source: CSLS calculations based on Statistics Canada data (CANSIM Table 031-0002).

The capital stock trends seen above become easier to understand when we analyze long-term investment trends in the sector. Looking at overall gross investment in fixed non-residential business assets in the primary agriculture sector, we can see that it grew at an average annual rate of 0.96 per cent during the 1961-2007 period, less than one fifth of the growth rate experienced by the business sector as a whole, 4.94 per cent per year (Summary Table 8, Chart 15).

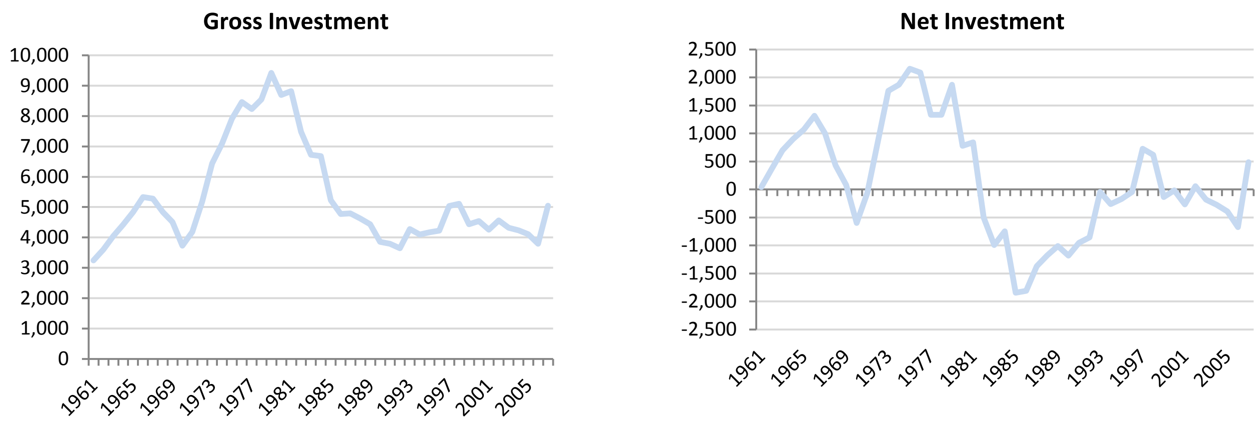
Summary Table 8: Gross Investment (Fixed, Non-Residential) in the Primary Agriculture Sector, Canada, Compound Annual Growth Rates, per cent, 1961-2007

	1961-2007	1961-2000	2000-2007
Business Sector	4.94	4.88	5.30
Primary Agriculture Sector	0.96	0.86	1.52

Source: CSLS calculations based on Statistics Canada data (CANSIM Table 031-0002).

The weak growth rates observed in the primary agriculture sector's gross investment during the 1961-2007 period were not enough to counter capital depreciation, which explains why net investment in the sector was actually negative in 21 years between 1981 and 2007 (Chart 15).

Chart 15: Investment (Fixed, Non-Residential) in the Primary Agriculture Sector, Canada, Millions of Chained 2002 Dollars, 1961-2007



Source: Statistics Canada (CANSIM Table 031-0002).

Although informative, the importance of capital stock and investment trends in absolute terms should not be overstated. As we discuss in Part V of the report, what matters to productivity growth is capital intensity, i.e. the amount of capital per worker (or hour worked). This is particularly important to remember when analyzing the primary agriculture sector because of the massive decline in labour input use the sector has witnessed over the last 50 years.

Canadian Productivity Accounts (CPA)

Although Statistics Canada's Fixed Capital Flows and Stocks data provides valuable insight into how capital input use in primary agriculture evolved over the past 50 years, it has two important limitations: 1) it does not control for the fact that different assets provide capital services at different rates; 2) it includes only fixed reproducible business assets. Statistics Canada's CPA solves both of these problems by calculating a capital services input measure that includes not only fixed reproducible business assets, but also inventories, and land.[22] As mentioned previously, the capital services input measure differs from the capital stock in that it takes into account that different assets provide capital services at different rates, with short-lived assets providing more capital services per dollar of capital stock.

Summary Table 9 shows that during the 1961-2007 period the business sector's capital services input grew at an average annual rate of 5.06 per cent, whereas the growth seen in the primary agriculture sector was only 0.89 per cent per year.

---

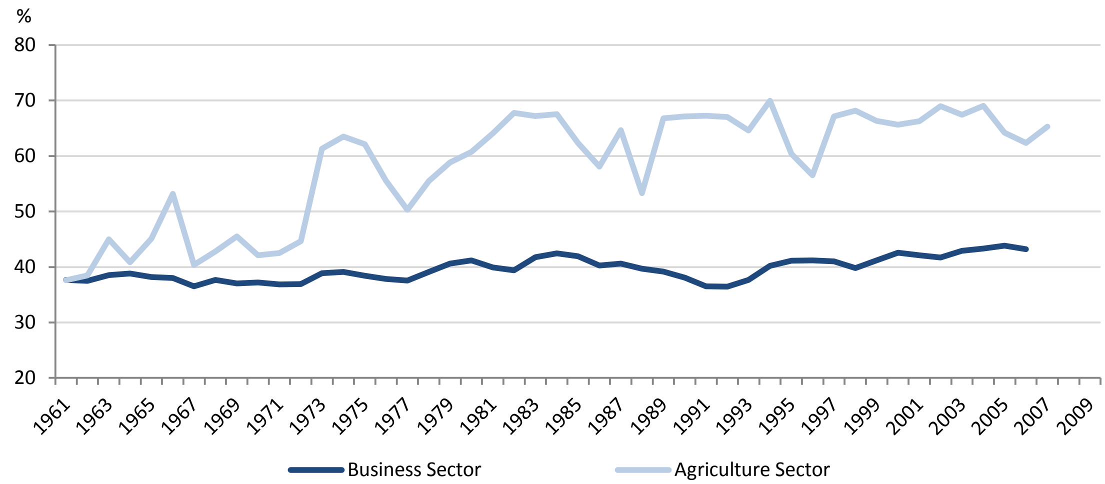
[22] For a detailed discussion on how the CPA treats inventories and land, refer to Harchaoui and Tarkhani (2002) and Baldwin and Gu (2007).

Summary Table 9: Capital Services Input in the Primary Agriculture Sector, Canada, Compound Annual Growth Rates, per cent, 1961-2007

	1961-2007	1961-2000	2000-2007
Business Sector	5.06	5.24	4.07
Primary Agriculture Sector	0.89	0.98	0.36

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

Chart 16: Capital Compensation as a Share of Nominal GDP in the Agriculture Sector and in the Business Sector, Canada, 1961-2007[23]



Source: CSLS calculations based on Statistics Canada data (CANSIM Table 383-021, and 383-0022).

As was seen in the previous subsection, the labour compensation share of GDP in primary agriculture declined sharply over the 1961-2006 period, which implies that the capital compensation share increased consistently over the years. In fact, the capital compensation share of GDP in the agriculture sector was only 37.6 per cent in 1961, but by 2006 it was 62.3, a 24.7 percentage point increase. Chart 16, which is the mirror image of Chart 12, shows the evolution of the capital compensation share of GDP in primary agriculture during the entire period.

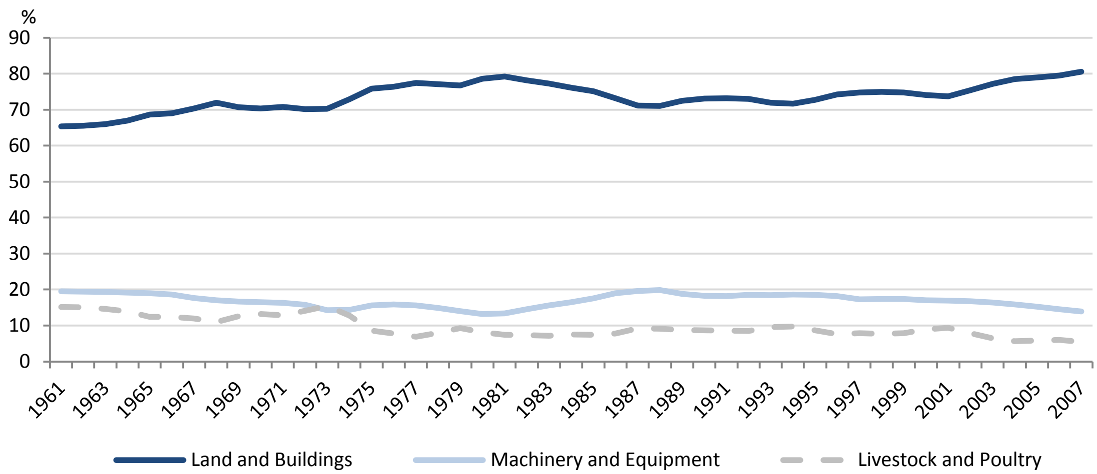
Value of Farm Capital

Statistics Canada's Value of Farm Capital survey divides farm capital into three categories: machinery and equipment, land and buildings, and livestock and poultry. In 2007, total farm capital in Canada was valued at $263 billion (current dollars), up from $13 billion in 1961, which entails an average annual growth rate of 6.72 per cent during the 1961-2007 period. Robust growth rates were seen especially during the 1961-1981 period, after which there was a marked decline in farm capital growth (and even negative rates during most of the 1980s).

[23] According to Harchaoui *et al.* (2001), "labour income of self-employed (…) is (…) subtracted from mixed income to arrive at the concept of other capital income, a measure of capital compensation of unincorporated businesses used by the productivity program. Other capital income is then aggregated with other operating surplus and net indirect taxes on production to obtain the total capital compensation of incorporated and unincorporated businesses" (p. 157).

Chart 17 shows the share of land and buildings, machinery and equipment, and livestock and poultry in terms of total farm capital. Both livestock and poultry, and machinery and equipment lost importance as a share of total farm capital from 1961 to 2007. Machinery and equipment represented 19.5 per cent of farm capital in 1961, but by 2007 it accounted for only 13.9 per cent, while livestock and poultry went from 15.1 per cent in 1961 to 5.5 per cent in 2007. Conversely, the share of land and buildings in total farm capital increased substantially during the period, from 65.4 per cent in 1961 to 80.6 per cent in 2007, driven in large part by increases in land prices.

Chart 17: Machinery and Equipment, Land and Buildings, and Livestock as a Share of Total Farm Capital, per cent, 1961-2007



Source: CSLS calculations based on Statistics Canada data, Value of Farm Capital (CANSIM Table 20007).

Even though the share of livestock in total farm capital has fallen over time, it still plays an important role, and differentiates the primary agriculture sector from other sectors in the economy. Thus, we discuss the role of livestock and poultry in total farm capital in more detail below.

As mentioned previously, in 2007, livestock and poultry accounted for 5.5 per cent of total farm capital, 97.0 per cent of which was livestock and 3.0 per cent of which was poultry. Cattle and calves were by far the most important subset, accounting for 88.3 per cent of livestock capital, followed by hogs (9.9 per cent), sheep and lambs (1.4 per cent) and fur bearing animals (0.4 per cent).

Using Statistics Canada data from the Livestock Survey, we constructed a constant dollar measure of livestock capital. Due to data unavailability, however, it was not possible to control for changes in the quality of livestock (for a brief discussion on the subject, refer to Box 2). To the extent that the quality of animals has improved (due to average size, milk yield, work capability), this measure underestimates the acquisition of real livestock capital. The measures that follow control for compositional changes (cattle, for instance, is composed of bulls, dairy cows, beef cows, dairy heifers for breeding, beef heifers for breeding, beef heifers for slaughter, slaughter steers, calves) and hold prices constant for each subset at their 2002 level. For example, roughly five calves contribute the same to the index as one bull does because the price of an average bull in 2002 was about five times that of a calf.

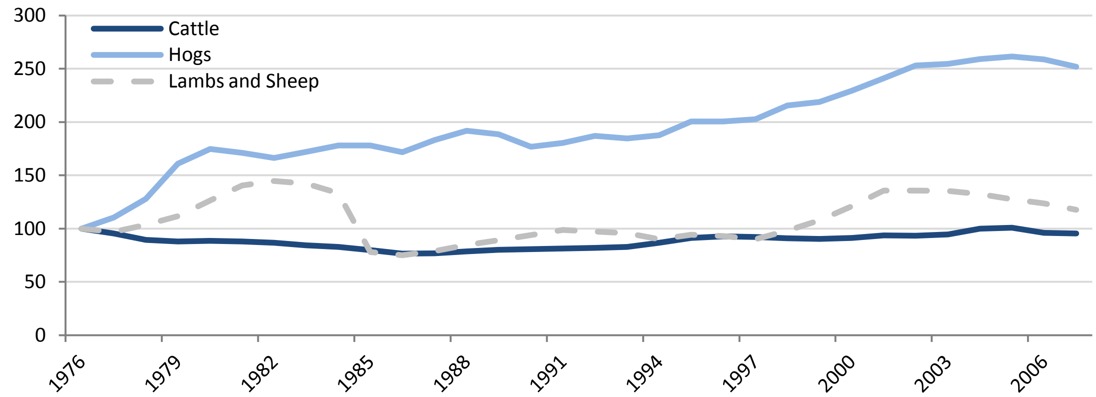
The 1976-2007 period witnessed major changes in the composition of livestock. The real stock of cattle declined 0.16 per cent per year over the entire period while lamb and sheep increased by 0.53 percent; in contrast with these moderate changes, the stock of hogs increased at an annual rate of 3.02 per cent (Summary Table 10, Chart 18). Due to the large proportion of livestock capital accounted for by cattle, the composite index including cattle, lamb and sheep, and hogs grew at an average annual rate of 0.03 per cent.

Summary Table 10: Livestock Farm Capital, Compound Annual Growth Rates, per cent 1976-2007

	1976-2007	1976-2000	2000-2007
Composite	0.03	-0.16	0.67
Cattle	-0.16	-0.38	0.62
Hogs	3.02	3.52	1.34
Lambs and Sheep	0.53	0.79	-0.37

Source: CSLS calculations based on Statistics Canada data, Value of Farm Capital and Livestock Survey (CANSIM Tables 30004, 30025, 30031, and 30032).

Chart 18: Indexes of Select Livestock Real Capital, Constant 2002 Dollars, 1976=100, 1976-2007



Source: CSLS calculations based on Statistics Canada data, Value of Farm Capital and Livestock Survey (CANSIM Tables 30004, 30025, 30031, and 30032).

c. Land Input

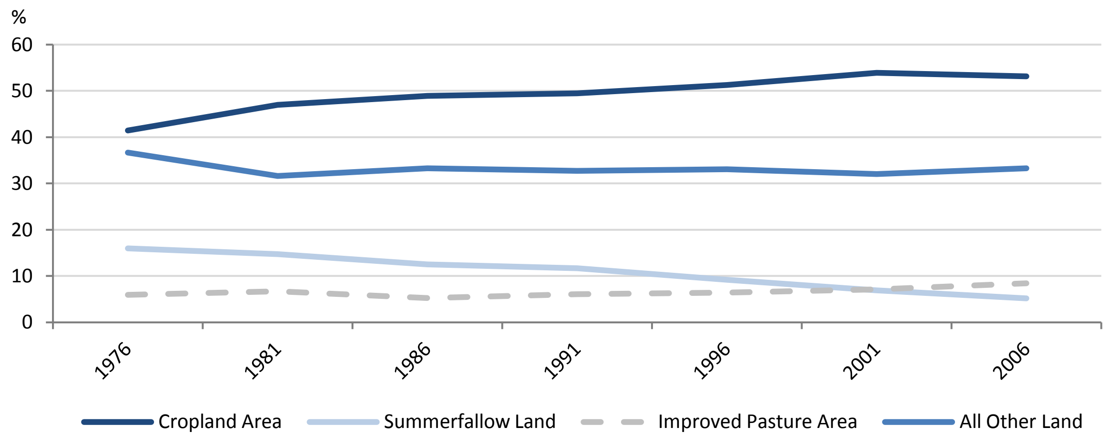
In the mid-1970s, there were 68,425 thousand hectares of agricultural land in Canada, which comprised 7.42 per cent of the total land area in the country. By 2006, the agricultural land area had reduced marginally by 1.2 per cent, to 675,586 thousand hectares. Despite this small reduction, cropland area increased consistently over the 1976-2006 period, from 28,343 thousand hectares in 1976 (41.4 per cent of total agricultural land area) to 35,912 thousand hectares (53.1 per cent), an increase of 26.7 per cent during the overall period (Summary Table 11, Chart 19). The share of improved pasture area also increased during the period, from 5.9 per cent of total agricultural area in 1976 to 8.4 per cent in 2006. The increased shares of cropland area, and improved pasture area relative to total agricultural land reflect the decline in summerfallow land area.

Summary Table 11: Use of Agricultural Land Area in Canada, 1976-2006

	1976-2006	1976-2001	2001-2006
	(compound annual growth rates, per cent)		
Total Farmland Area	-0.04	-0.05	0.02
Cropland Area	0.79	1.01	-0.27
Summerfallow Land	-3.72	-3.33	-5.62
Improved Pasture Area	1.13	0.67	3.46
All Other Land	-0.37	-0.59	0.78
	1976	**2001**	**2006**
	(thousand hectares)		
Total Farmland Area	68,425	67,502	67,587
Cropland Area	28,343	36,395	35,912
Summerfallow Land	10,920	4,680	3,506
Improved Pasture Area	4,063	4,804	5,694
All Other Land	25,098	21,622	22,475

Note: The category "All Other Land" includes all uses of farmland that are not accounted for in the other three categories, such as woodland and wetlands, idle land, farm buildings, etc.
Source: CSLS calculations based on Statistics Canada data, Census of Agriculture (http://www.statcan.gc.ca/ca-ra2006/).

Chart 19: Use of Agricultural Land Area in Canada, % of Agricultural Land Area, 1976-2006



Note: The category "All Other Land" includes all uses of farmland that are not accounted for in the other three categories, such as woodland and wetlands, idle land, farm buildings, etc.
Source: CSLS calculations based on Statistics Canada data, Census of Agriculture (http://www.statcan.gc.ca/ca-ra2006/).

d. Intermediate Inputs

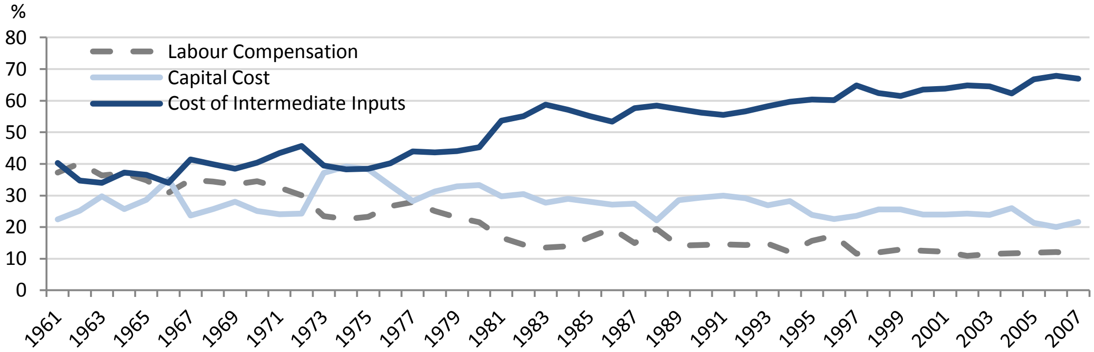
In addition to labour, capital, and land, it is also important to keep track of how intermediate input use has changed over time. This is particularly true in the case of primary agriculture, where seed, feed, fertilizers, pesticides, etc. play an essential role in the productive process.

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, etc.), while the services input category aggregates nine sub-categories of services.[24]

The value of intermediate inputs in the primary agriculture sector was $31,966 million (current dollars) in 2007, of which $22,813 million refer 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 20 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 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).

Chart 20: Cost of Intermediate Inputs as a Share of Nominal Gross Output in the Primary Agriculture Sector, per cent, 1961-2007

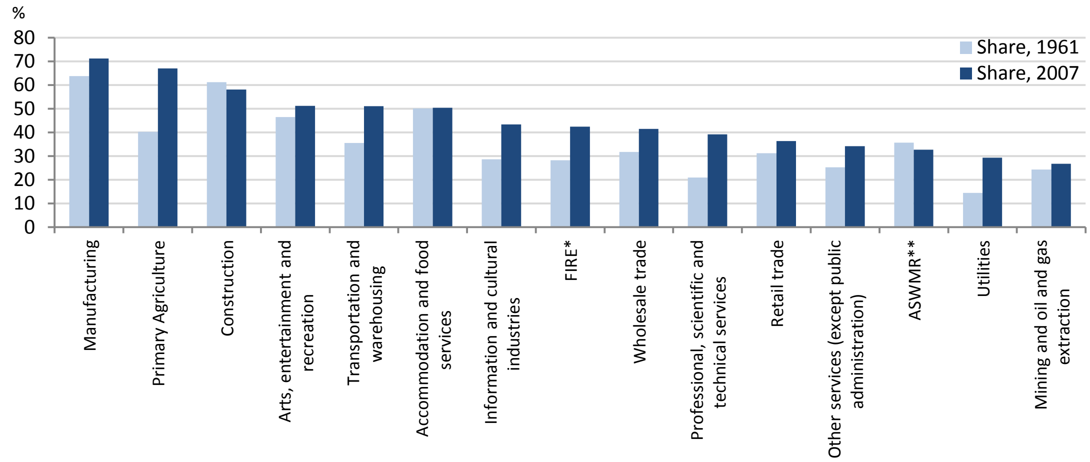


Source: CSLS calculations based on Statistics Canada data (CANSIM Table 383-0022).

[24] 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.

Chart 21 compares the importance of intermediate inputs as a share of gross output at the two-digit NAICS level in 2007. The only sector where intermediate inputs played an even larger role than in primary agriculture was the manufacturing sector (71.2 per cent of the value of the sector's gross output). This is not surprising, given that the main purpose of the manufacturing sector is to transform raw materials into finished products.

Chart 21: Cost of Intermediate Inputs as a Share of Nominal Gross Output, Sectoral Comparison, per cent, 1961 and 2007



*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).

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 (Summary Table 12). 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).

Summary Table 12: Real Intermediate Input Use in the Primary Agriculture Sector, Canada, Compound Annual Growth Rates, per cent, 1961-2007

	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).

iii. Productivity Measures

In this subsection, we discuss the overall productivity performance of the Canadian primary agriculture sector over the 1961-2007 periods. Two sets of labour and multifactor productivity estimates are presented: one calculated using a **value added approach (VA)**; the other computed using a **gross output approach (GO)**. Intermediate input productivity, and land productivity estimates are also discussed.

a. Labour Productivity (VA)

Labour productivity can be defined either as output per hour worked (*unadjusted* by quality) *or* output per worker. Using hours worked leads to a more accurate productivity measure because the average number of hours worked per worker can change over time. Therefore, this report calculates labour productivity as output (either GDP or gross output) per hour worked. In this subsection, labour productivity is defined as GDP per hour worked.

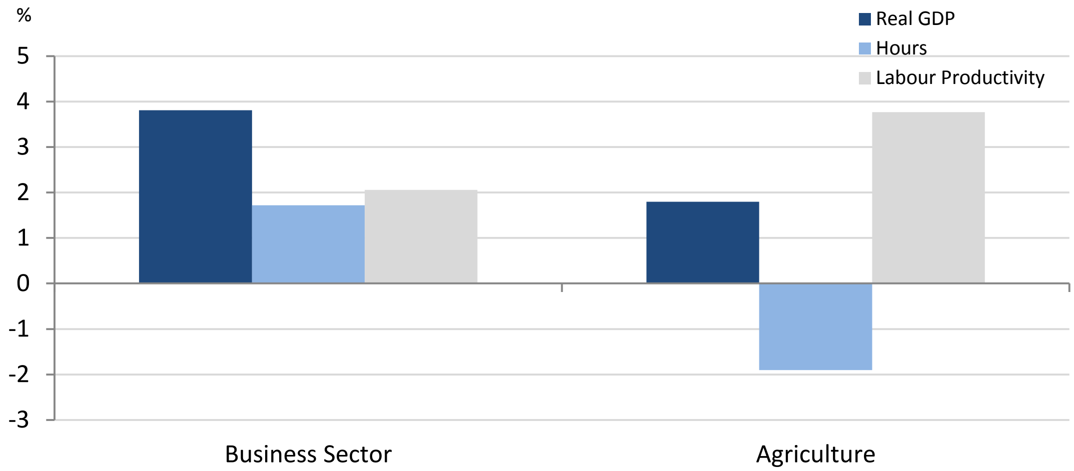
Labour productivity in the primary agriculture sector grew at an average annual rate of 3.77 per cent during the 1961-2007 period, much faster than the rate of growth observed in the business sector as a whole, which was only 2.06 per cent per year (Summary Table 13, Chart 22). Growth rates in primary 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.

Summary Table 13: 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).

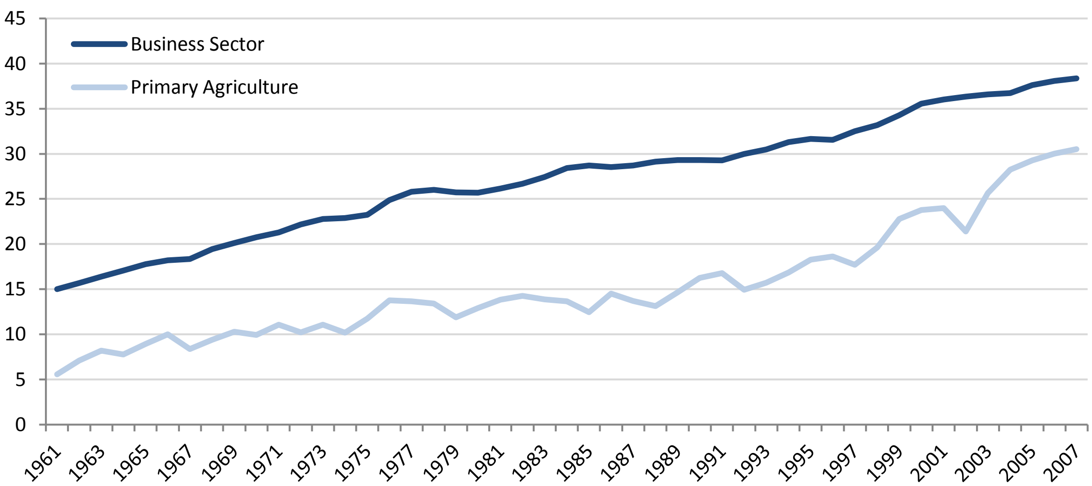
Chart 22: Labour Productivity (VA) Growth in the Primary Agriculture Sector, Canada, Compound Annual Growth Rates, per cent, 1961-2007



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

The labour productivity level (expressed in chained 2002 dollars) in primary agriculture remained below the business sector average during the entire period (Chart 23). 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 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.

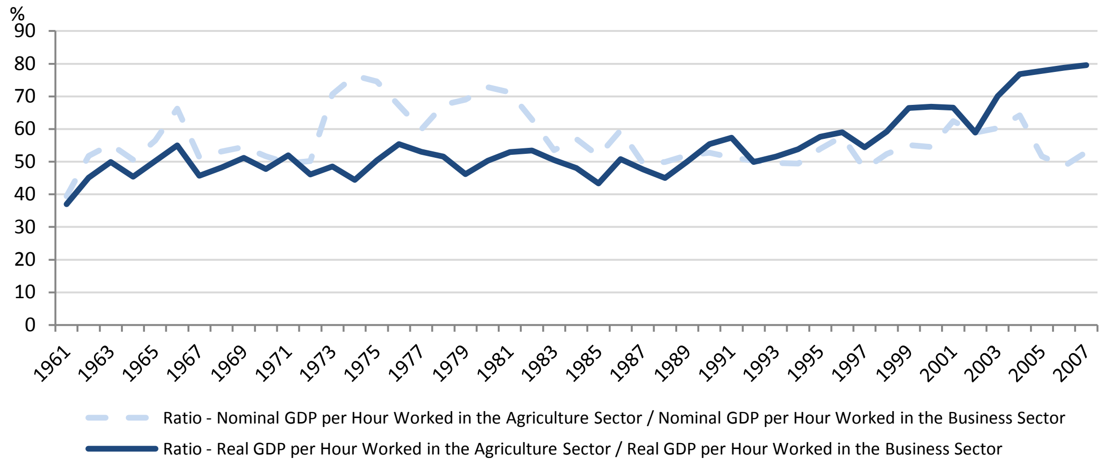
Chart 23: Labour Productivity (VA) in the Primary Agriculture Sector, Canada, Chained 2002 Dollars, 1961-2007



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

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 24). 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.

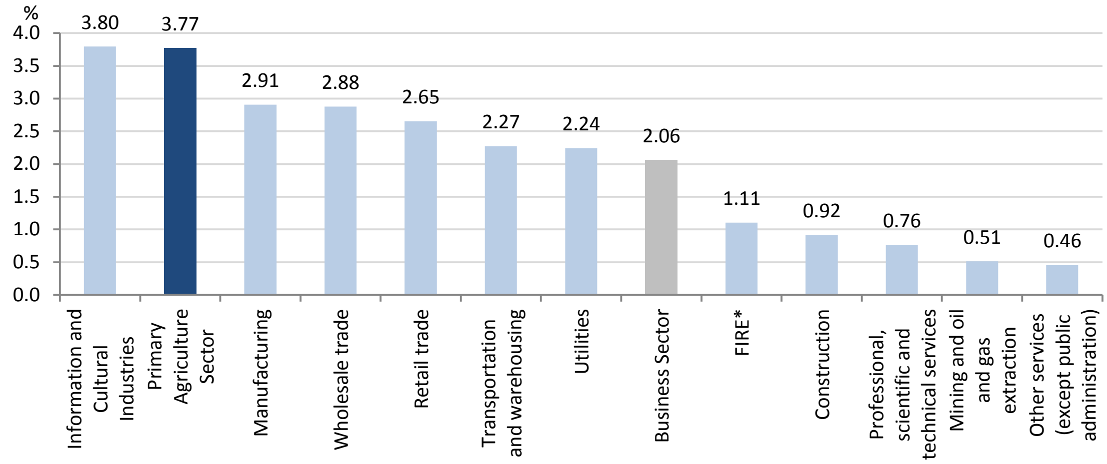
Chart 24: GDP per Hour Worked in the Primary Agriculture Sector as a Share of GDP per Hour Worked in the Business Sector, Canada, 1961-2007



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

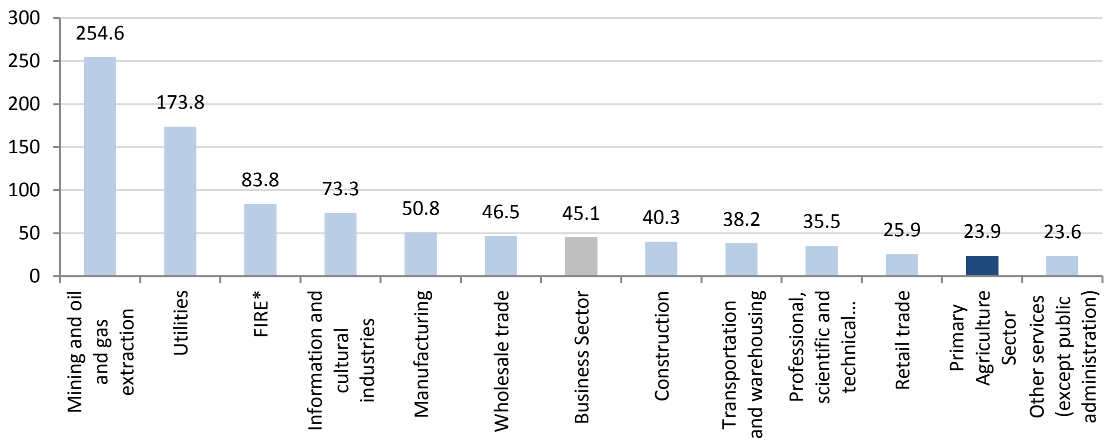
This point becomes clear when we compare the labour productivity performance of the primary agriculture sector to that of other sectors (Summary Table 14, Chart 25, and Chart 26). As discussed previously, labour productivity in the agriculture sector grew at a much faster pace than in the business sector during the overall period. Looking at more detailed data, it can be seen that the sector outperformed most of the two-digit NAICS sectors, with the exception of information and cultural industries, which grew at 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, which had a marginally lower level at $23.64 per hour.

Chart 25: Real GDP per Hour Worked, Sectoral Comparison, Compound Annual Growth Rates, per cent, 1961-2007



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

Chart 26: 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).

Summary Table 14: The Paradoxical Productivity Performance of the Primary Agriculture Sector, Labour Productivity (VA), Sectoral Comparison, 1961-2007

	1961-2007	1961-2000	2000-2007
	Growth Rates - Chained 2002 Dollars per Hour Worked		
Business Sector	2.06	2.24	1.08
Primary Agriculture Sector	3.77	3.79	3.62
Mining and oil and gas extraction	0.56	1.34	-3.64
Utilities	2.04	2.52	-0.60
Construction	0.98	1.16	0.04
Manufacturing	2.89	3.26	0.82
Wholesale trade	2.77	2.67	3.32
Retail trade	2.60	2.57	2.79
Transportation and warehousing	2.29	2.62	0.46
Information and cultural industries	3.80	3.78	3.89
FIRE*	1.04	1.08	0.81
Professional, scientific and technical services	0.82	0.76	1.16
Other services (except public administration)	0.50	0.44	0.88
	1961	**2000**	**2007**
	Levels - Nominal Dollars per Hour Worked		
Business Sector	2.77	34.99	45.07
Primary Agriculture Sector	1.09	19.09	23.92
Mining and oil and gas extraction	9.70	189.38	254.61
Utilities	11.47	154.54	173.83
Construction	2.71	29.03	40.28
Manufacturing	3.00	46.66	50.82
Wholesale trade	3.26	31.76	46.46
Retail trade	1.95	18.39	25.87
Transportation and warehousing	3.19	31.35	38.16
Information and cultural industries	4.72	50.47	73.32
FIRE*	6.89	66.62	83.79
Professional, scientific and technical services	3.06	27.51	35.53
Other services (except public administration)	1.72	18.05	23.64
	As a Share of the Business Sector, per cent		
Primary Agriculture Sector	39.4	54.6	53.1
Mining and oil and gas extraction	350.7	541.2	564.9
Utilities	414.8	441.6	385.7
Construction	97.8	82.9	89.4
Manufacturing	108.4	133.3	112.8
Wholesale trade	117.7	90.8	103.1
Retail trade	70.7	52.6	57.4
Transportation and warehousing	115.4	89.6	84.7
Information and cultural industries	170.7	144.2	162.7
FIRE*	249.2	190.4	185.9
Professional, scientific and technical services	110.7	78.6	78.8
Other services (except public administration)	62.1	51.6	52.5

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

This divergence in trends started in the early 1980s, and shows that the increase in agricultural labour productivity, i.e. a worker now producers more real output than before, was accompanied by an overall fall of agricultural prices relative to economy-wide prices. In Canada, prices of most agricultural commodities are determined in competitive markets, which means that the average agricultural producer is a price taker, not a price maker, and prices reflect the underlying cost structures. The cost structures, in turn, are affected by several factors, one of the most important being productivity growth. In this context, changes in relative prices are driven by productivity developments at an industry level. As agriculture has enjoyed above average productivity growth, the relative price of its products have fallen. Falling relative prices indicate that an important share of the sector's productivity gains during the 1961-2007 period was passed on to consumers.

b. 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 (Summary Table 15). 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.

Summary Table 15: Labour Productivity (GO) in the Primary Agriculture Sector, Sectoral Comparison, 1961-2007

	1961-2007	1961-2000	2000-2007
	(compound annual growth rates, per cent)		
Primary Agriculture Sector	5.11	5.41	3.43
Mining and oil and gas extraction	1.17	2.02	-3.44
Utilities	2.43	2.76	0.59
Construction	1.06	1.23	0.10
Manufacturing	2.92	3.22	1.28
Wholesale trade	2.89	2.65	4.22
Retail trade	2.57	2.61	2.34
Transportation and warehousing	2.24	2.46	1.00
Information and cultural industries	3.78	3.81	3.62
FIRE*	1.43	1.54	0.78
Professional, scientific and technical services	1.53	1.67	0.77
ASWMR**	-0.12	-0.07	-0.41
Arts, entertainment and recreation	0.50	0.70	-0.59
Accommodation and food services	0.39	0.26	1.12
Other services (except public administration)	1.63	1.77	0.89

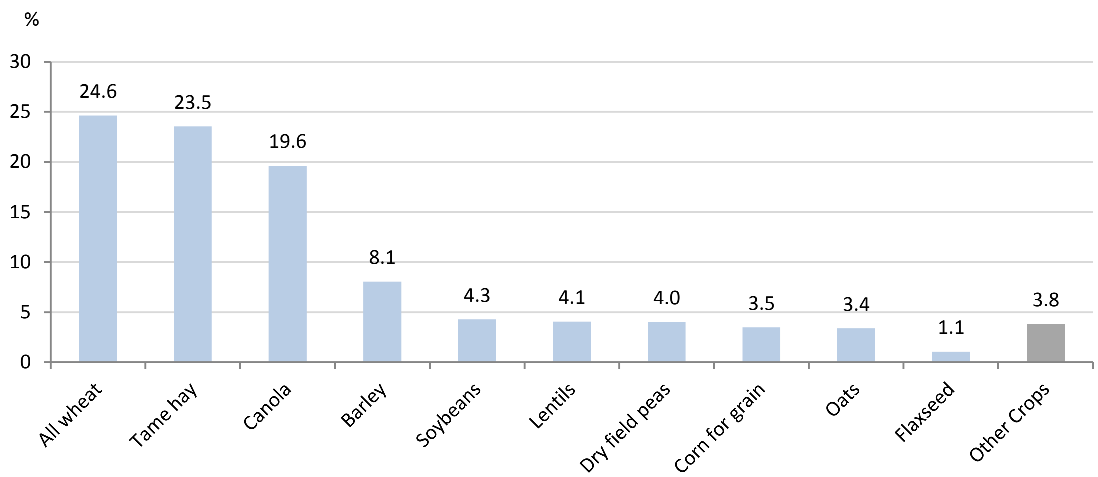
*Finance, Insurance, Real Estate, Rental and Leasing
**Administrative and Support, Waste Management and Remediation Services
Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0022).

c. Land Productivity

Crop yields, defined here as the quantity produced (in kilograms) of a certain crop per hectare of seeded area, are a measure of land productivity. In this subsection, we detail the evolution of crop yields for ten of the most important field crops in Canada during the 1961-2010 period.

In terms of seeded area, wheat, tame hay and canola are by far the most relevant field crops in Canada, representing 67.8 per cent of total seeded area for field crops in 2010 (Chart 27). These crops are followed in importance by barley (8.1 per cent of total seeded area), and soybeans (4.3 per cent).

Chart 27: Seeded Area of Principal Field Crops as a Share of Total Seeded Area for Field Crops, Canada, 2010



Source: CSLS calculations based on Statistics Canada data, Field Crop Reporting Series (CANSIM Table 10010).

During the 1961-2010 period, the crops that experienced the fastest yield growth rates were wheat (all varieties) (2.71 per cent per year), barley (2.21 per cent), and flaxseed (2.09 per cent) (Summary Table 16, Chart 28). These robust growth rates allowed, for instance, wheat crop yields to jump from 755 kg per hectare in 1961 to 2,800 kg per hectare in 2010, more than tripling in size. On the other hand, crop yields for tame hay and soybeans grew at a much slower pace during the period (0.31 and 0.66 per cent per year, respectively).

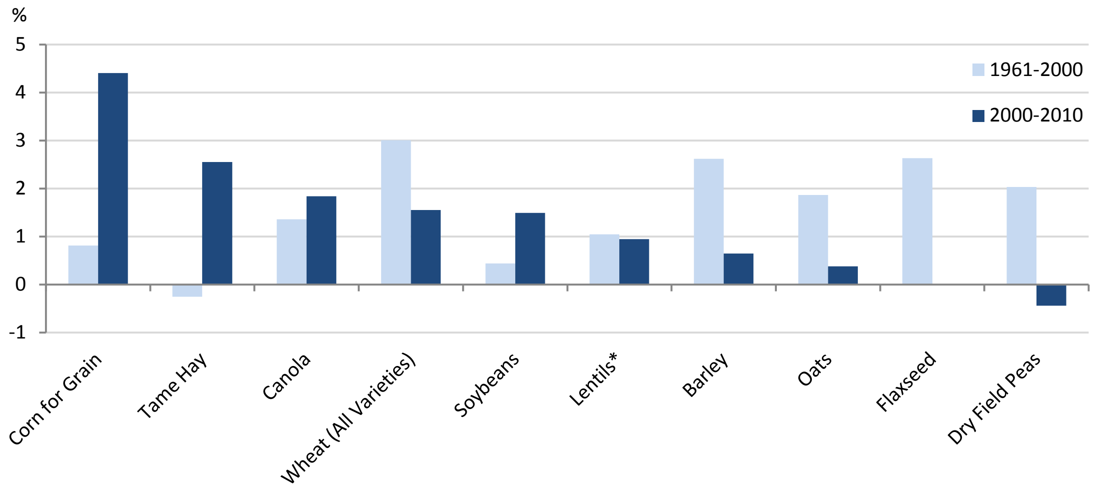
Despite its rapid growth during the overall period, crop yield growth for wheat, barley, and flaxseed experienced a considerable decline in the 2000-2010 period when compared to the 1961-2000 period. Conversely, crop yields for tame hay, canola, soybeans and corn for grain witnessed higher growth rates in the 2000-2010 period than in the 1961-2000 period.

Summary Table 16: Average Yield for Principal Field Crops in Canada, Compound Annual Growth Rates, per cent, 1961-2010

	1961-2010	1961-2000	2000-2010
	(compound annual growth rates, per cent)		
Wheat (All Varieties)	2.71	3.01	1.55
Tame Hay	0.31	-0.25	2.55
Canola	1.46	1.36	1.84
Barley	2.21	2.62	0.65
Soybeans	0.66	0.44	1.50
Lentils	..	..	0.94
Dry Field Peas	1.52	2.03	-0.44
Corn for Grain	1.54	0.82	4.41
Oats	1.56	1.86	0.38
Flaxseed	2.09	2.64	0.00
	1961	**2000**	**2010**
	(kilograms per hectare of seeded area)		
Wheat (All Varieties)	755	2,400	2,800
Tame Hay	3,810	3,450	4,440
Canola	885	1,500	1,800
Barley	1,095	3,000	3,200
Soybeans	2,105	2,500	2,900
Lentils	..	1,329	1,460
Dry Field Peas	1,050	2,300	2,200
Corn for Grain	4,590	6,300	9,700
Oats	1,265	2,600	2,700
Flaxseed	435	1,200	1,200

Source: CSLS calculations based on Statistics Canada data, Field Crop Reporting Series (CANSIM Table 10010).

Chart 28: Average Yield for Principal Field Crops in Canada, Compound Annual Growth Rates, per cent, 1961-2000 and 2000-2010



*Crop yields for lentils refer to the 1981-2000 period (light blue), and 2000-2010 period (dark blue).
Source: CSLS calculations based on Statistics Canada data, Field Crop Reporting Series (CANSIM Table 10010).

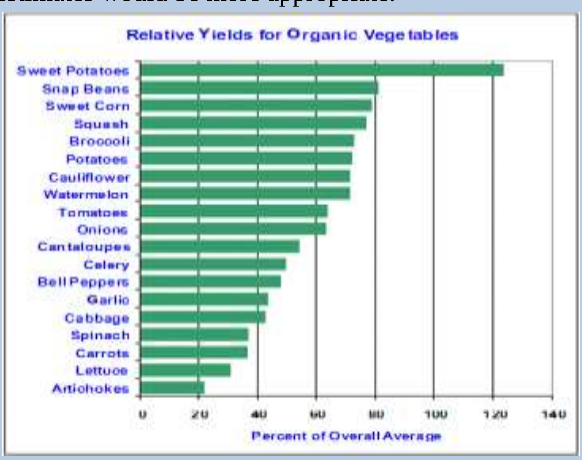
BOX 2 –The Land Productivity of Organic Agriculture

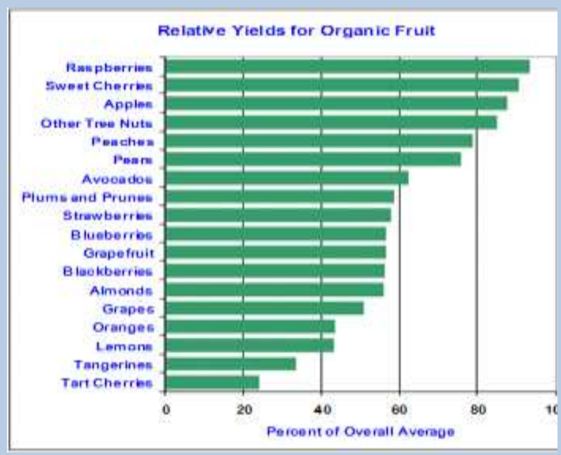
Organic agriculture has experienced impressive growth over the past decade. This growth is driven by several reasons, including: 1) health concerns over chemical, hormonal, and transgenic contamination of conventional agricultural products; 2) minimizing the environmental impact of agricultural activities; 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.

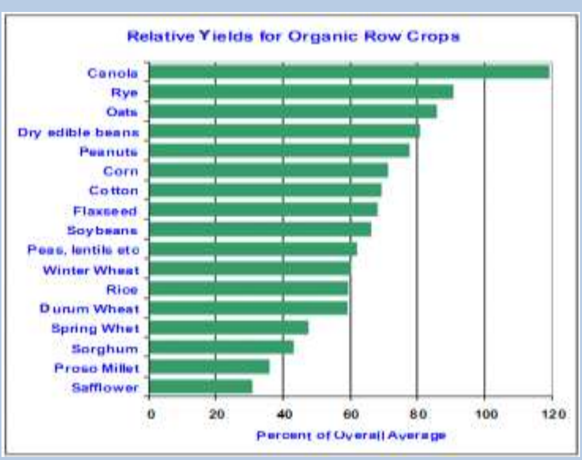
Savage (2011) compared acreage and yields of organic crops to those of “conventionally” grown crops in the United States using data from the U.S. Department of Agriculture’s 2008 Survey of Organic Agriculture, which encompassed 14,500 certified organic farms. He had two major findings: 1) In 2008, there 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.

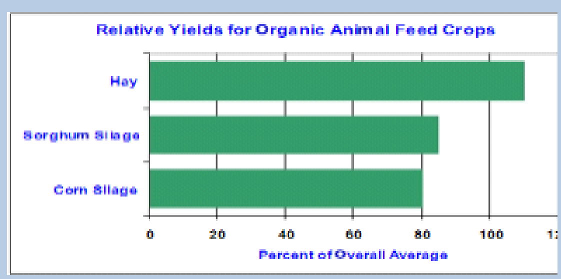
According to Savage, the overall lower yields of organic crops imply that a complete switch to organic production in the U.S. would require an additional 121.7 million acres of cropland, almost the same land area as Spain. This would represent an increase of 39 per cent in current U.S. cropland area.

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.









Source: Savage (2011)

d. Intermediate Input Productivity

Intermediate input productivity is defined as real gross output (in chained 2002 dollars) per unit of intermediate input used. This partial productivity measure can be highly informative when analyzing primary agriculture because of the prominent (and growing) role intermediate inputs play in this sector, accounting for more than 66.9 per cent of the sector's nominal gross output in 2007.

Summary Table 17 shows that overall intermediate input productivity declined at an average annual rate of 1.45 per cent during the 1961-2007 period. This is largely due to negative growth rates in the 1961-1981 period. Between 1981 and 2000, intermediate input productivity was still negative, but slowly approaching zero. In the 2000-2007 period, intermediate input productivity became slightly positive.

All three intermediate inputs categories had negative productivity growth rates in the 1961-2007 period, with energy input productivity declining by 2.69 per cent per year, services input productivity by 1.54 per cent, and material input by 1.11 per cent.

Summary Table 17: Intermediate Input Productivity in the Agriculture Sector, Canada, Compound Annual Growth Rates, per cent, 1961-2007

	1961-2007	1961-2000	1961-1981	1981-2000	2000-2007
Intermediate Inputs	-1.45	-1.72	-2.82	-0.55	0.08
Energy Input	-2.69	-3.41	-5.62	-1.04	1.41
Material Input	-1.11	-1.31	-2.27	-0.29	0.04
Services Input	-1.54	-1.74	-2.29	-1.15	-0.42

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

e. 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 (Summary Table 18, Chart 29). While MFP growth in the business sector slowed significantly in the 2000-2007, 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).

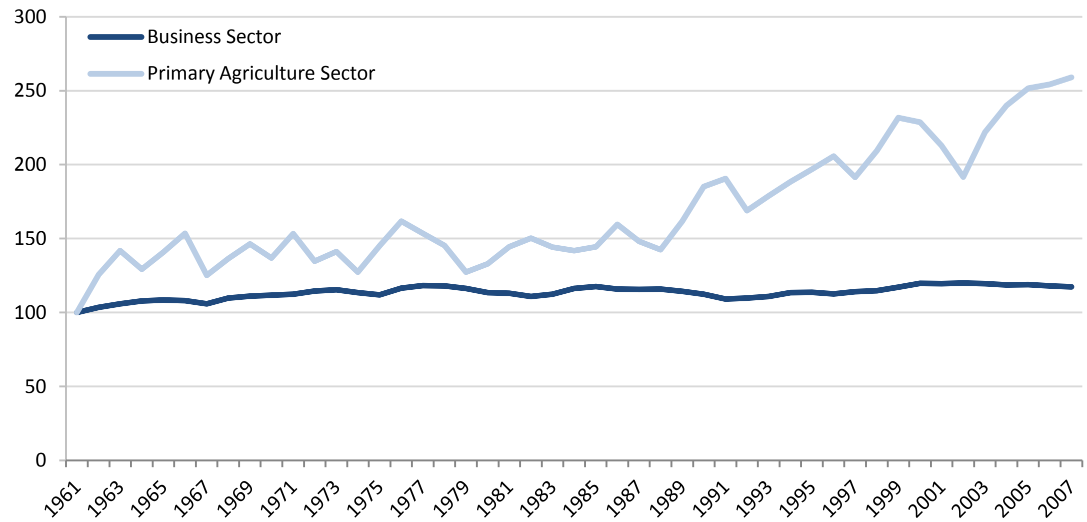
Chart 30 shows that, in terms of MFP (VA) growth, the primary agriculture sector outperformed all other sectors in the Canadian business sector during the 1961-2007 period, with information and cultural industries coming close second (2.00 per cent per year), followed by wholesale trade (1.92 per cent).

Summary Table 18: MFP (VA) Growth, Sectoral Comparison, Canada, Compound Annual Growth Rates, per cent, 1961-2007

	1961-2007	1961-2000	2000-2007
Business Sector	0.35	0.46	-0.30
Primary Agriculture Sector	2.09	2.14	1.79
Mining and oil and gas extraction	-1.91	-1.21	-5.71
Utilities	1.06	1.11	0.78
Construction	0.23	0.38	-0.58
Manufacturing	1.59	1.93	-0.27
Wholesale trade	1.92	1.85	2.29
Retail trade	1.61	1.59	1.77
Transportation and warehousing	1.30	1.61	-0.42
Information and cultural industries	2.00	1.88	2.67
Finance, insurance, real estate and renting and leasing	-1.18	-1.47	0.41
Professional, scientific and technical services	-2.21	-2.59	-0.06
Other services (except public administration)	-1.63	-1.82	-0.54

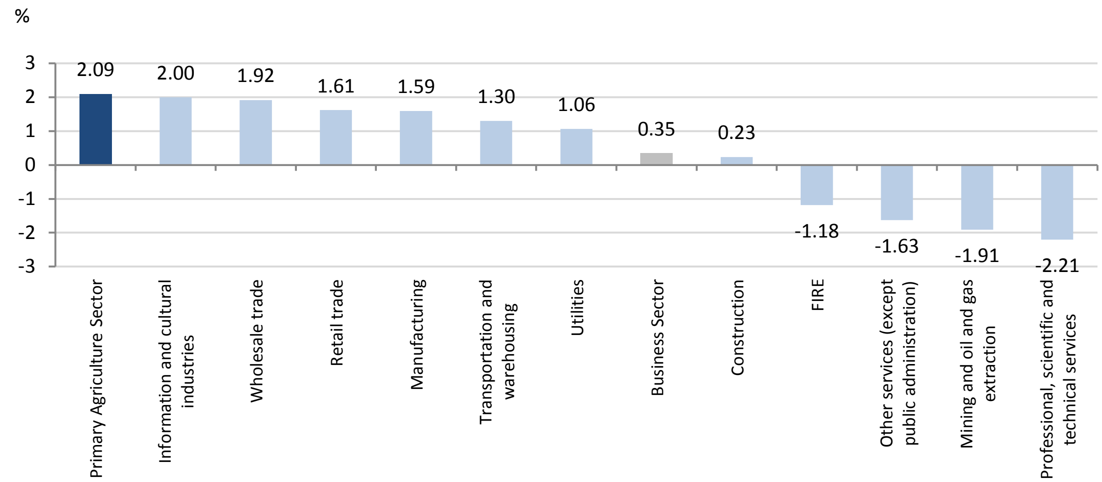
Source: CSLS Calculations based on Statistics Canada data (CANSIM Tables 383-0021, and 383-0022).

Chart 29: MFP (VA) in the Primary Agriculture Sector, Canada, Index 1961=100, 1961-2007



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

Chart 30: MFP (VA) Growth, Sectoral Comparison, Compound Annual Growth Rates, per cent, 1961-2007



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

f. 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 (Summary Table 19). 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 input aggregate to grow faster than the VA input aggregate.

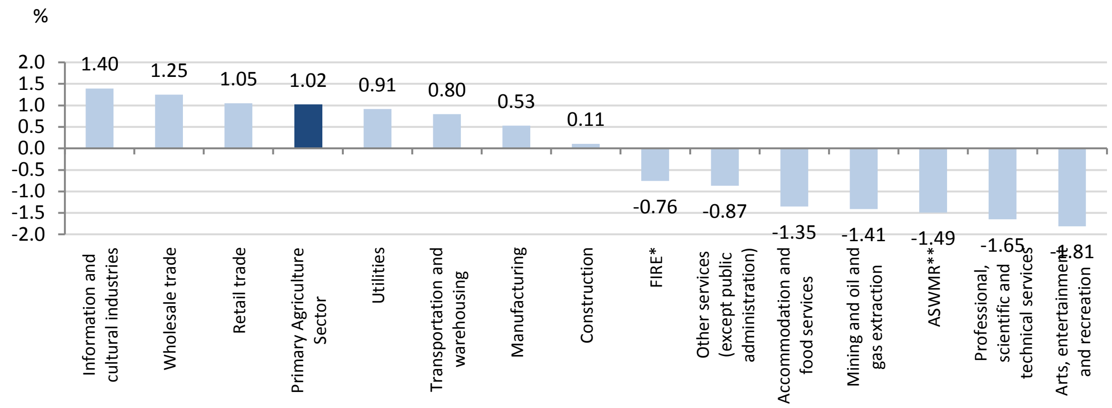
Summary Table 19: Multifactor Productivity (GO), Sectoral Comparison, Canada, Compound Annual Growth Rates, per cent, 1961-2007

	1961-2007	1961-2000	2000-2007
	(compound annual growth rates, per cent)		
Primary Agriculture Sector	1.02	1.09	0.61
Mining and oil and gas extraction	-1.41	-0.93	-4.05
Utilities	0.91	0.92	0.90
Construction	0.11	0.18	-0.28
Manufacturing	0.53	0.65	-0.10
Wholesale trade	1.25	1.24	1.33
Retail trade	1.05	1.07	0.91
Transportation and warehousing	0.80	0.99	-0.26
Information and cultural industries	1.40	1.38	1.47
FIRE*	-0.76	-0.92	0.17
Professional, scientific and technical services	-1.65	-1.92	-0.10
ASWMR**	-1.49	-1.71	-0.26
Arts, entertainment and recreation	-1.81	-2.02	-0.63
Accommodation and food services	-1.35	-1.63	0.26
Other services (except public administration)	-0.87	-1.07	0.29

*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).

As Chart 31 shows, 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 slightly faster: information and cultural industries (1.40 per cent per year), wholesale trade (1.25 per cent), and retail trade (1.05 per cent).

Chart 31: Multifactor Productivity (GO), Sectoral Comparison, Compound Annual Growth Rates, per cent, 1961-2007



*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).

BOX 2 – 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).

B. Productivity Trends in the Primary Agriculture Sector by Province

This section examines productivity trends in the primary agriculture sector by province. Unfortunately, **gross output (GO)** productivity data at the provincial level were not available, so only **value added (VA)** productivity measures are analyzed. In general, data at the provincial level do not span as long a period as data at the national level. Official nominal GDP figures for the provinces' primary agriculture sector are available from 1984-2007, and productivity data spans the 1997-2009 period. For consistency, the discussion in this section centers on the 1997-2007 period.

i. Overview of the Provinces' Primary Agriculture Sector

In this subsection, we give a quick overview of the primary agriculture sector in each of the provinces, showing their relative importance in terms of both agricultural land area and nominal GDP.

Agricultural land area is heavily concentrated in the Prairie Provinces. In 2006, Saskatchewan, Alberta, and Manitoba accounted for 81.1 per cent of total agricultural land in Canada (Summary Table 20). Ontario, Quebec, and British Columbia had smaller, although still significant, shares of the total agricultural land (8.0, 5.1, and 4.2 per cent, respectively), while Atlantic Canada played a marginal role in primary agriculture, accounting for only 1.6 per cent of total agricultural land.

The importance of the primary agriculture sector in terms of nominal GDP varied considerably across provinces in 2007. According to this measure, Ontario had the largest agriculture sector in Canada, accounting for 22.5 per cent of the sector's national GDP. This province was followed closely by Quebec (20.4 per cent), Alberta (19.2 per cent), Saskatchewan (16.8 per cent), and Manitoba (9.8 per cent), while British Columbia and the Atlantic provinces were less significant (7.0 per cent and 4.3 per cent, respectively).

Note that the importance of each province changes significantly whether we use the first criterion (share of agricultural land area), or the second one (nominal GDP). The Prairie Provinces accounted for more than 80 per cent of total agricultural land in Canada, but represented only 45.8 per cent of nominal GDP in the Canadian primary agriculture sector. Quebec and Ontario, on the other hand, were responsible for 42.9 per cent of nominal GDP in primary agriculture, while having only 13.1 per cent of total agricultural land. The main reason for this divergence between the two criteria is the different composition of each of the provinces' agriculture sector (with some commodities contributing more to GDP than others). However, both criteria make it clear that five provinces account for most of the Canadian agricultural sector production: Ontario, Quebec, Alberta, Saskatchewan, and Manitoba.

Summary Table 20: The Primary Agriculture Sector by Province

	Primary Agriculture Sector		
	Nominal GDP, 2007 (millions of current dollars)	Hours Worked for All Jobs, 2007 (millions)	Agricultural Land Area, 2006 (thousand hectares)
Canada	15,790	660	67,586,741
NL	54	3	36,195
PE	191	9	250,859
NS	215	12	403,044
NB	220	11	395,228
QC	3,225	108	3,462,935
ON	3,550	194	5,386,453
MB	1,548	66	7,718,570
SK	2,653	98	26,002,605
AB	3,029	101	21,095,393
BC	1,113	58	2,835,458
	(as a share of Canada)		
Canada	100.0	100.0	100.0
NL	0.3	0.4	0.1
PE	1.2	1.3	0.4
NS	1.4	1.9	0.6
NB	1.4	1.7	0.6
QC	20.4	16.3	5.1
ON	22.5	29.3	8.0
MB	9.8	10.1	11.4
SK	16.8	14.9	38.5
AB	19.2	15.2	31.2
BC	7.1	8.8	4.2

Note: Provincial shares may not add up to 100.0 due to rounding.
Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 381-0015, and 153-0039).

iii. Labour Productivity (VA)

Overall, labour productivity in the provinces' primary agriculture sector observed robust growth rates during the 1997-2007 period (Summary Table 21). In particular, labour productivity in Alberta's primary agriculture grew at an average annual rate of 7.99 per cent, followed by New Brunswick (7.10 per cent), and Manitoba (5.59 per cent). Labour productivity in Ontario's and Quebec's agriculture sector grew at slower rates (4.10 and 3.14 per cent per year, respectively), but still significantly above the average labour productivity growth experienced by the Canadian economy during the period (1.66 per cent per year). Only Prince Edward Island's primary agriculture sector observed poor labour productivity growth in the 1997-2007 period (0.31 per cent per year).

Labour productivity levels in primary agriculture varied widely by province. One important reason behind this variation was the overall composition of the provinces' primary agriculture sector. The data seems to indicate, for instance, that labour productivity levels in crop production are considerably higher than in animal production. Thus, provinces where the crop production subsector played a large role in the overall primary agriculture sector, such as Saskatchewan and Alberta, tended to have higher labour productivity levels. Of course, it is important to keep in mind that even within each subsector there is considerable variation of labour productivity levels depending on the commodity produced.

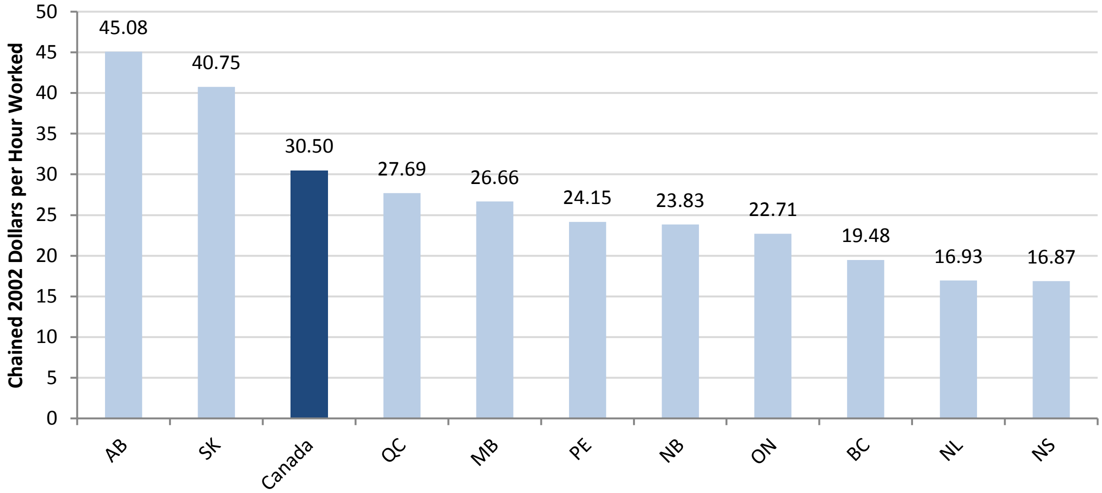
Summary Table 21: Labour Productivity (VA) in the Primary Agriculture Sector by Province, 1997-2007

	1997-2007	1997-2000	2000-2007
	(compound annual growth rates, per cent)		
Canada	5.60	10.37	3.62
NL	2.11	3.78	1.41
PE	0.31	-2.53	1.56
NS	4.22	14.88	-0.04
NB	7.10	19.62	2.15
QC	3.14	3.14	3.14
ON	4.10	10.97	1.29
MB	5.59	19.25	0.23
SK	4.96	10.17	2.81
AB	7.99	13.95	5.53
BC	1.73	-0.06	2.50
	1997	**2000**	**2007**
	(chained 2002 dollars per hour worked)		
Canada	17.69	23.78	30.50
NL	13.74	15.36	16.93
PE	23.41	21.68	24.15
NS	11.16	16.91	16.87
NB	12.00	20.53	23.83
QC	20.33	22.31	27.69
ON	15.19	20.76	22.71
MB	15.47	26.23	26.66
SK	25.11	33.57	40.75
AB	20.90	30.93	45.08
BC	16.41	16.38	19.48

Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 379-0025, and 383-0010).

In 2007, the province that had by far the highest labour productivity level in its primary agriculture sector was Alberta, $45.08 per hour, followed by Saskatchewan ($40.75 per hour), Quebec ($27.69 per hour), and Manitoba ($26.66 per hour) (Chart 32). Agricultural labour productivity levels in Prince Edward Island, New Brunswick, and Ontario were somewhat lower ($24.15 per hour, $23.83 per hour, and $22.71 per hour, respectively), but still well above the levels in British Columbia ($19.48 per hour), Newfoundland and Labrador ($16.93 per hour), and Nova Scotia ($16.87 per hour).

Chart 32: Labour Productivity (VA) Level in the Primary Agriculture Sector by Province, 2007



Source: Statistics Canada (CANSIM Table 383-0011).

IV. International Comparison of Productivity Trends in the Primary Agriculture Sector

This part of the report examines productivity trends in the primary agriculture sector from an international perspective. First, the productivity performance of the United States is compared to that of Canada; next data on countries that are members of the Organisation for Economic Co-operation and Development (OECD) are examined.

A. The United States

In this section, we compare the productivity performance of the primary agriculture sector in Canada to that of the United States, analyzing long-term trends in agricultural output, input use, and productivity for both countries.

The U.S. Department of Agriculture's Economic Research Service (ERS) provides detailed productivity data for the U.S. agriculture sector from 1948 to 2008. Since the data from Statistics Canada's Canadian Productivity Accounts (CPA) span a slightly shorter timeframe, we focus on the 1961-2007 period. The ERS provides indexes for gross output, inputs (labour, capital, and intermediate inputs), and MFP computed using a **gross output approach (GO)**. Although the ERS does not provide figures for partial productivity measures, they can be calculated using the ERS' indexes, as well as hours worked data from the United States' Bureau of Labor Statistics (BLS).[25] It should be noted that the ERS does not calculate **value added (VA)** productivity measures. This is not, however, a major limitation. As we have seen in Section I-B, the agricultural productivity literature favours the use of gross output productivity measures when comparing the productivity performance of different countries because of the importance of intermediate inputs in agricultural production.

The output, input and productivity aggregates calculated by the ERS use the methodology described in Ball *et al.* (1997), while Statistics Canada's methodology is summarized in Baldwin *et al.* (2007). The different methodologies and treatment of measurement issues might explain why the gross output and intermediate input growth rates for the two countries are so different (Summary Table 22), which seems unreasonable to expect, at least in a longer time frame such as the 1961-2007 period. The upside of using the official numbers, however, is that the input aggregates are adjusted for changes in quality, and the construction of quality adjusted input series is far from trivial. A quality adjusted input aggregate is necessary for good quality MFP measures, as the use of an non-quality adjusted input aggregate to calculate MFP would bias productivity growth due to mismeasurement issues.

[25] Although the ERS calculates an index for labour input, this index refers to quality adjusted hours worked, and thus cannot be used to compute labour productivity.

During the 1961-2007 period, labour productivity (GO) in Canada grew considerably faster than in the United States, 5.11 versus 3.48 per cent per year. Since total hours worked in the sector declined at practically the same pace in both countries during the period (-1.90 versus -1.84 per cent per year) (Summary Table 22, Chart 33), the difference in labour productivity growth was mainly due to a more robust growth in the gross output of the Canadian agriculture sector, 3.11 per cent year, roughly double the rate experienced by the United States agriculture, 1.58 per cent per year.

Summary Table 22: Output, Input, and Productivity Growth in the Primary Agriculture Sector, Canada and United States Comparison, Compound Annual Growth Rates, per cent, 1961-2007[26]

	1961-2007		1961-2000		2000-2007	
	CAN	US	CAN	US	CAN	US
Gross Output	3.11	1.58	3.42	1.71	1.41	0.85
Capital	0.89	-0.46	0.98	-0.52	0.36	-0.16
Hours Worked	-1.90	-1.84	-1.89	-1.75	-1.95	-2.32
Intermediate Inputs	4.63	1.18	5.23	1.23	1.33	0.88
Labour Productivity	5.11	3.48	5.42	3.52	3.42	3.25
Intermediate Input Productivity	-1.45	0.39	-1.72	0.47	0.08	-0.02
MFP	1.02	1.53	1.09	1.68	0.61	0.72

Source: CSLS calculations based on Statistics Canada data (CANSIM Table 383-0022), and USDA-ERS data (http://www.ers.usda.gov/Data/AgProductivity/).

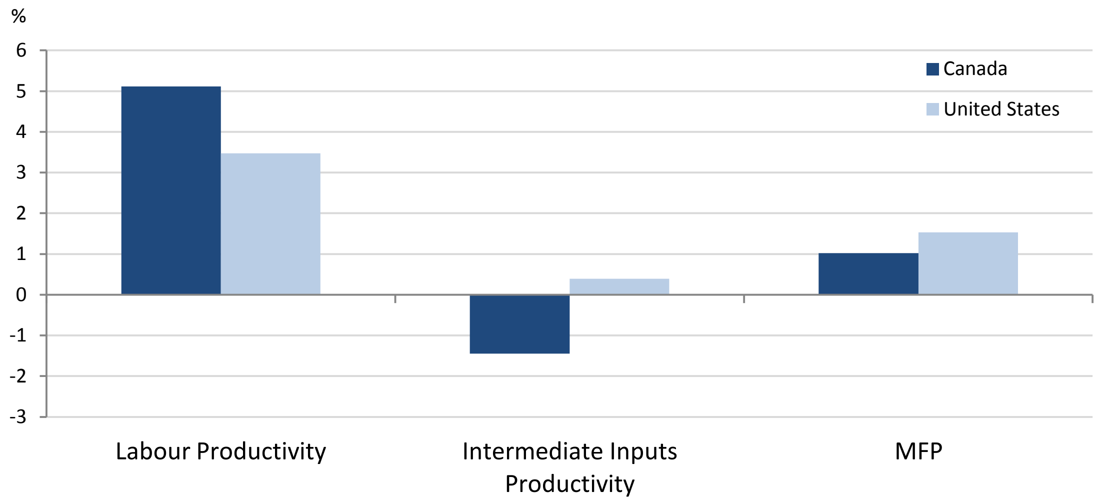
The primary agriculture sector in the United States outperformed Canada's in terms of intermediate input productivity (0.39 versus -1.45 per cent per year). One major difference between primary agriculture in the two countries refers to intermediate input use. While in Canada intermediate input use in the sector grew by 4.63 per cent per year, in the United States it expanded by only 1.18 per cent per year. This difference may be overstated by differences in the methodologies used to calculate intermediate input aggregates in each country, which, in turn, have an effect in gross output growth.

Finally, the primary agriculture sector in the United States also outpaced Canada's in terms of MFP (GO) growth during the overall period, 1.53 versus 1.02 per cent per year. The agriculture sector in both countries saw a strong deceleration in MFP growth in the 2000-2007

[26] The figures shown for the Canadian primary agriculture sector in Summary Table 22 are significantly different from the ones in AAFC (2011). The growth rates in Summary Table 22 were calculated by the CSLS based on data from Statistics Canada, while AAFC (2011) used their own estimates. In particular, the following differences should be highlighted: 1) According to Statistics Canada's numbers, gross output in the agriculture sector grew by 3.2 per cent per year during the 1961-2005 period, well above the growth rate in AAFC (2011), 2.2 per cent per year; 2) Statistics Canada's estimates for intermediate input use in the agriculture sector give an average annual growth rate of 4.8 per cent in the 1961-2005 period, again substantially above the AAFC's estimate of 2.7 per cent per year; 3) Finally, MFP (GO) in this report is 1.0 per cent per year in 1961-2005, less than AAFC's estimate of 1.4 per cent per year. AAFC's estimates use the methodology described in Ball *et al.* (1997), which is also used by the ERS. The only difference is that, while the ERS uses quality adjusted input estimates for the agricultural sector in the United States, AAFC quality adjusts only some of their inputs.

period (more so in the United States), with agricultural MFP in Canada growing only slightly slower than that of the United States (0.61 versus 0.72 per cent per year).

Chart 33: Productivity (GO) Growth in the Primary Agriculture Sector, Canada and United States Comparison, Compound Annual Growth Rates, per cent, 1961-2007



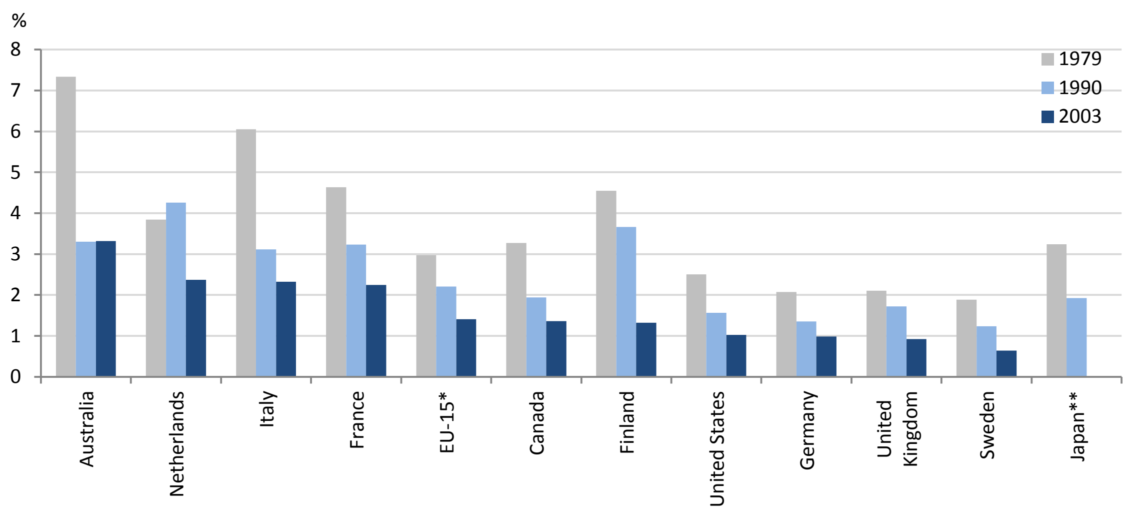
Source: Source : CSLS calculations based on Statistics Canada data (CANSIM Table 383-0022), and USDA-ERS data (http://www.ers.usda.gov/Data/AgProductivity/).

B. OECD Countries

This section compares the productivity performance of the primary agriculture sector in Canada to that of other developed countries. It uses the Groningen Growth and Development Centre's (GGDC) 60-Industry Database, which covers the 1979-2003 period, and has labour productivity data calculated on a **value added basis (VA)** for more than 25 countries.

In 2003, the primary agriculture sector in Canada was responsible for 1.4 per cent of total economy GDP, slightly more than in Finland (1.3 per cent) and the United States (1.0 per cent), but significantly less than in the Netherlands (2.4 per cent) and Australia (3.3 per cent). As can be seen in Chart 34, the relative importance of the primary agriculture sector in Canada has been consistently declining over the years. In 1979, it represented 3.3 per cent of total economy GDP, more than twice its relative size in 2003. Not surprisingly, this downward trend in the relative importance of the agriculture sector is widespread among developed countries. The speed at which this process occurs, however, varies widely. In Australia and Italy, for example, the share of the agriculture sector in total economy GDP experienced huge drops of more than 3 percentage points in only one decade, while Germany, the United Kingdom, and the United States experienced more gradual declines.

Chart 34: Nominal GDP in the Primary Agriculture Sector as a Share of the Total Economy, Selected OECD Countries, 1979, 1990, and 2003



*EU-15 includes the following countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal, Spain, Sweden and the United Kingdom.
**Nominal GDP data for Japan's primary agriculture sector was not available for 2003.
Source: Data for Canada from Statistics Canada (CANSIM Tables 379-0023 and 379-0024); data for all other countries from the Groningen Growth and Development Centre, 60-Industry Database, September 2006, http://www.ggdc.net.

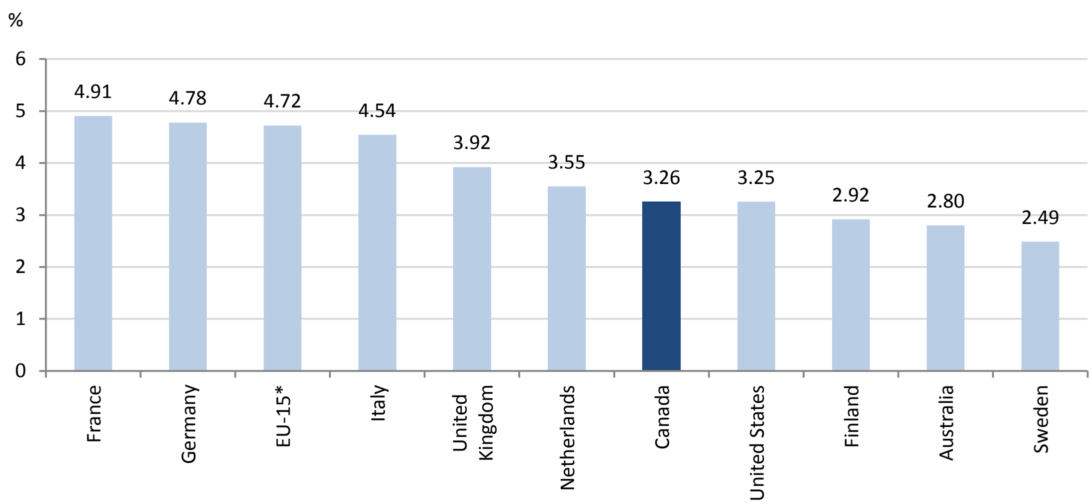
In comparison to other OECD countries, Canada experienced average labour productivity (VA) growth in the primary agriculture sector during the 1979-2003 period (Summary Table 23, Chart 35). During this period, labour productivity in the agriculture sector increased at an average annual rate of 3.26 per cent in Canada, practically the same rate observed in the United States (3.25 per cent) and higher than the rates experienced in Sweden, Australia, and Finland (2.49, 2.80, and 2.92 per cent, respectively). However, France's, Germany's, and Italy's primary agriculture sector grew at rates significantly higher (4.91, 4.78, and 4.54 per cent per year), while in the Netherlands and the United Kingdom productivity growth was only slightly above Canada's (3.55 and 3.92 per cent per year).

Summary Table 23: Labour Productivity (VA) Growth in the Primary Agriculture Sector, Selected OECD Countries, Compound Annual Growth Rates, per cent, 1979-2003

	1979-2003	1979-1989	1989-2003
Canada	3.26	2.11	4.08
Australia	2.80	1.54	3.70
Finland	2.92	2.16	3.46
France	4.91	4.91	4.91
Germany	4.78	5.71	4.12
Italy	4.54	5.14	4.12
Japan	n.a.	3.83	n.a.
Netherlands	3.55	3.03	3.93
Sweden	2.49	3.73	1.60
United Kingdom	3.92	3.26	4.40
United States	3.25	4.86	2.12
EU-15	4.72	5.31	4.30

*EU-15 includes the following countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal, Spain, Sweden and the United Kingdom.
Source: Data for Canada from Statistics Canada (CANSIM Table 383-0022); data for all other countries from the Groningen Growth and Development Centre, 60-Industry Database, September 2006, http://www.ggdc.net.

Chart 35: Labour Productivity (VA) Growth in the Agriculture Sector, Selected OECD Countries, Compound Annual Growth Rates, per cent, 1979-2003



*EU-15 includes the following countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal, Spain, Sweden and the United Kingdom.
Source: Data for Canada from Statistics Canada (CANSIM Table 383-0022); data for all other countries from the Groningen Growth and Development Centre, 60-Industry Database, September 2006, http://www.ggdc.net.

V. Factors Influencing Productivity in the Primary Agriculture Sector

Parts III and IV described in detail the productivity performance of the Canadian primary agriculture sector over the past 50 years, and how it compares to the performance of the agriculture sectors of other countries. While highly informative, these sections also raised important questions as to what exactly drives productivity improvements in primary agriculture. The goal of this part of the report is to identify the sources and drivers of labour productivity growth in the sector, and discuss their relative importance, which can have serious implications for policy-making.

This part of the report is organized as follows: first, we use the standard neo-classical growth accounting framework to estimate the contributions of capital intensity, intermediate input intensity (in the case of gross output based labour productivity), labour quality, and MFP growth to labour productivity growth at the national level; next, we list and discuss the drivers of agricultural productivity that have been identified by the literature so far and evaluate their role in the Canadian primary agriculture sector.

A. Sources of Labour Productivity Growth

In this section, we use the standard neo-classical growth accounting framework to estimate the contributions of different factors to labour productivity growth. The section is divided into two subsections. In the first one, the growth accounting exercise uses a **value added (VA)** labour productivity measure, while in the second one it uses a **gross output (GO)** labour productivity measure.

i. Labour Productivity (VA) Growth Decomposition

The framework used in this subsection is the same as the one used in Sharpe and Thomson (2010a). It assumes a Cobb-Douglas production function such that:

$$Y = AK^{\alpha}L^{1-\alpha}$$

where Y is real GDP, K stands for capital services, L for labour input (quality adjusted hours), A for multifactor productivity and α is the share of GDP that takes the form of capital compensation.

Using this framework, contributions to labour productivity (VA) growth can be broken down into three factors: 1) capital intensity (defined here as capital services input per hour worked); 2) labour quality; and 3) multifactor productivity (VA).[27] Formally, this decomposition

[27] To understand the reasons behind this decomposition, refer to Appendix 3.

is a consequence of the growth accounting framework adopted in this report. However, it is also quite intuitive:

- Workers that have access to more capital (i.e. higher capital intensity) tend to have, ceteris paribus, higher labour productivity. Imagine, for example, two teams with the same number of workers each. The first team has access to only one combine harvester, while the second has access to two. The second team uses capital more intensively than the first, and thus is able to harvest more crops in the same period of time.

- Improvements in labour quality tend to increase the amount of output a worker can produce in a given time period. Labour quality refers not only to formal training, but also to how experienced a worker is. In this sense, an experienced farmer will normally be able to produce more in an hour of work than a novice farmer.

- Technological progress can substantially increase output per worker. This can be seen, for instance, in the effect of disembodied technological change in the production process. Organizational changes can affect how efficiently firms use labour, capital, and other inputs, leading to stronger productivity growth.

Labour productivity (VA) in the Canadian agriculture sector grew at an average annual rate of 3.77 per cent during the 1961-2007 period, significantly above the business sector average of 2.07 per cent per year (Summary Table 24, Chart 36).

During the overall period, the primary agriculture sector's labour productivity (VA) growth was driven almost entirely by MFP (VA) and capital intensity growth, which were responsible for 2.09 and 1.51 percentage points of the overall labour productivity growth (or 55.5 and 40.2 per cent, respectively). The rest of labour productivity (VA) growth was driven by increases in labour quality.[28]

The picture in the business sector was quite different. First, labour productivity (VA) in the Canadian business sector increased at a slower rate than in the primary agriculture sector, 2.07 per cent per year during the 1961-2007 period. Second, most of this growth came from increases in capital intensity, which accounted for 62.6 per cent of total labour productivity (VA) growth. Labour quality growth also played a very relevant role, accounting for 20.8 per cent of total growth, significantly more than its role in primary agriculture. The contribution of MFP (VA) growth to labour productivity (VA) growth in the business sector was only 16.8, while it played a major role in primary agriculture.

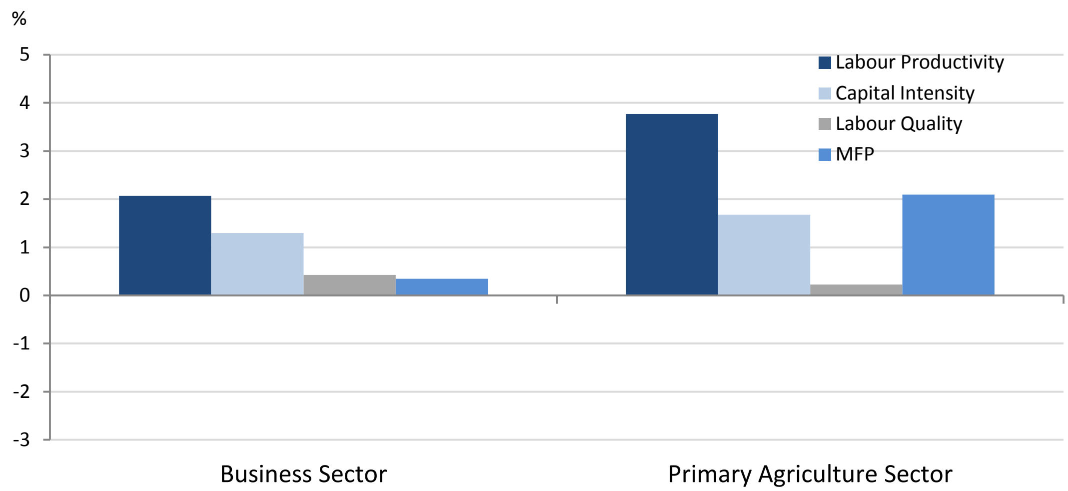
[28] The relatively low contribution of labour quality growth to labour productivity growth in primary agriculture is due in part to the fact that the labour compensation share in the sector has declined consistently over the past 50 years. In 2006, for instance, it reached 34.7 per cent of the sector's nominal GDP, significantly less than in the business sector, where it accounted for 56.8 per cent.

Summary Table 24: Sources of Labour Productivity (VA) Growth in the Primary Agriculture Sector, Canada, 1961-2007

	1961-2007	1961-2000	2000-2007
	Compound Annual Growth Rates, per cent		
Business Sector			
Labour Productivity	2.07	2.24	1.07
Capital Intensity	3.29	3.42	2.54
Labour Quality	0.71	0.74	0.54
MFP	0.35	0.46	-0.30
Agriculture Sector			
Labour Productivity	3.77	3.79	3.62
Capital Intensity	2.84	2.93	2.34
Labour Quality	0.55	0.53	0.69
MFP	2.09	2.14	1.79
	Average Cost Shares, per cent of nominal GDP		
Business Sector			
Capital	39.7	39.1	42.9
Labour	60.3	60.9	57.1
Agriculture Sector			
Capital	60.0	58.8	66.2
Labour	40.0	41.2	33.8
	Contribution to Labour Productivity Growth, Percentage Points		
Business Sector			
Labour Productivity	2.07	2.24	1.07
Capital Intensity	1.29	1.33	1.10
Labour Quality	0.43	0.45	0.31
MFP	0.35	0.46	-0.30
Agriculture Sector			
Labour Productivity	3.77	3.79	3.62
Capital Intensity	1.51	1.50	1.58
Labour Quality	0.21	0.20	0.25
MFP	2.09	2.14	1.79
	Contribution to Labour Productivity Growth, Per Cent		
Business Sector			
Labour Productivity	100.0	100.0	100.0
Capital Intensity	62.6	59.1	102.0
Labour Quality	20.8	20.1	28.9
MFP	16.8	20.7	-28.3
Agriculture Sector			
Labour Productivity	100.0	100.0	100.0
Capital Intensity	40.2	39.6	43.5
Labour Quality	5.5	5.3	6.8
MFP	55.5	56.5	49.5

Note: Sum of contributions may be slightly different than total labour productivity growth due to rounding.
Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0021, and 383-0022).

Chart 36: Sources of Labour Productivity (VA) Growth in the Primary Agriculture Sector, percentage points, 1961-2007



Note: Sum of contributions may be slightly different than total labour productivity growth due to rounding.
Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0021, and 383-0022).

ii. Labour Productivity (GO) Growth Decomposition

To deal with labour productivity (GO), a small change is made to the model used in the previous subsection, such that:

$$Y = AK^{\alpha}I^{\beta}L^{1-\alpha-\beta}$$

where Y is real gross output, K stands for capital services, I for intermediate inputs, L for labour input (quality adjusted hours), A for multifactor productivity, α is the share of output that takes the form of capital compensation, and β is the share of intermediate input costs in total gross output.

Using this framework, contributions to labour productivity (GO) growth can be broken down into four factors: 1) capital intensity (defined here as capital services input per hour worked); 2) intermediate input intensity (defined here as intermediate input per hour worked); 3) labour quality; and 4) multifactor productivity (GO).[29]

Labour productivity (GO) in the Canadian agriculture sector grew at an average annual rate of 5.11 per cent during the 1961-2007 (Summary Table 25, Chart 37). It was driven mainly by intermediate input intensity, which was responsible for 3.14 percentage points of the overall labour productivity growth (or 61.5 per cent of the total). In fact, as we have seen in Part III, intermediate input use in Canadian primary agriculture increased at an average annual rate of

[29] This decomposition is analogous to the labour productivity (VA) growth decomposition explained in Appendix 3.

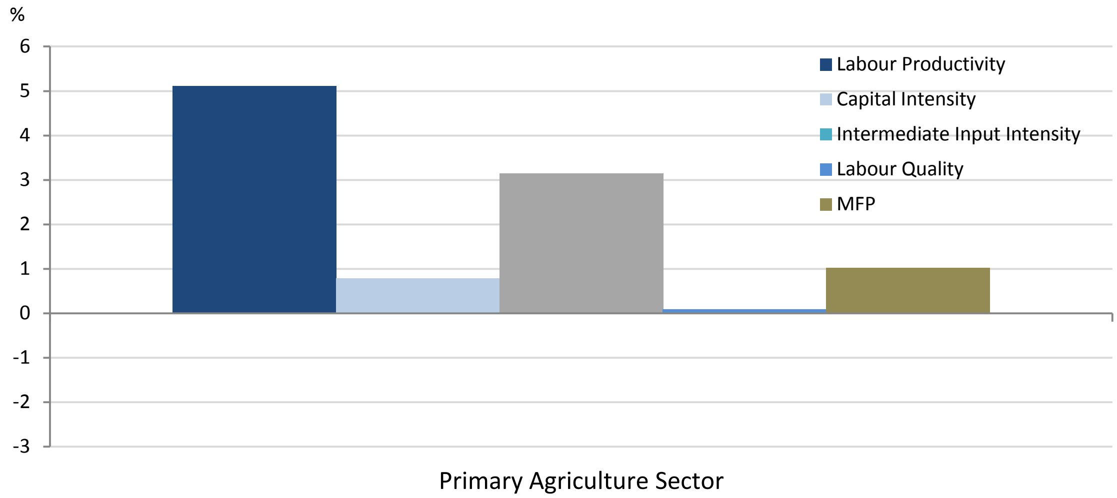
4.63 per cent during the 1961-2007 period. Coupled with the steep decline of 1.90 per cent per year in the sector's total hours worked, this implies an increase of intermediate input intensity of 6.65 per cent per year. The other sources of labour productivity (GO) growth were: MFP (GO) growth, which accounted for 1.02 percentage points of total growth (20.0 per cent of the total), capital intensity growth, responsible for 0.79 percentage points (15.5 per cent), and labour quality growth, which had a negligible contribution to total growth.

Summary Table 25: Sources of Labour Productivity (GO) Growth in the Primary Agriculture Sector, Canada, 1961-2007

	1961-2007	1961-2000	2000-2007
	Compound Annual Growth Rates, per cent		
Labour Productivity	5.11	5.42	3.42
Capital Intensity	2.84	2.93	2.35
Intermediate Input Intensity	6.65	7.26	3.34
Labour Quality	0.55	0.53	0.69
MFP	1.02	1.09	0.61
	Average Cost Shares, per cent of GDP		
Capital	27.46	28.24	23.14
Intermediate Inputs	51.53	49.12	65.07
Labour	21.01	22.64	11.79
	Contribution to Labour Productivity Growth, Percentage Points		
Labour Productivity	5.11	5.42	3.42
Capital Intensity	0.79	0.83	0.56
Intermediate Input Intensity	3.14	3.33	2.15
Labour Quality	0.09	0.09	0.09
MFP	1.02	1.09	0.61
	Contribution to Labour Productivity Growth, Per Cent		
Labour Productivity	100.0	100.0	100.0
Capital Intensity	15.4	15.3	16.3
Intermediate Input Intensity	61.5	61.4	62.7
Labour Quality	1.7	1.7	2.5
MFP	19.9	20.2	17.7

Note: Sum of contributions may be slightly different than total labour productivity growth due to rounding.
Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0021, and 383-0022).

Chart 37: Sources of Labour Productivity (GO) Growth in the Primary Agriculture Sector, percentage points, 1961-2007



Note: Sum of contributions may be slightly different than total labour productivity growth due to rounding.
Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 383-0021, and 383-0022).

B. Drivers of Productivity Growth

The growth accounting exercises in the previous section allowed us to decompose labour productivity growth into its sources using the neo-classical framework. These sources are *proximate determinants* of productivity growth. They are, usually, determined by several underlying factors, which are the *fundamental determinants* and real drivers behind labour productivity growth. In this section, we review the drivers of agricultural productivity that have been identified by the literature so far, and evaluate their role in the Canadian primary agriculture sector. This can help shed light into the sector's exceptional productivity performance during the 1961-2007 period, as well as help identify areas for improvement, and possible barriers to productivity growth.

The drivers discussed in this section include: research and development (R&D), education and quality of labour, investment in physical capital, use of fertilizers and pesticides, scale effects, international trade, among others. There is a subsection devoted to each of the main drivers. Each subsection opens with a short summary table that highlights: 1) the **main channels** through which this particular driver affects labour productivity growth, where the four possible channels are, according to the growth accounting framework used in the previous section, capital intensity, intermediate input intensity, labour quality, and MFP growth; 2) and the **key facts** related to that driver.

i. Research and Development (R&D)

Channels	Affects labour productivity growth mainly through MFP growth.
Key Facts	- Even though agricultural R&D intensity in Canada (defined here as BERD divided by nominal GDP in the agriculture sector) has increased consistently since mid-1990s, reaching 0.6 per cent of the sector's nominal GDP in 2007, it is still substantially below R&D intensity in the business sector, 1.5 per cent. - Agricultural BERD, however, represents only a small part of total agricultural R&D. During the 2002-2008 period, federal intramural expenditures on agricultural R&D averaged $313 million, almost four times the average agricultural BERD of $84 million. - Federal expenditures in science and technology for the agriculture sector averaged $554 million over the 2002-2008 period, 75 per cent of which were spent in R&D. - Federal spending on agricultural R&D represented roughly 7 per cent of total federal expenditures on R&D in the 2002-2008 period. It increased at an average annual rate of 4.29 per cent during the period, less than the growth rate experienced by total federal R&D spending, 5.14 per cent.

Innovations take place in the primary agriculture sector through two key channels: either the sector performs R&D itself, or it adopts innovations from other countries and other sectors. The adoption of innovations can occur through imports of machinery and equipment, skilled personnel, new productive processes, and product innovations.

Technical change and increases in technical efficiency play a vital role in productivity growth in the primary agriculture sector, and are, in turn, highly influenced by R&D spending. As James *et al.* (2008) note, the agriculture sector's share of total R&D spending in developed countries is usually modest, representing on average only 4 per cent of total R&D spending in 2000. The public sector tends to play a prominent role in agricultural R&D, with average spending in the sector reaching 7 per cent of public R&D spending during the 1981-2000 period. It is interesting to note that these shares probably underestimate agricultural R&D spending because they do not take into account research in fields such as basic biology, health, bio-informatics, *etc.*, which can have a direct impact in agricultural practices.

Fare *et al.* (2008) find that not only there is a positive correlation between R&D expenditures and agricultural productivity, but that there is a causal relationship between the two, with R&D affecting agricultural productivity with a lag of 4 to 10 years.[30] Alston *et al.* (2001) find that the rate of return to agricultural R&D worldwide has been very high, with marginal and average benefit-cost ratios considerably greater than 1.0, which implies that more investment would have been optimal. Thus, the authors argue that there has been significant underinvestment in agricultural R&D to date.[31] This underinvestment could be partially explained if agricultural R&D spending had rapidly decreasing marginal returns, but there is no evidence to that effect.

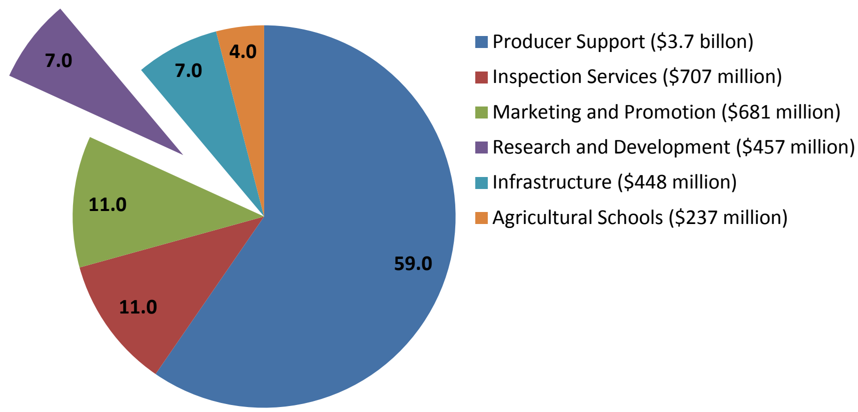
In the case of Canadian agriculture, Veeman and Gray (2010) argue that the past 15 years have seen a slowdown in public R&D spending in the agriculture sector, which had an adverse effect in crop yield growth, and, to a lesser extent, MFP growth. Crop production was more affected by this slowdown in R&D spending than animal production, because its MFP growth was driven mainly by R&D spending, while MFP growth in animal production was mostly caused by scale economies.[32] The authors conclude, however, that "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" (p.146).

According to a recent report by the Canadian Agri-Food Policy Institute (CAPI, 2011), there is reason for concern regarding the state of public R&D spending in the agri-food sector. Although total public spending in the agri-food sector averaged $6.3 billion over the 2000-2009 period, only $457 million were destined for R&D, which represented roughly 7 per cent of the total (Chart 38). Most of the spending in the agri-food sector ($3.7 billion, which accounts for 59 per cent of total public spending in the sector) went to producer support, which represents mainly income support for small producers. The CAPI report argues that: "R&D capacity does not seem

[30] The "real" duration of the lag is debatable, with Chavas and Cox (1992) and Alston and Pardey (2001) arguing that agricultural R&D has long term effects that could have an impact even 30 years after the original R&D spending took place.
[31] Mullen (2007) makes a similar argument.
[32] This point is discussed in more detail in the subsection dedicated to scale economies.

to be well coordinated for optimum effect (…) the many federal and provincial government departments and research institutes do not have a strategic plan to coordinate innovation priorities in the agri-food sector" (p. 35).

Chart 38: Distribution of Average Public Spending in the Agri-Food Sector, Per Cent, 2000-2009



Source: CAPI (2011).

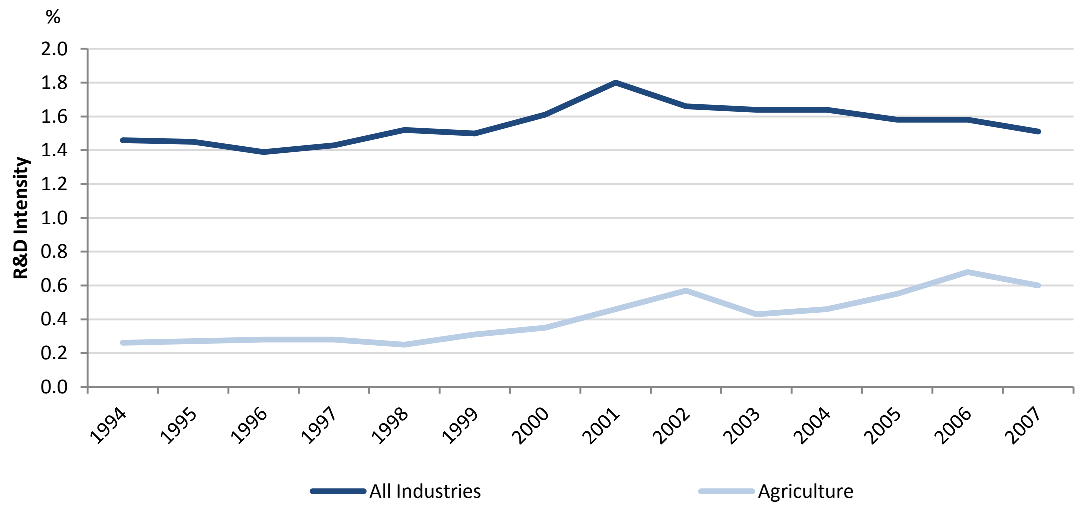
One of the most commonly used measures of R&D effort is R&D intensity, calculated as business enterprise research and development intramural expenditures (BERD) divided by nominal GDP in the sector. In 1994, BERD in the primary agriculture sector was equal to $32 million. By 2007, this number had tripled, reaching $94 million. R&D intensity in the sector also increased significantly in the period, going from 0.26 to 0.60 per cent (Chart 39). Despite the increase, the sector's R&D intensity was notably lower than the business sector's R&D intensity during the entire period, which remained fairly stable at around 1.5 per cent. Furthermore, even though BERD in the agriculture sector has been increasing over the years, it still represented only 0.69 per cent of total BERD in 2010.

Data from the OECD allows a comparison of R&D intensity across countries. Unfortunately, the OECD groups R&D spending in agriculture with forestry and hunting, so the reader should bear in mind that part of the international differences may be driven by sectors other than agriculture.[33] Chart 40 shows that average R&D intensity in the agriculture, forestry and hunting sector was substantially lower in Canada (0.29 per cent), than Belgium (0.96 per cent), France (0.81 per cent), and the Netherlands (0.63 per cent) during the 1987-2007 period. However, it was only marginally lower than the sector's R&D intensity in Germany (0.32 per cent) and Australia (0.41 per cent), while being substantially above Ireland's (0.08 per cent),

[33] As a counterpoint, in most countries primary agriculture represents the bulk of nominal GDP in the agriculture, forestry, and hunting sector, usually around 65 to 75 per cent of the total.

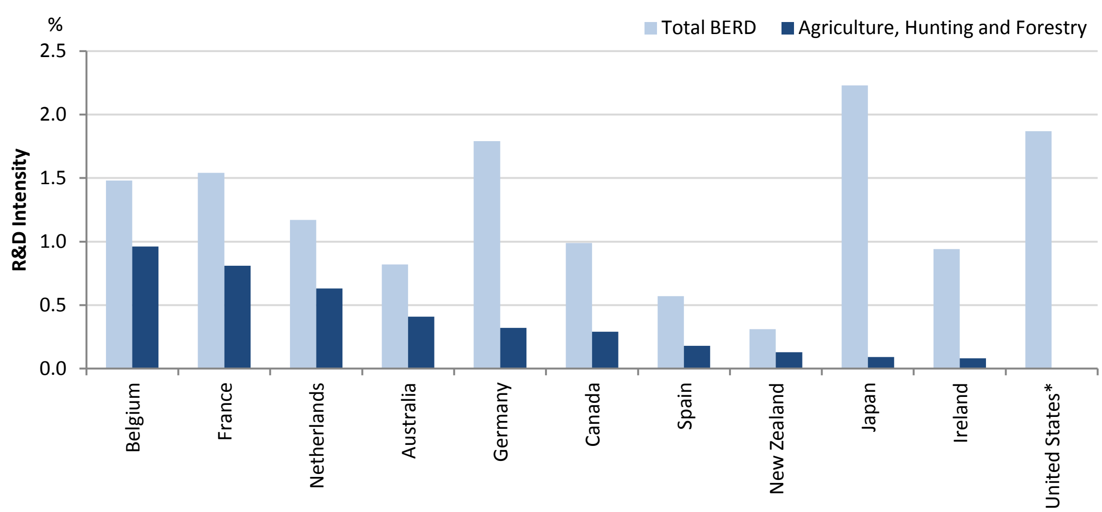
Japan's (0.09 per cent), New Zealand's (0.13 per cent), and Spain's (0.18 per cent). The OECD does not have R&D intensity data for the United States agriculture, hunting and forestry sector.

Chart 39: (BERD) R&D Intensity in the Primary Agriculture Sector, 1994-2007



Source: CSLS calculations based on Statistics Canada data, Research and Development in Canadian Industry (CANSIM Table 358-0024).

Chart 40: Average (BERD) R&D Intensity, International Comparison, 1987-2007



* Data for agricultural BERD in the United States was not available.
Source: CSLS calculations based OECD data ("Business enterprise R-D expenditure by industry and by type of cost", OECD Science, Technology and R&D Statistics, database; "Detailed National Accounts: Value added and its components by activity", OECD National Accounts Statistics, database).

BERD data for primary agriculture have, however, two important limitations. First, much of the business expenditures on agricultural R&D takes place in other sectors, and thus is not captured by BERD estimates. An example of this would be seed research done by companies such as Monsanto. Second, BERD represents only a small fraction of R&D spending in Canadian agriculture. The federal and provincial governments play a vital role in fostering innovation and research in the sector. Thus, even though BERD plays a relevant role in Canadian primary agriculture, its importance should not be overstated.

We do not have data on agricultural R&D spending at the provincial level,[34] but Statistics Canada provides data for total federal expenditures in science and technology broken down by socio-economic objectives, one of which is agriculture. The data are divided into intramural (made within the statistical unit) and extramural (made outside the statistical unit) expenditures, as well as direct expenditures on R&D and expenditures on related scientific activities.[35] Federal expenditures in science and technology for the agriculture sector averaged $554 million over the 2002-2008 period, 75 per cent of which were spent in R&D, and 80 per cent of which were classified as intramural expenditures (Summary Table 26). Federal expenditures on agricultural R&D accounted for roughly 7 per cent of total federal R&D expenditures (Chart 41).

Summary Table 26: Federal Expenditures on Science and Technology in the Primary Agriculture Sector, 2002-2008

		2002	2008	2002-2008
		(millions of current dollars)		(compound annual growth rates, per cent)
All Industries				
Total	Total Science and Technology	8,014	10,573	4.73
	Research and Development	4,927	6,655	5.14
	Related Scientific Activities	3,087	3,918	4.05
Agriculture				
Total	Total Science and Technology	512	650	4.06
	Research and Development	377	485	4.29
	Related Scientific Activities	136	166	3.38
Intramural	Total Science and Technology	414	442	1.10
	Research and Development	287	348	3.26
	Related Scientific Activities	128	94	-5.02
Extramural	Total Science and Technology	98	208	13.36
	Research and Development	90	137	7.25
	Related Scientific Activities	8	72	44.22

Source: CSLS calculations based on Statistics Canada data, Federal Science Expenditures and Personnel, Activities in the Social Sciences and Natural Sciences (CANSIM Table 358-0151).

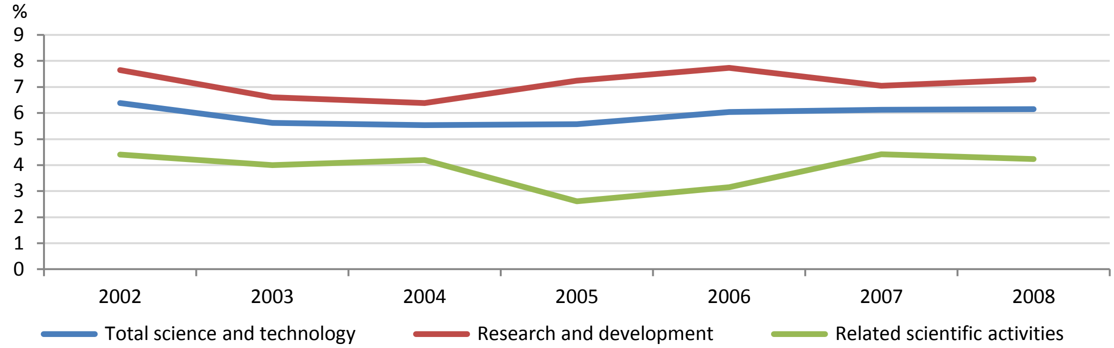
During the 2002-2008 period, federal spending on science and technology for the agriculture sector grew at an average annual rate of 4.06 per cent, with R&D increasing 4.29 per cent, and related scientific activities 3.38 per cent. These rates are slightly lower than the ones experienced by overall federal spending in science and technology, 4.73 per cent per year for total science and technology expenditures, 5.14 per cent for R&D and 4.05 per cent for related scientific activities.

[34] Higher education also plays a relevant role in R&D. Unfortunately, we do not have data on the contribution of universities to agricultural R&D expenditures.

[35] Examples of related scientific activities include tasks related to data collection, information services, special services and studies, education support, administration of extramural programs, etc.

Looking only at federal intramural agricultural R&D, average expenditures reached $313 million over the 2002-2008 period, almost four times the average agricultural BERD over the same period, which was only $84 million.

Chart 41: Federal Expenditures on Science and Technology in the Primary Agriculture Sector as a Share of Total Federal Expenditures in Science and Technology, 2002-2008



Source: Source: CSLS calculations based on Statistics Canada data, Federal Science Expenditures and Personnel, Activities in the Social Sciences and Natural Sciences (CANSIM Table 358-0151).

ii. Quality of the Workforce

Channels	Affects labour productivity growth mainly through labour quality growth.
Key Facts	- According to Statistics Canada's Canadian Productivity Accounts (CPA), labour quality in primary agriculture grew at an average annual rate of 0.55 per cent during the 1961-2007 period, slightly less than the growth of 0.71 per cent observed in the business sector. The 2000-2007 period saw a change in this long-term trend, with labour composition in agriculture increasing by 0.69 per cent, more than in the business sector, which saw an increase of 0.54 per cent. - In line with the CPA's labour quality measure, average years of schooling in the agriculture sector has been increasing at a slightly faster pace than the national average in recent years (0.45 versus 0.29 per cent per year, respectively). This has led to a small decline in the schooling gap between the agriculture sector and the national average, with average years of schooling in primary agriculture at 89.5 per cent of the national level in 2007, up from 87.8 per cent in 1990. In absolute terms, average years of schooling in the agriculture sector rose from 11.4 years in 1990 to 12.4 years in 2007 - The proportion of workers with post-secondary certificate or diplomas in the agriculture sector increased considerably, jumping from only 17.7 per cent of total workers in the sector in 1990 to 28.2 per cent in 2007. This number was still below the national average, which reached 35.0 per cent of total workers (all industries) in 2007, but the gap is clearly closing. In 1990 the proportion of workers in the agriculture sector that had a post-secondary certificate or diploma was only 67.2 per cent of national average, but in 2007 this number had gone up to 80.5 per cent. - Average age of farm operators increased from 47.5 years in 1991 to 52.0 years in 2006, an increase of 9.5 per cent. The ageing of the agricultural workforce will most likely have a negative impact in the sector's productivity, although the magnitude of this impact is debatable.

Several economists, such as Lucas (1988), and Mankiw, Romer and Weil (1992), have emphasized the importance of human capital in driving economic progress. In general, the higher the education level and the greater the experience of workers, the more output they can produce per hour of labour. In the case of Canada, Sweetman (2002) writes: "In particular, educational quality has a significant impact on labour market outcomes, and per capita economic growth. Further, the Canadian education system, with the evidence being mostly at the elementary and secondary levels, produces students with very high outcomes by international standards, which in turn has positive implications for future productivity growth" (p. 158).

Changes in the human capital embodied in the labour force of the primary agriculture sector are captured by Statistics Canada's measure of labour composition, which is the ratio of labour input to hours worked. The labour input, in turn, is the weighted sum of hours worked across different categories of workers, with the weights being equal to the relative labour compensation shares. Thus, the labour services input can be decomposed into an hours component and a labour quality (or composition) component. The variables used to differentiate labour quality are education (four education levels), experience (proxied by seven age groups) and class of workers (paid employees versus self-employed workers). Overall, there are 56 different categories of workers.

Labour composition in primary agriculture increased at an average annual rate of 0.55 per cent during the 1961-2007 period, slightly less than the growth rate observed in the business sector, 0.71 per cent per year (Summary Table 27). More recently, the data show a change in this long-term trend, with labour composition in the primary agriculture sector slightly outpacing that of the business sector (0.69 versus 0.54 per cent per year in the 2000-2007 period), although this difference might not be statistically significant.

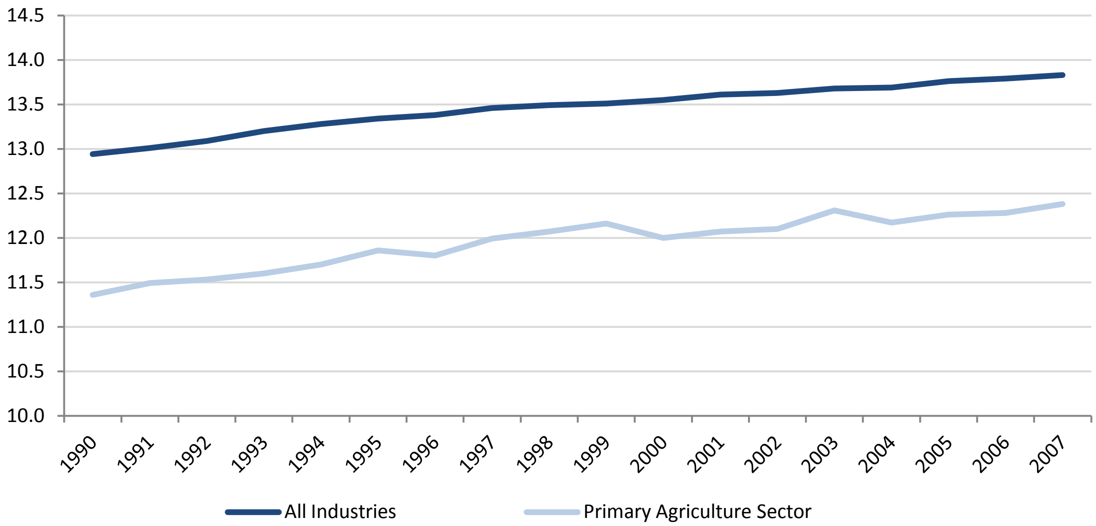
Summary Table 27: Labour Composition in the Agriculture Sector, Canada, Compound Annual Growth Rates, per cent, 1961-2007

	1961-2007	1961-2000	2000-2007
Business Sector	0.71	0.74	0.54
Primary Agriculture Sector	0.55	0.53	0.69

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

In line with the labour composition measure, average years of schooling in the agriculture sector has been increasing at a slightly faster pace than the national average in the 2000-2007 period (0.45 versus 0.29 per cent per year, respectively). This has led to a small decline in the schooling gap between the agriculture sector and the national average, with average years of schooling in primary agriculture at 89.5 per cent of the national level in 2007, up from 87.8 per cent in 1990. In absolute terms, average years of schooling in the agriculture sector rose from 11.4 years in 1990 to 12.4 years in 2007 (Chart 42).

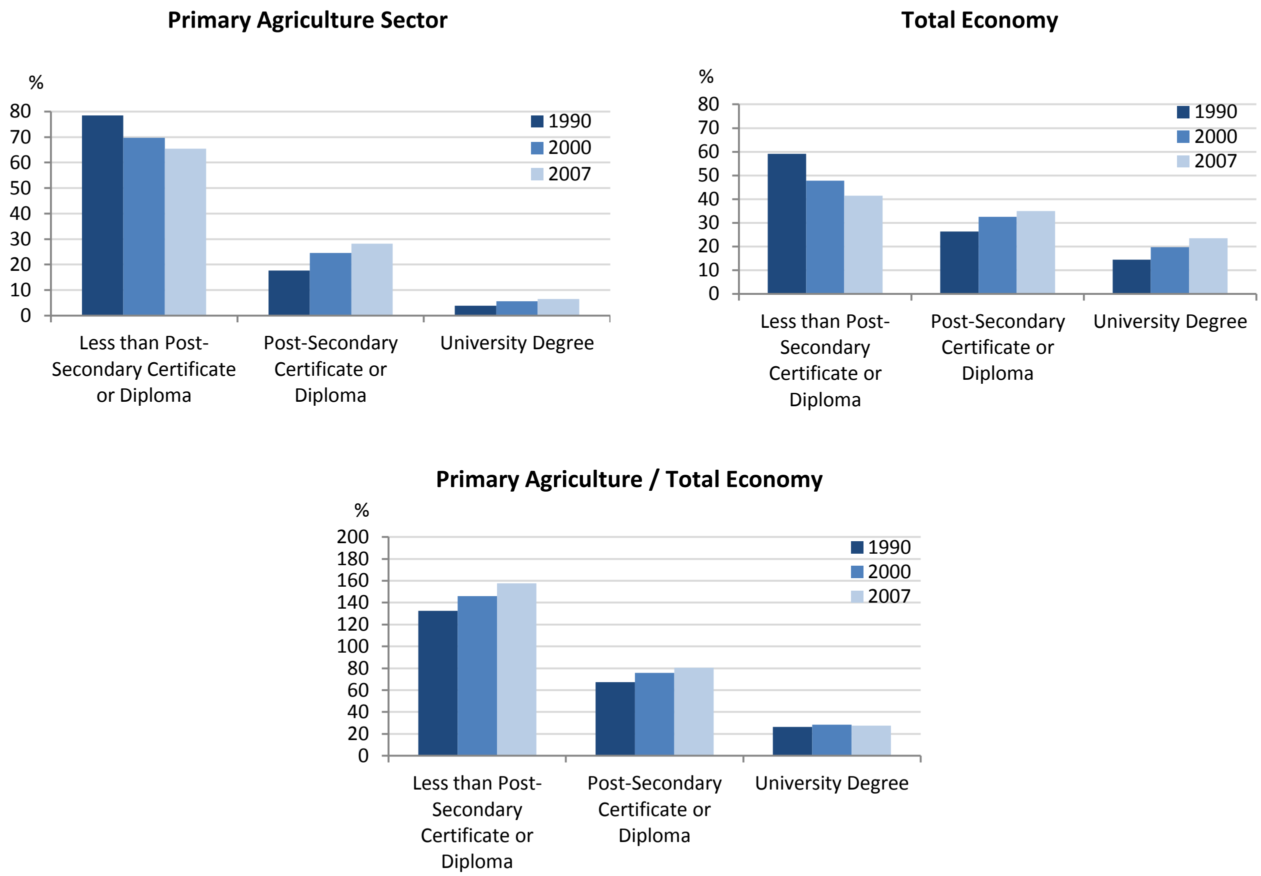
Chart 42: Average Years of Schooling in the Primary Agriculture Sector, Canada, 1990-2007



Source: CSLS calculations based on unpublished Statistics Canada data from the Labour Force Survey.

Chart 43 shows the reason why average years of schooling in the agriculture sector has been increasing over the past 20 years. The proportion of the sector's workforce with less than post-secondary certificate or diploma has been shrinking over the years, from 78.5 per cent in 1990 to 65.4 per cent in 2007, but not as fast as the national average, which explains why the ratio between the primary agriculture sector and the total economy in that particular category increased from 132.6 per cent to 157.6 per cent in the 1990-2007 period. The proportion of workers with post-secondary certificate or diplomas in the agriculture sector, however, increased considerably, jumping from only 17.7 per cent of total workers in the sector in 1990 to 28.2 per cent in 2007. This number was still below the national average, which reached 35.0 per cent of total workers (all industries) in 2007, but the gap is clearly closing. In 1990 the proportion of workers in the agriculture sector that had a post-secondary certificate or diploma was only 67.2 per cent of national average, but in 2007 this number had gone up to 80.5 per cent. The proportion of workers in the sector with a university degree also saw a significant increase, from 3.8 per cent in 1990 to 6.5 per cent in 2007. Despite this increase, it remains well below the national average of 23.5 per cent in 2007. The ratio between the proportion of people in the agriculture sector with a university degree and the Canadian average remained relatively stable over time (26.2 per cent in 1990, 27.7 per cent in 2007).

Chart 43: Workers by Highest Level of Educational Attainment as a Share of Total Workers, Canada, per cent, 1990-2007



Source: Source: CSLS calculations based on unpublished Statistics Canada data from the Labour Force Survey.

Another important issue that relates to the quality of the workforce is the overall age distribution of the workers. This is particularly relevant in the case of primary agriculture where, despite increasing mechanization, workers may have to engage in a variety of physical activities that require both strength and dexterity. Also, an older work force might have a negative impact on the speed at which new technologies are incorporated to the production process. According to Statistics Canada's Census of Agriculture, average age of farm operators in Canada increased in the 1991-2006 period, from 47.5 years in 1991 to 52.0 years in 2006, an increase of 9.5 per cent. The proportion of farm operators between 35 to 54 years remained fairly stable over time, representing 51.9 per cent of total farm operators in 1991 and 50.2 per cent in 2006. The proportion of farm operators aged 35 or less, however, decreased considerably, from 15.8 per cent of the total in 1991 to 9.1 per cent of the total in 2006, while the proportion of farm operators aged 55 or more increased, from 32.1 per cent of the total in 1991 to 40.7 per cent in 2006. The ageing of the agricultural workforce may have a negative impact in the sector's productivity, although the magnitude of this impact is debatable.

iii. Investment Intensity

Channels	Affects labour productivity growth mainly through capital intensity growth and MFP growth.
Key Facts	- *Capital stock intensity* (defined here as real capital stock 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). - However, *capital services intensity* (defined here as capital services input per hour worked) growth in the business sector (which relies on ICT equipment much more than primary agriculture) was higher than in the agriculture sector during the 1961-2007 period (3.27 versus 2.82 per cent per year). - The different performances in terms of capital stock intensity and capital services intensity is driven by the composition of the agriculture sector's capital stock. Primary agriculture does not use ICT equipment (and other short-lived assets) as intensively as other sectors of the economy. This type of equipment provides more capital services over a single year than assets with a longer lifespan. - ICT investment in the agriculture, forestry, fishing and hunting sector has seen substantive growth over the last thirty years, increasing 9.88 per cent per year during the 1981-2009 period. Despite this impressive figure, the sector had the second lowest level of ICT investment per worker in 2008, and represented only half of the United States' level ($235 versus $449, PPP adjusted U.S. dollars), which suggests that the sector still has a long way to go in terms of incorporating ICT to its daily activities.

The relationship between physical capital and labour 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 labour 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 in 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.

Fixed non-residential *investment intensity* (defined here as *gross* investment per hour worked) [36] in the primary agriculture sector increased at an average annual rate of 2.92 per cent during the 1961-2007 period, only slightly below the investment intensity growth experienced by the Canadian business sector as a whole, 3.17 per cent (Summary Table 28, Chart 44). Investment intensity in primary agriculture experienced a boom during the 1970-1985 period, after which it declined considerably to levels consistent with the rest of the business sector.

[36] Gross investment numbers were used to calculate investment intensity rather than net investment numbers because net investment numbers can sometimes be negative, which makes it problematic to calculate compound annual growth rates.

Although total fixed non-residential investment intensity is definitely an important variable for understanding productivity growth, not all capital assets have the same impact in productivity. In particular, a number of cross-country studies have found investment in M&E to have a particularly strong positive relationship with economic growth and productivity growth (see, for instance, De Long and Summers, 1991).

Looking only at M&E investment intensity, we can see that business sector growth was considerably faster than that of the primary agriculture sector during the 1961-2007 period (4.76 versus 3.04 per cent per year, respectively). However, it is clear from the data that the 2000-2007 period witnessed a significant boost in the agriculture sector's M&E investment intensity, which increased at an average annual rate of 4.29 per cent, basically the same growth rate experienced by the business sector, 4.36 per cent.

Summary Table 28: Real Gross Investment per Hour Worked in the Primary Agriculture Sector, Canada, Compound Annual Growth Rates, per cent, 1961-2007

A) Total Investment (Fixed, Non-Residential)

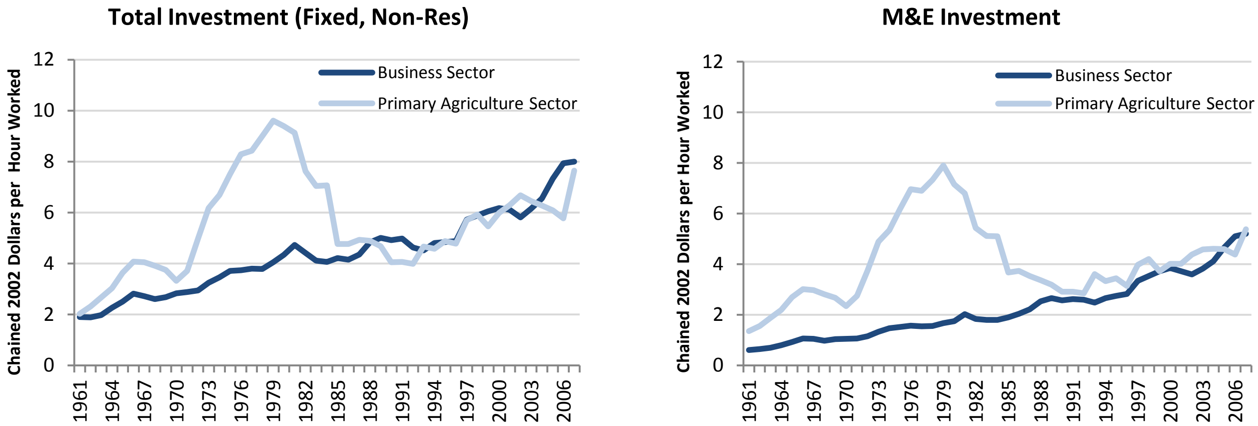
	1961-2007	1961-2000	2000-2007
	(compound annual growth rates, per cent)		
Business Sector	3.17	3.07	3.75
Primary Agriculture Sector	2.92	2.81	3.55
	1961	**2000**	**2007**
	(chained 2002 dollars of investment per hour worked)		
Business Sector	1.90	6.18	8.00
Primary Agriculture Sector	2.03	5.99	7.65

B) M&E Investment

	1961-2007	1961-2000	2000-2007
	(compound annual growth rates, per cent)		
Business Sector	4.76	4.83	4.36
Primary Agriculture Sector	3.04	2.82	4.29
	1961	**2000**	**2007**
	(chained 2002 dollars of investment per hour worked)		
Business Sector	0.61	3.86	5.20
Primary Agriculture Sector	1.36	4.02	5.39

Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 031-0002, 383-0021/22).

Chart 44: Real Gross Investment per Hour Worked in the Primary Agriculture Sector, Canada, 1961-2007

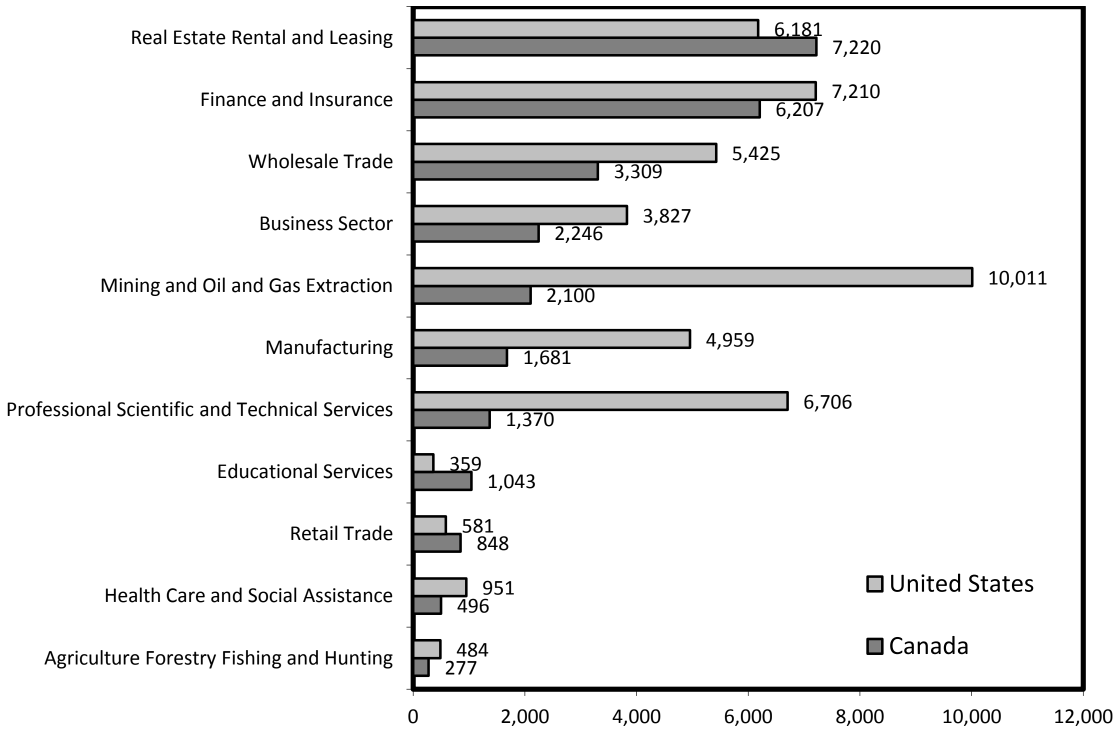


Source: CSLS calculations based on Statistics Canada data (CANSIM Tables 031-0002, 383-0021/22).

M&E investment encompasses investment in information and communication technologies (ICTs). A large empirical literature (see Jorgenson, 2001, Jorgenson *et al.*, 2002, and Sharpe, 2006, for a detailed literature review) has identified the importance of ICT investment in driving productivity growth. In particular, ICTs are seen as the main force behind the labour productivity surge in the United States post-1990, working through increased MFP growth. Basu *et al.* (2003) argue that ICTs should be understood as general purpose technologies that require substantial investment in order to be fully incorporated into firms' business models. In this sense, ICT investment would not have an immediate impact on productivity growth. Rather, its effects would only be felt after a lag of 5 to 15 years.

As shown by the CSLS ICT Investment Database, ICT investment in in the agriculture, forestry, fishing and hunting sector has seen substantive growth over the last thirty years, increasing 9.60 per cent per year during the 1981-2009 period. Despite this impressive figure, the sector had the second lowest level of ICT investment per worker in 2009, $277 (PPP adjusted U.S. dollars), which represented only slightly more than half of the level in the United States ($484, PPP adjusted U.S. dollars) (Chart 45), and suggests that the sector still has a long way to go in terms of incorporating ICT to its daily activities. As an example, data from Statistics Canada's Census of Agriculture show that, even though the number of farms using computers in farm management increased consistently over the last 25 years, from 2.7 per cent of total farms in 1986 to 46.4 per cent of the total in 2006, there is still a long way to go until the Canadian farm sector as a whole can maximize the potential benefits from ICT use.

Chart 45: Total ICT Investment per Worker by Sector, Canada and United States Comparison, current PPP adjusted U.S. Dollars, 2009



Source: CSLS Information and Communication Technology Database (http://www.csls.ca/data/ict.asp).

BOX 3 – 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, 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).

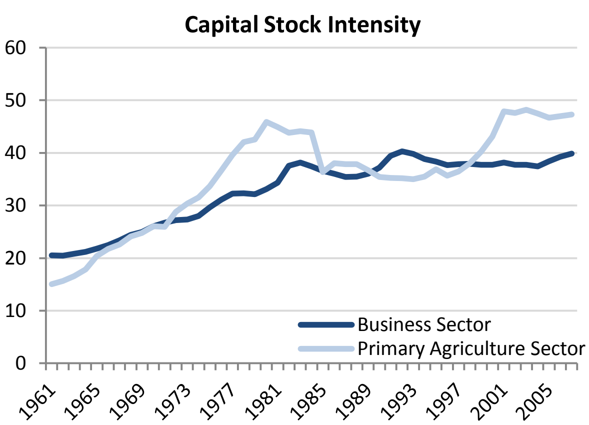
Despite growing slightly less than the business sector in terms of gross investment intensity, *capital stock intensity* (defined here as real capital stock per hour worked) in the primary agriculture sector increased at a faster rate than in the business sector during the 1961-2007 period (2.52 versus 1.46 per cent per year) (Summary Table 29, Chart 46). The reason behind this result is the lower depreciation rates faced by the agriculture sector. Different capital assets depreciate at different rates. Thus, average depreciation rates in a sector depend on the composition of the capital stock, i.e. capital stocks that rely more heavily in ICT equipment (which, as we have seen, is not the case in primary agriculture), for instance, need constant investment to replenish the rapidly depreciating equipment.

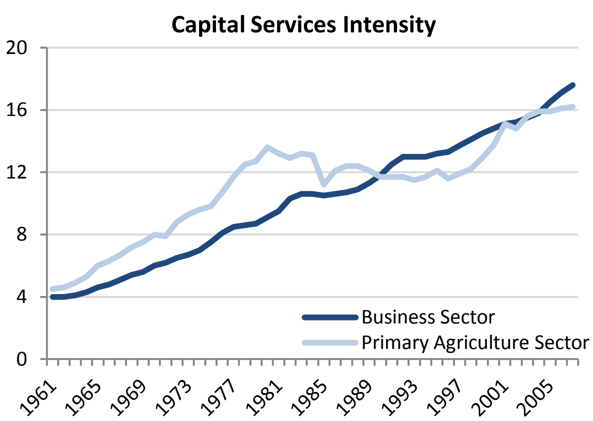
Summary Table 29: Real Capital Stock per Hour Worked in the Primary Agriculture Sector, Canada, per cent, 1961-2007

	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	**1981**	**1987**
	(chained 2002 dollars of capital stock per hour worked)		
Business Sector	20.51	34.30	35.44
Primary Agriculture Sector	15.02	44.91	37.83

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

Chart 46: 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 031-0002, 383-0021/22).

On the other hand, short-lived assets, such as a truck or computers, must provide all of their services in just a few years before they completely depreciate, while office building provide their services over decades. As a consequence, over a single year, a dollar's worth of a computer provides relatively more capital services than a dollar's worth of a building. This explains why *capital services intensity* (defined here as capital services input per hour worked) growth in the business sector (which relies on ICT equipment much more than primary agriculture) was higher than in the agriculture sector during the 1961-2007 period (3.27 versus 2.82 per cent per year)

(Summary Table 30), despite the fact that primary agriculture experienced slower capital stock intensity growth.

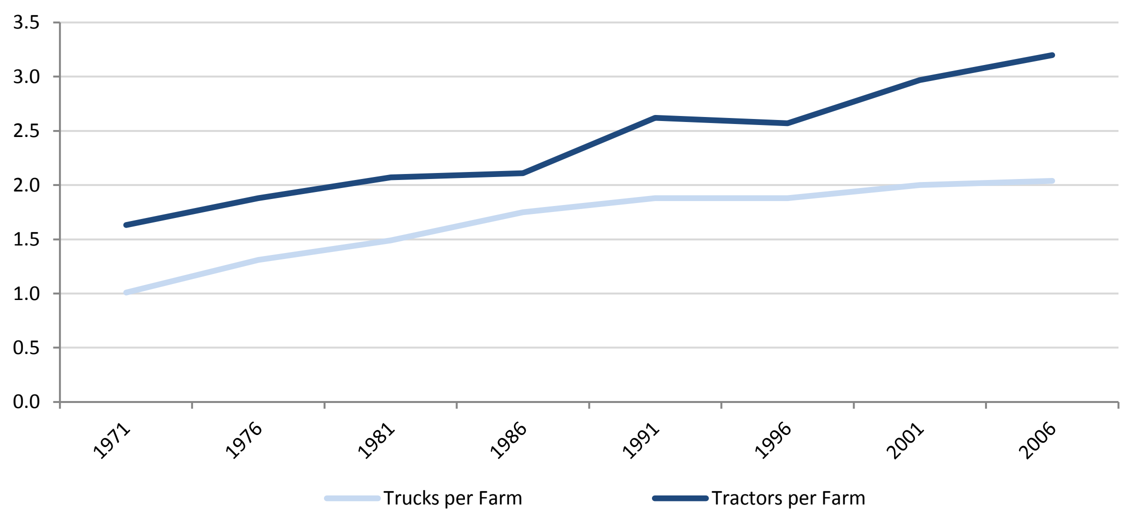
Summary Table 30: Real Capital Services Input per Hour Worked in the Agriculture Sector, Canada, per cent, 1961-2007

	1961-2007	1961-2000	2000-2007
	(compound annual growth rates, per cent)		
Business Sector	3.27	3.41	2.51
Primary Agriculture Sector	2.82	2.90	2.42
	1961	**1981**	**1987**
	(chained 2002 dollars of capital services input per hour worked)		
Business Sector	4.00	9.50	10.70
Primary Agriculture Sector	4.50	13.20	12.40

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

An interesting way to understand 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 (Chart 47). 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.

Chart 47: Number of Trucks and Tractors per Farm Unit, Canada, 1971-2006



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

BOX 4 – 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:

> 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 (p. 29).

Source: Calvin and Martin (2010).

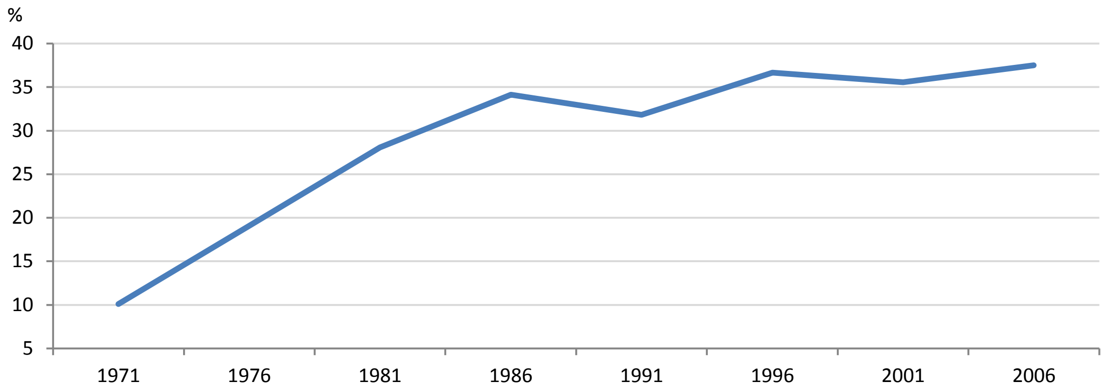
iv. Fertilizer Use

Channels	Affects labour productivity mainly through intermediate input intensity growth.
Key Facts	- Fertilized land area in Canada increased from 6,928 thousand hectares in 19971 (which represented 10 per cent of total agricultural land area in the country) to 25,348 thousand hectares in 2006 (37.5 per cent of agricultural land area). - Real expenses in fertilizer use in the Canadian primary agriculture sector grew at a rapid rate of 3.75 per cent per year during the 1971-2006 period, reaching $1,422 million (constant 1992 dollars) in 2006. - Fertilizer use expenses per hour worked in the primary agriculture sector increased at an average annual growth rate of 5.35 per cent during the 1971-2006 period, from $0.35 (constant 1992 dollars) in 1971 to $2.16 (constant 1992 dollars) in 2006.

Fertilizers play an essential part in increasing agricultural productivity by supplying crops with nutrients the land lacks, thus improving soil fertility. Researchers at Texas A&M University and the Tennessee Valley Authority calculated the effects of eliminating inorganic nitrogen fertilizers on crop yields of several major crops in the United States, including corn, cotton, rice, barley, wheat , and soybean. Although soybean crop yields remained constant, corn crop yields declined 41 per cent, cotton 37 per cent, rice 27 per cent, barley 19 per cent, and wheat 16 per cent (Stewart, 2002). In another study, it was estimated that nitrogen and phosphorus fertilizers were responsible for 40 per cent of wheat yields in the Magruder Plots, a wheat research plot in the Great Plains (Oklahoma State University, 2000). Overall, nutrient inputs seem to be responsible for 30 to 50 per cent of crop yields (Stewart, 2002).

Canada had 6,928 thousand hectares of fertilized land area in 1971, which represented 10 per cent of total agricultural land in the country (Chart 48). By 2006, fertilized land area had increased to 25,348 thousand hectares, now comprising 37.5 per cent of agricultural land area. Most of the increase in fertilized land area happened between 1971 and 1986, after which the rate of increase dropped considerably.

Chart 48: Fertilized Land Area as a Share of Total Agricultural Land Area, Canada, 1971-2006



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

Real expenses in fertilizer use in Canada grew at a rapid rate of 3.75 per cent per year during the 1971-2006 period (Summary Table 31). 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 (Chart 49).

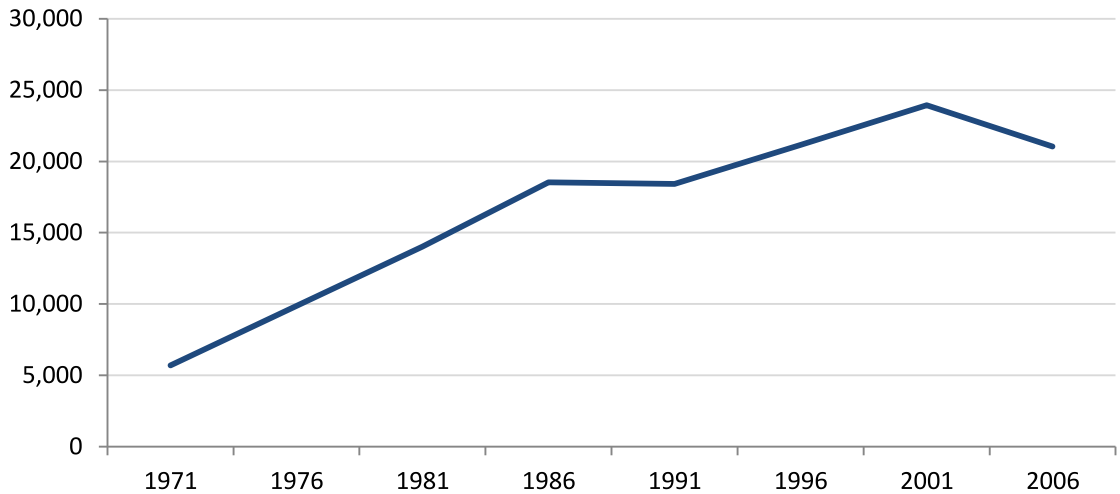
Summary Table 31: Fertilizer Use in Canada, 1971-2006

	1971	2001	2006
	(millions of constant 1992 dollars)		
Fertilizer Use Expenses	392.07	1,615.69	1,422.32
	(thousand 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

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

Fertilizer 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 5.35 per cent during the 1971-2006 period, from $0.35 (constant 1992 dollars) in 1971 to $2.16 (constant 1992 dollars) in 2006.

Chart 49: Fertilizer Use Expenses per Thousand Hectares of Agricultural Land Area, Canada, Constant 1992 Dollars, 1971-2006



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

v. Chemical Pesticides

Channels	Affects labour productivity mainly through intermediate input intensity growth.
Key Facts	- Real expenses in pesticide use in the Canadian primary agriculture sector grew at a rapid rate of 4.98 per cent per year during the 1971-2006 period, reaching $1,228 million (constant 1992 dollars) in 2006. - Pesticide use expenses per hour worked in the primary agriculture sector 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.

When used in the right amount, chemical pesticides can contribute to increased agricultural productivity by keeping pests and diseases in check. However, the misuse of pesticides has been associated with several negative effects, including decreases in crop yields, devastation of soil microorganisms, along with residue accumulation in food crops that could be potentially hazardous to human health (Glover-Amengor and Tetteh, 2008).

Real expenses in pesticide use in 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 (Summary Table 32, and Chart 50), 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.

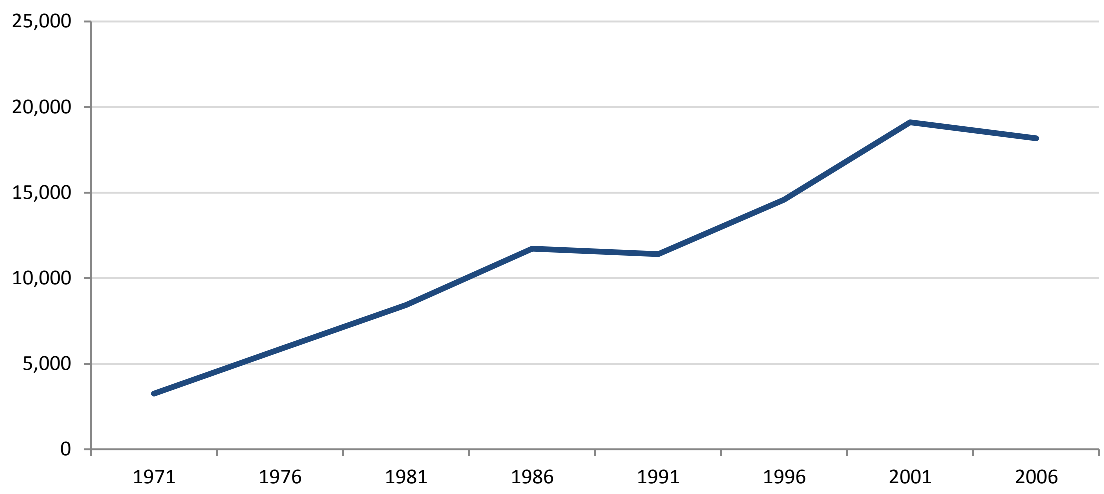
Pesticide use expenses per hour worked in the primary agriculture sector (which is a component of intermediate input intensity) increased at an average annual growth rate of 6.61 per cent during the 1971-2006 period, from $0.20 (constant 1992 dollars) in 1971 to $1.87 (constant 1992 dollars) in 2006.

Summary Table 32: Pesticide Use in Canada, 1971-2006

	1971	2001	2006
	(millions of 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).

Chart 50: Pesticide Use Expenses per Thousand Hectares of Agricultural Land Area, Canada, Constant 1992 Dollars, 1971-2006



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

vi. Scale Economies

Channels	Affects labour productivity mainly through MFP growth.
Key Facts	- Stewart *et al.* (2009) find that scale economies are responsible for the lion's share of MFP growth in the Prairie Provinces' livestock production during the 1940-2008 period, while playing a significantly less important role in crop production. - Mosheim and Lovell (2009) find evidence of important economies of scale in dairy farming. Furthermore, their estimated cost function does not show any region of decreasing returns to scale. - During the 1971-2006 period, the Canadian farm sector saw a strong movement towards consolidation, with the number of farms declining from 336 thousand in 1971 to 229 thousand in 2006, and average farm size increasing from 188 hectares in 1971 to 295 hectares in 2006. Although this should not be regarded as definitive evidence of the overall impact of scale economies in Canadian primary agriculture, it is suggestive of their important role.

In general, scale economies are relevant to productivity growth. Advantages enjoyed by large production units over small production units can include lower cost of capital, greater efficiency in the use of resources and production, and better risk management. However, how important are they in the Canadian primary agriculture sector?

Stewart *et al.* (2009) conduct a detailed study on the impact of scale economies in Canadian Prairie agriculture. The authors estimate MFP growth in Alberta's, Manitoba's, and Saskatchewan's primary agriculture between 1940 and 2004, and then use econometrics to decompose productivity growth into three main components. The first, technical change, is mainly driven by R&D. The second, scale effects, represents the productivity benefits of increasing the scale of operation. The third effect is a residual, which they connect to technical efficiency, or the effective use of the above two effects. The idea behind the latter is that the first two effects can expand the production possibilities frontier, while technical efficiency takes into account how far the actual production level is from the frontier.

The authors find that technical change was responsible for most of MFP growth in the Prairies' crop production subsector, accounting for 80.8 per cent of productivity growth over the 1940-2004 period, while scale effects played a smaller role (but far from insignificant), accounting for 17.2 per cent (Summary Table 33). This picture changes somewhat drastically once we focus on the Prairies' animal production subsector, where 50.5 per cent of MFP growth is explained by scale effects, 39.5 per cent by technical change, and the remainder by the residual term.

Veeman and Gray (2010) argue that increases in Canadian livestock productivity from 1971 to 2008 were driven by four factors, one of which was economies of scale (the others were improved genetics, feed conversion and management practices). Mosheim and Lovell (2009) find that there are economies of scale in dairy farms and further find that their estimated cost function does not show any region of decreasing returns to scale. The authors hypothesize that this is the reason behind the increase in average dairy farm size, and the trend of consolidation of farm units. Tweeten, Gray and Salcedo (2002) argue that economies of scale exist in Mexico for grain and livestock farming because banks are more willing to extend credit to larger farms, which can then invest in improved technology.

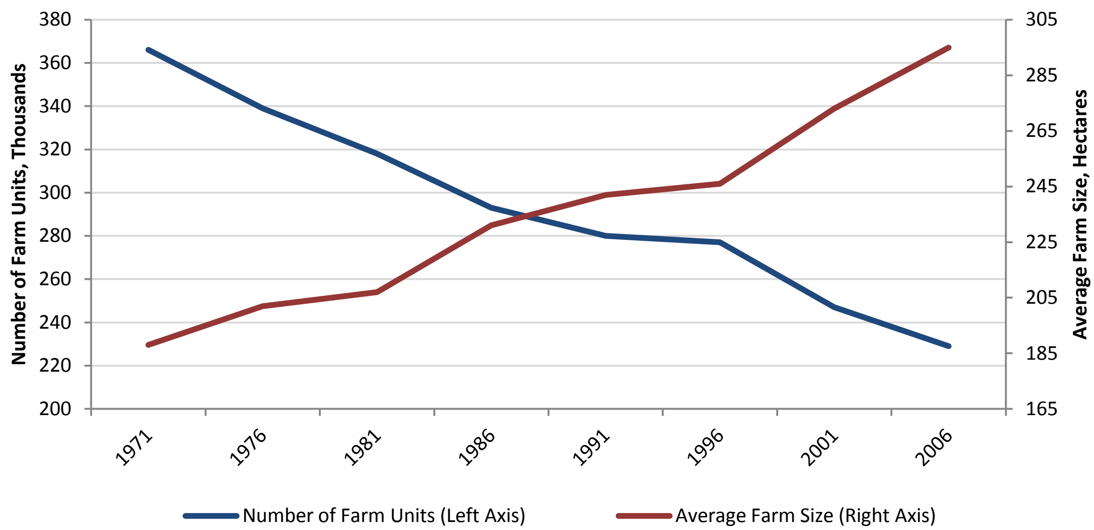
Summary Table 33: MFP Growth Decomposition for Crop Production and Animal Production, Prairie Provinces, 1940-2004

	MFP Growth	Scale Effects	Technical Change	Residual
	(Percentage Point Contribution to MFP Growth)			
Crop Production				
Prairies	1.77	0.30	1.43	0.04
Alberta	1.65	0.08	1.57	0.01
Saskatchewan	1.76	0.30	1.49	-0.03
Manitoba	2.12	0.35	1.70	0.07
Animal Production				
Prairies	0.65	0.33	0.26	0.07
Alberta	0.54	0.28	0.20	0.06
Saskatchewan	0.59	0.37	0.34	-0.12
Manitoba	0.97	0.35	0.52	0.11
	(Per Cent Contribution to MFP Growth)			
Crop Production				
Prairies	100.0	17.2	80.8	2.0
Alberta	100.0	4.9	94.7	0.4
Saskatchewan	100.0	16.9	84.5	-1.5
Manitoba	100.0	16.5	80.4	3.1
Animal Production				
Prairies	100.0	50.5	39.5	9.9
Alberta	100.0	51.0	37.3	11.7
Saskatchewan	100.0	62.4	57.4	-19.8
Manitoba	100.0	36.0	53.2	10.8

Note: Scale effects and technical change contributions to MFP growth are significant at the 1 per cent level.
Source: Stewart *et al.* (2009).

In order to ascertain the importance of scale economies in the Canadian primary agriculture sector, one has to estimate a cost function for agricultural production, which is beyond the scope of this paper. We can suggest, however, that the importance of scale economies in the sector can be seen in the movement towards larger, and fewer farms that has been taking place in Canada over the last 30 years. According to Statistics Canada's Census of Agriculture, there were 336 thousand farm units in Canada in 1971, and the average farm unit size was 188 hectares. By 2006, the number of farm units had declined 37 per cent, to 229 thousand, and average farm size had increased more than 50 per cent, to 295 hectares (Chart 51). It is important to keep in mind that even though the existence of scale economies constitutes an important rationale for consolidation, it is not the only one. Thus, as we mentioned before, while the trend towards larger, and fewer farms is suggestive of scale economies, by no means it should be seen as definitive evidence.

Chart 51: Number of Farm Units and Average Farm Size in Canada, 1971-2006



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

vii. International Trade

Channels	Affects labour productivity growth mainly through MFP growth.
Key Facts	- Exports and imports in the Canadian primary agriculture sector were equal to \$16.2 billion and \$6.8 billion (current dollars) in 2007, representing 3.6 per cent and 1.7 per cent of the country's total merchandise exports and imports, respectively. - International trade openness (measured as the sum of exports and imports divided by GDP) in the Canadian primary agriculture sector increased over the 1992-2007 period. In 1992, the sum of exports and imports represented 95.6 per cent of the sector's GDP. By 2007, despite significant fluctuations during the period, the sum of exports and imports reached 145.3 per cent of the sector's GDP. This reflects a considerable increase of 49.7 percentage points in the sector's trade openness, and indicates that international trade contributed to the strong productivity growth rates observed in Canadian primary agriculture during the period.

A number of economists emphasize the importance of international trade in driving productivity growth. After all, international trade can increase competition, forcing firms to rethink their production processes and implement innovations. Not only that, it can serve as an important channel through which technology transfers happen. Alcalá and Ciccone (2004) identify an economically and statistically significant causal effect of international trade on labour productivity by using instrumental variables to account for possible reverse causation. Furthermore, the authors find that international trade affects labour productivity through MFP growth (while institutional quality, for instance, works through capital accumulation).

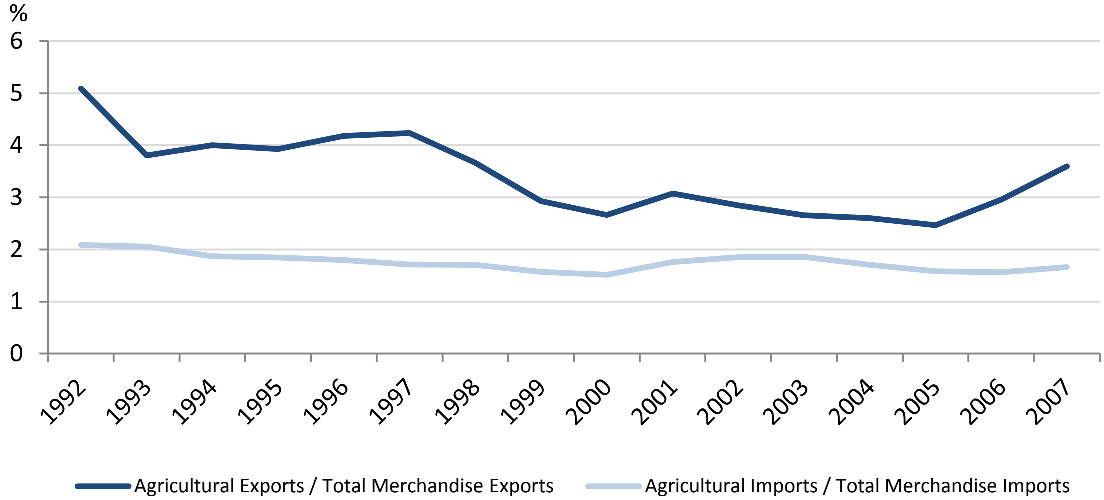
In 2007, total merchandise exports in Canada were equal to $450.3 billion, while merchandise imports totaled $407.3 billion. In the primary agriculture sector, exports and imports were equal to $16.2 billion and $6.8 billion, representing 3.6 per cent and 1.7 per cent of the country's total merchandise exports and imports, respectively (Summary Table 34, Chart 52). The share of agricultural exports in total exports has seen considerable variation over the last twenty years, ranging from 2.6 per cent in 2004 to 5.1 per cent in 1992. Conversely, the share of agricultural imports remained relatively stable throughout the entire period.

Summary Table 34: Exports and Imports in the Primary Agriculture Sector, Canada, 1992-2010

	1992-2010	1992-2000	2000-2007
	(compound annual growth rates, per cent)		
Exports			
All Industries (Merchandise)	5.10	12.35	1.24
Primary Agriculture Sector	4.44	3.58	5.69
Crop Production	4.68	3.10	5.92
Animal Production	3.17	5.59	4.79
Imports			
All Industries (Merchandise)	5.73	11.63	1.90
Primary Agriculture Sector	5.27	7.26	3.24
Crop Production	5.36	6.68	4.04
Animal Production	3.86	13.74	-5.56
	1992	**2000**	**2007**
	(millions of current dollars)		
Exports			
All Industries (Merchandise)	162,828	413,215	450,321
Primary Agriculture Sector	8,291	10,988	16,184
Crop Production	6,787	8,665	12,961
Animal Production	1,503	2,323	3,223
Imports			
All Industries (Merchandise)	148,018	356,992	407,301
Primary Agriculture Sector	3,089	5,411	6,765
Crop Production	2,883	4,834	6,378
Animal Production	206	577	387
	(as a share of the sector's GDP)		
Exports			
All Industries (Merchandise)	23.2	38.4	29.4
Primary Agriculture Sector	69.7	76.0	102.5
Imports			
All Industries (Merchandise)	21.1	33.2	26.6
Primary Agriculture Sector	26.0	37.4	42.8
Net Exports (Exports - Imports)			
All Industries (Merchandise)	2.1	5.2	2.8
Primary Agriculture Sector	43.7	38.6	59.7

Source: CSLS calculations based on Industry Canada data, Canadian Trade by Industry (http://www.ic.gc.ca/sc_mrkti/tdst/tdo/tdo.php?lang=30&productType=NAICS).

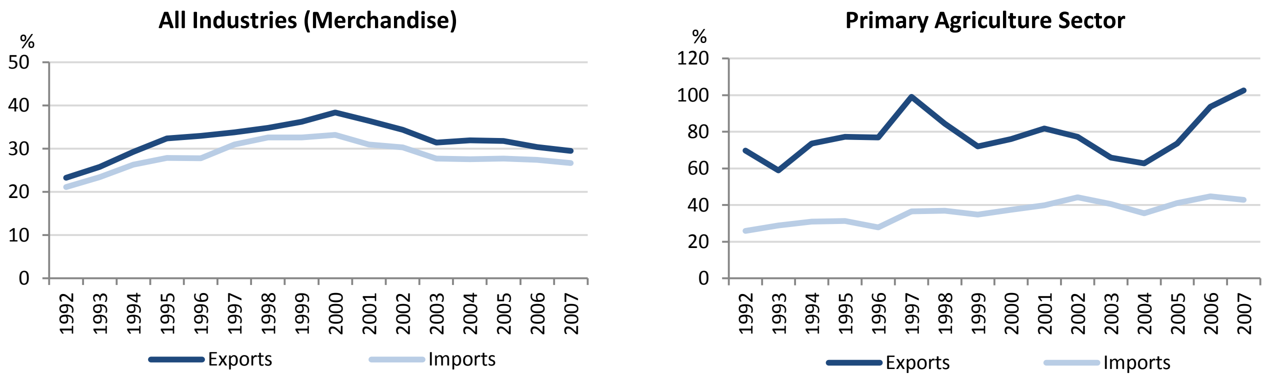
Chart 52: Nominal Exports and Imports in the Agriculture Sector as a Share of Total Merchandise Exports and Total Merchandise Imports, Canada, per cent, 1992-2007



Source: CSLS calculations based on Industry Canada data, Canadian Trade by Industry (http://www.ic.gc.ca/sc_mrkti/tdst/tdo/tdo.php?lang=30&productType=NAICS).

In terms of international trade intensity (export or imports divided by nominal GDP in the sector), total merchandise exports in Canada represented 29.4 per cent of the country's nominal GDP in 2007, while merchandise imports accounted for only 26.6 per cent. Looking at the primary agriculture sector only, the picture is quite different, with exports accounting for 102.5 per cent of the sector's nominal GDP, and imports 42.8 per cent (Chart 53).

Chart 53: Merchandise Exports and Imports in Canada as a Share of Nominal GDP, Canada, per cent, 1992-2007

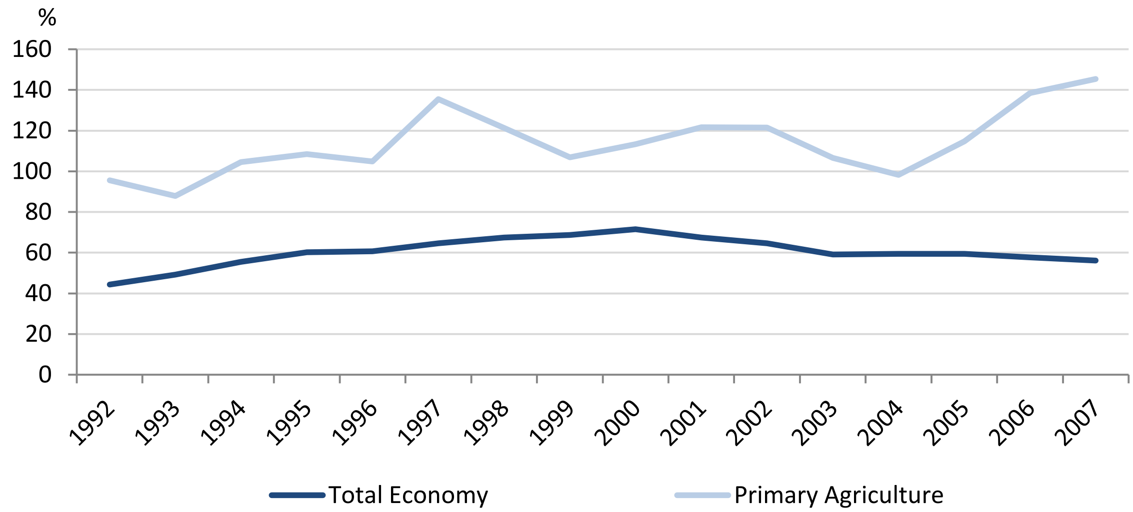


Source: Source: CSLS calculations based on Industry Canada data, Canadian Trade by Industry (http://www.ic.gc.ca/sc_mrkti/tdst/tdo/tdo.php?lang=30&productType=NAICS).

During the 1992-2007 period, the value of agricultural exports was more than twice that of agricultural imports. Crop production dominated both exports and imports in the primary agriculture sector, accounting (on average) for 80 per cent of agricultural exports and over 90 per cent of agricultural imports. In 2007, the bulk of agricultural goods exported by Canada went to the United States (39.7 per cent of total agricultural exports), Japan (9.9 per cent), Mexico (4.7 per cent), and China (3.8 per cent). Canada's main import partners in agricultural production were the United States (responsible for 57.8 per cent of total imports in primary agriculture), and Mexico (9.2 per cent), with a group of countries from South and Central America accounting for 17.9 per cent of total agricultural imports.

International trade theorists often measure a country's trade openness as the sum of nominal exports and imports divided by nominal GDP. Applying that same concept to a specific sector, we can measure the trade openness of the primary agriculture sector in Canada (Chart 54). In 1992, the sum of exports and imports represented 95.6 per cent of the sector's GDP. By 2007, despite significant fluctuations during the period, the sum of exports and imports reached 145.3 per cent of the sector's GDP. This reflects a considerable increase of 49.7 percentage points in the sector's trade openness, and indicates that international trade contributed to the strong productivity growth rates observed in Canadian primary agriculture during the period.

Chart 54: Trade Openness in the Agriculture Sector, Canada, 1992-2007



Source: CSLS calculations based on Industry Canada data, Canadian Trade by Industry (http://www.ic.gc.ca/sc_mrkti/tdst/tdo/tdo.php?lang=30&productType=NAICS).

viii. Regulatory Environment

The Canadian Agri-Food Policy Institute (CAPI, 2011) cites the lack of a "modern and responsive regulatory environment" as an important impediment to innovation and productivity growth in the agriculture sector. Two general limitations identified by the report in the current regulatory environment are: 1) regulatory disconnects; 2) policy silos.

The first of these limitations, regulatory disconnects, refers to the lack of an integrated and efficient bureaucracy that effectively raises the costs related to innovation in the sector. The report lists as inhibiting factors "the time it takes to obtain approvals, acceptance of research/evidence and other documentary requirements for seed certification, novel traits, novel food products, health claims and minor use registrations of pest control products, and overall timeliness of regulatory decisions" (p. 80).

The second limitation, policy silos, refers to the fact that the objectives of different departments are not integrated, creating a situation where, instead of cooperating towards a common goal, departments actually compete with each other. This happens because "each department and level of government must adhere to specific objectives that fall under its respective domain of responsibility" (p. 80).

ix. Other Drivers

The literature identifies many other factors that can affect productivity growth in the agriculture sector, some of which are discussed in this subsection.

Makki *et al.* (1999) find that better terms of trade (i.e. the ratio between the prices of exports and imports) had a positive impact on agricultural productivity in the United States. A one per cent increase in terms of trade was estimated to raise farm productivity by 0.16 per cent. According to the authors, better terms of trade allows farmers to buy higher quality inputs, which in turn increases productivity.

The same authors find that public spending on commodity support programs had either no effect or small negative effects on agricultural productivity in the United States. In practice, they argue that even if commodity support programs had a positive effect on productivity, public spending in R&D and education tend to have a much higher impact. Thus, Makki *et al.* state that "Results of this study suggest that any loss of global competitiveness from cutting commodity programs can be offset by investments in agricultural research, extension, and education to leave the nation better off" (p. 92).

Antle (1983) uses econometric analysis and an inter-country dataset to highlight the role of infrastructure capital that is not directly related to the primary agriculture sector, such as transportation and communication facilities, in improving the sector's productivity. According to the author, the null hypothesis that a country's infrastructure capital contributes positively to productivity in primary agriculture could not be rejected. Mullen (2007) makes a similar point with respect to the Australian farm sector, arguing that "TFP in agriculture is likely to be influenced by 'spillovers' of technology from other countries and by improvements in public infrastructure in the form of communications and transport (…)" (p. 15).

Loureiro (2009) analyzes productivity in Norway's primary agriculture sector and finds that a farmer's health status plays a significant role in explaining the variance in agricultural productivity over time. The author argues that, since the workers' health condition can considerably influence efficiency gains in the sector, "(…) policy actions directed to train farmers in work-related risk reduction, with the objective of reducing hazards and accidents, may impact farmers' wealth and agricultural productivity, much like past programs that improved access to inputs (such as machinery, land, etc) and other technology investments" (p. 388).

Hall and Jones (1999) find that much of the difference in productivity across nations is due to social infrastructure differences, which is to say differences in institutions and government policies that provide incentives for people and firms. According to the authors, productivity growth can only take place in an environment where it is encouraged rather than punished. The authors find that corruption, law and order, bureaucratic quality, risk of expropriation and government repudiation of contracts along with trade openness are important indicators of social infrastructure. Canada certainly excels in many of these metrics, having a strong legal infrastructure, a history of government honouring obligations and, according to Transparency International (2010), Canada is perceived as being the sixth least corrupt nation in the world. Canada is also generally a country quite open to trade, though primary agriculture is one of the more protected sectors of the economy owing to traits unique to the industry.

VI. Policy Implications

Productivity growth will be more important for Canada's agriculture and agri-food sector in the future than in the past for two main reasons: increased need for the sector's output globally; and rising competitive pressures internationally. According to a recent report from the United Nation's Food and Agriculture Organization (FAO), agricultural productivity needs to increase by about 70 per cent globally between now and 2050, to feed an estimated world population of 9.2 billion people (up 35 per cent from the global population of 6.8 billion people in 2009). In addition, the demand for the sector's output from emerging economies is expected to accelerate because of the fast growth in real incomes and the rising middle-class in these countries. Canada is currently the fourth largest global exporter of agricultural and agri-food products, and therefore is expected to play a major role in meeting the increased global demand for these products.

The increased production of agricultural commodities in Canada in the future needs to come primarily from increases in labour productivity, because of the limits to cultivable land and the potential adverse impact of deterioration in land quality, climate change and climate variability. Hence, strong productivity growth in the sector is necessary to meet effectively the rising demand for agriculture and agri-food products and the rising competitive challenge.

Both the federal and provincial agriculture and agri-food departments should make productivity the central tenant of their policy discussion. Furthermore, they should consider evaluating and disseminating widely the productivity impacts (both direct and indirect) of all new policies and programs relating to the agriculture and agri-food sector. In addition to these two broad policy directions, a number of specific policy suggestions could be considered for raising the productivity growth rate of the sector. These include stimulating innovation by encouraging and undertaking effective R&D spending; encouraging and facilitating the increased adoption rates of available technologies and knowledge; facilitating market induced shifts in resources within the sector; promoting competition; reducing the regulatory burden; improving market access to Canadian exports; and fostering effective responses to climate change and other environmental pressures.

A. Research and Development (R&D)

Despite the paramount importance of R&D for productivity growth, federal R&D spending in agriculture has been lagging overall federal R&D spending in recent years. Moreover, in view of the tight fiscal situation of federal and provincial governments, the medium-term outlook for government R&D is not very promising, unless federal and provincial departments of agriculture and agri-food make considerable efforts to protect and expand their

R&D budgets. In addition to undertaking sufficient R&D on their own, governments need to increase the effectiveness of their financial support to private sector R&D spending.

Adequate and effective intellectual property protection (IPR) in the agriculture and agri-food sector is essential for encouraging private sector R&D. But, in some cases, intellectual property rights could hinder the adoption and diffusion of new technologies. Federal governments need to ensure a proper balance with its IPR policies between the interests of creators and users of new technologies and knowledge so that the overall productivity benefits from R&D spending to the sector are maximized.

Furthermore, federal and provincial regulatory approval processes of new pesticides, new approaches to plant breeding and genetics and new animal health tools such as improved vaccines and veterinary drugs need to be flexible and responsive to the needs of farmers, so that the regulatory burden is not excessive and producers and manufacturers of agricultural and agri-food products realize quickly the full economic benefits of these new tools and methods.

B. Innovation Adoption

According to a recent report by the Science, Technology and Innovation Council (STIC, 2011), "Canada's strengths are a strong talent pool and a robust public research capacity. Its two main challenges are to increase private sector investment in innovation and to improve Canada's capacity to transfer knowledge into the market".

For a small open economy like Canada, the widespread use and effective adoption of new technologies and knowledge developed outside of Canada, especially in the United States, is more important to productivity growth than domestic innovation.

Factors that would stimulate innovation adoption include continued government efforts toward increasing investments in M&E, especially ICTs, R&D, education, skills development and upgrading, and transport and telecommunications infrastructure.

The economic life of M&E capital in general, especially ICT capital, is being shortened increasingly quickly because of rapid technological advances. Consequently, the capital cost allowance rates need to respond quickly to these fast moving technology trends so that the cost of capital in Canada is competitive with other jurisdictions and does not become a hindrance to investments in new technologies in the agriculture and agri-food sector.

Better coordination of the innovation and innovation adoption activities of businesses, universities and governments would also increase overall productivity dividends to the sector from innovation and innovation adoption.

Increased competition intensity from both domestic and external sources, improved market access to export markets, the availability of skilled and unskilled labour and the wage rates, and climate change and other environmental factors would increase the incentives to innovate, adopt and adjust.[37]

C. Regulatory and Other Policy Settings

The regulatory systems with regard to food safety, health concerns, approval of new seeds, pesticides, vaccines and veterinary drugs should try to minimize the regulatory burden on farmers and food manufacturers – without neglecting other goals of regulation, such as public safety – and encourage innovation and innovation adoption.

Policies with regard to income support, supply management, production subsidies and marketing arrangements need to ensure that they do not distort the incentive structures so that innovation, innovation adoption, flexibility and economic adjustment within the sector are not adversely affected.

D. Market Access

Canada exports much of its agricultural output, with net exports averaging around 40 per cent of the sector's GDP over the 1992-2007 period. The agri-food industry is becoming increasingly export oriented as Canada exports more and more of its agricultural output in processed form. Therefore, a healthy growth in domestic and foreign demand for Canada's agriculture and agri-food products is vital for expanding the scale and scope of production, increasing investments in innovation and innovation adoption, the key drivers of trend productivity.

Reducing the remaining inter-provincial barriers to trade in agricultural and agri-food products, especially trade in meat products, would be helpful in addressing the domestic side of market access concerns. In addition, improving access to the United States and other export markets, especially emerging markets in Asia and Latin America, would ensure sufficient external demand for the sector's products.

Since the United States is Canada's largest export market for the sector's products, reduction of non-tariff barriers between Canada and the United States to trade in agricultural and agri-food products would improve the sector's access to the United States market and increase the two-way trade between the two countries.

---

[37] For a detailed discussion on policies that could help foster innovation adoption in Canada, refer to a recent study by the Institute of Competitiveness and Prosperity (ICP, 2011).

Non-tariff barriers, such as differences in food and health standards and food safety regulations, in the two countries act as major barriers to Canada's trade in agricultural and agri-food products with the United States. Canada could work towards harmonization of these with the United States and improve a great deal the access to the United States market.

Furthermore, given that the Doha Round of multi-lateral negotiations of issues related to agriculture and agri-food trade are not likely to produce any concrete results in the near future, Canada might consider negotiating bilateral trade agreements with fast growing emerging economies, especially China, India, South Korea, and Brazil.

E. Environmental Conditions and Climate Change

Land quality, soil fertility, water quality and availability, and climate change all affect farm productivity. Farmers' flexibility and adaptability to changing environmental conditions are likely to become increasingly important for productivity growth. Government policy responses to climate change will also have implications for the sector's productivity growth. Market-based approaches to climate change mitigation could reduce the compliance cost on producers and encourage innovation, flexibility and economic adjustment.

BOX 5 – The Impact of Global Warming on Crop Yields

Although the full range of consequences of climate change is still not fully understood, more and more researchers are attempting to quantify its possible impact on global agricultural production. A recent study by Lobell *et al.* (2011) sheds light on how global warming might affect crop yields for wheat, maize, rice, and soybeans. The authors model the effects of rising temperature on crop yields during the 1980-2008 period, and compare it to a counter-factual where climate trends remain constant. According to the study, while the effect of warming on rice and soybeans were small and not statistically significant, its effects on wheat and maize yields were not only statistically significant, but quite large as well. Lobell *et al.* estimate that global wheat and maize yields were, respectively, 5.5 and 3.8 per cent lower than they would have been if average temperature had not increased. These effects, however, were not uniformly distributed, with some countries suffering much more severe consequences than others. Wheat yields in Russia, for instance, were 10 per cent lower than they would have been if average temperatures had not changed. Meanwhile, wheat and maize yields in Canada and the United States were not affected, because temperatures in those two countries remained relatively stable. According to the authors, the cumulative impact of global warming on wheat and maize yields was equivalent to the loss of Mexico's annual maze harvest and France's annual wheat harvest. Furthermore, the authors calculate that the warming effect was responsible for a 20 per cent increase in the prices of maize and wheat. Taking into account the beneficial role of increased CO2 during the period (the fertilization effect), climate change would be responsible for an overall 5 per cent increase in wheat and maize prices.

Source: Lobell *et al.* (2011).

F. Public Infrastructure

Adequate and state-of the art provision of transportation and telecommunication infrastructures is imperative to long-term productivity growth in the agriculture and agri-food sector. A good transportation system is a key determinant of productivity and competitiveness since it allows producers to deliver their products in an effective, efficient and timely manner to their domestic and foreign customers. Well-maintained road and rail networks help producers to minimize costs with longer shipping distances within North America. For exports destined to overseas markets, adequate port facilities are also essential.

Many industries, including agriculture and agri-food, are increasingly relying on telecommunications and web-based tools and services for making rational input and output choices, obtaining up-to-date market information and managerial skills and knowledge. Providing adequate telecommunication infrastructure, such as broadband, especially in rural areas, could yield significant productivity benefits to the Canadian agriculture and agri-food sector.

VII. Further Research

Even though the agricultural productivity literature has gone a long way in analyzing productivity trends in the sector and identifying its possible sources and drivers, there are still several topics that would benefit from additional research. Below, we highlight some of those topics.

- Measuring labour input in primary agriculture is notoriously hard. The sector has a significant number of part-time workers, with many farm operators relying on other sources of income. Also, unpaid family labour plays an important role in several agricultural activities. Although the Labour Force Survey tries to account for those factors, it is likely that substantial distortions in its labour input estimates for the sector remain. Further research on the topic could help produce better labour input estimates for the sector, which would lead to more reliable productivity estimates.

- By the same token, Statistics Canada uses NAICS to classify establishments into different categories. According to NAICS, an establishment is engaged in crop production if more than 50 per cent of its revenue comes from growing crops, plants, vines, trees and their seeds. Conversely, an establishment is classified under animal production if more than 50 per cent of its revenue comes from raising animals, producing animal products and fattening animals. Thus, a mixed farm where 60 per cent of its revenue is classified under crop production and 40 per cent under animal production would have all its output categorized as crop production. This distorts overall output and input allocation between the two subsectors. Further research on the topic could contribute towards alternative output and input measures in both subsectors, which would allow for specific productivity trends in the subsectors to be identified and understood with more precision.

- As mentioned previously, the consolidation of the Canadian farm sector seen in the last decades seems to indicate that scale economies play a very important role in increased agricultural productivity. Stewart *et al.* (2009) investigate their role in Prairie agriculture and find that they are much more relevant in livestock production than in crop production. Additional studies on scale economies could help identify their overall importance in Canadian primary agriculture, and the activities in which they play a more relevant role.

- Intermediate input use in primary agriculture increased at a robust pace during the 1961-2000 period (5.23 per cent per year), but at a much slower rate in the 2000-2007 period (1.33 per cent). Additional research could shed light as to the reasons underlying this slowdown, and its impact on productivity growth.

- Another important issue that future research must tackle refers to the possible effects of the ageing of the farm sector workforce on productivity. Despite increasing mechanization, workers still have to engage in a variety of physically extenuating activities, and this becomes more and more problematic as the average age of the workers in agriculture increases. Furthermore, an older work force might have a negative impact on the speed at which new technologies are incorporated into agricultural production processes.

VIII. 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.

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) to be lower than MFP (VA).

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 to 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.

Bibliography

Abramovitz, M. (1956) "Resource and output trends in the United States since 1870," *American Economic Review*, Vol. 46, No. 2, pp. 5-23.

Agriculture and Agri-Food Canada (AAFC) (2009) *An overview of the Canadian agriculture and agri-food system*, Ottawa.

Agriculture and Agri-Food Canada. (2010) *An overview of the Canadian agriculture and agri-food system*, Ottawa.

Agriculture and Agri-Food Canada. (2011a). *An overview of the Canadian agriculture and agri-food system*, Ottawa.

Agriculture and Agri-Food Canada (2011b) *Charting the way forward to 2020*, Discussion Paper.

Alcalà, F., & Ciccone, A. (2004) "Trade and productivity," *Quarterly Journal of Economics*, Vol. 119, No. 2, pp. 613-46.

Alston, J. M., & Beddow, J. M., & Pardey, P. G. (2010) "Global patterns of crop yields and other partial productivity measures and prices," Chapter 3 in Alston, J. M., & Babcock, B. A., & Pardey, P. G. (eds.) *The shifting patterns of agricultural production and productivity worldwide.* The Midwest Agribusiness Trade Research and Information Center, Iowa State University, Ames, IA, pp. 39-61.

Alston, J.M., & Chan-Kang, C., & Marra, M.C., & Pardey, P.G., & Wyatt, T.J. (2000) "A meta-analysis of rates of return to agricultural R&D," International Food Policy Research Institute Research Report 113, Washington, D.C.

Alston, J.M., & Pardey, P.G. (2001) "Attribution and other problems in assessing the returns to agricultural R&D," *Agricultural Economics*, Vol. 25, pp. 141-152.

Alston, J.M. (2010) "The benefits from agricultural research and development, innovation, and productivity growth," *OECD Food, Agriculture and Fisheries Working Papers*, No.31, OECD Publishing.

Antle, J. (1983) "Infrastructure and aggregate agricultural productivity: international evidence," *Economic Development and Cultural Change*, Vol. 31, No. 3, pp. 609-19.

Arrow, K.J. (1985) *Collected papers of Kenneth J. Arrow, volume 5: production and capital*, Belknap Press, Cambridge, MA.

Baldwin, J. R., & Gu, W. (2007) "Multifactor productivity in Canada: an evaluation of alternative methods of estimating capital services," *The Canadian Productivity Review*, Cat. no. 15-206-XIE2007009, Statistics Canada. http://www.statcan.gc.ca/pub/15-206-x/15-206-x2007009-eng.pdf

Baldwin, J. R., & Gu, W., & Yan, B. (2007) "User guide for Statistics Canada's annual multifactor productivity," Cat. no. 15-206-XOE–No. 14, Statistics Canada. http://www.statcan.gc.ca/pub/15-206-x/15-206-x2007014-eng.pdf.

Ball, E. V. (1985) "Output, input, and productivity measurement in U.S. agriculture, 1948-79," *American Journal of Agricultural Economics*, Vol. 67, No. 3, pp. 475-486.

Ball, E. V., & Bureau, J., & Nehring, R., & Somwaru, A. (1997) "Agricultural productivity revisited," *American Journal of Agricultural Economics*, Vol. 79, No. 4, pp. 1045-1063.

Basu, S., & Gernald, J., & Oulton, N., & Srinivasan, S. (2003) "The case of the missing productivity growth: or, does information technology explain why productivity accelerated in the United States but not the United Kingdom?" NBER Working Paper 10010.

Boothe, P., & Roy, R. (2008) "Business sector productivity in Canada: what do we know?" *International Productivity Monitor*, Vol. 16, pp. 3-13.

Calvin, L., & Martin, P. (2010) "Labour intensive U.S. fruit and vegetable industry competes in a global market," *Amber Waves*, United States Department of Agriculture, Economic Research Service, Vol.8, Issue 4.

CAPI (2011) *Canada's agri-food destination – A new strategic approach*, The Canadian Agri-Food Policy Institute, Ottawa.

Luke Chan, M. W., & Mountain, D. C. (1983) "A regional analysis of productivity change in Canadian agriculture, with special reference to energy prices," *Canadian Journal of Agricultural Economics*, Vol. 31, No. 3, pp. 319-330.

Chavas, J. P., & Cox, T. L. (1992) "A nonparametric analysis of the influence of research on agricultural productivity," *American Journal of Agricultural Economics*, Vol. 74, No. 3, pp. 583-591.

Christensen, L. R. (1975) “Concepts and measurements of agricultural productivity,” *American Journal of Agricultural Economics*, Vol. 57, No. 5, pp. 910-915.

Diewert, E., & Morrison, C. (1986) “Output and Productivity Indexes for Changes in the Terms of Trade,” *The Economic Journal*, Vol. 96, No. 383, pp. 659-679.

Diewert, E., & Fox (2008) "On the estimation of returns to scale, technical progress and monopolistic markups," *Journal of Econometrics*, Vol. 145, No. 1-2, pp. 174-193.

De Long, J. B., & Summers, L. H. (1991) “Equipment investment and economic growth,” *Quarterly Journal of Economics*, Vol. 106, No. 2, pp. 445-502.

Färe, R., & Grosskopf, S., & Margaritis, D. (2008) “U.S. productivity in agriculture and R&D,” *Journal of Productivity Analysis*, Vol. 30, Issue 1, pp. 7-12.

Fuglie, K. O. (2010) “Total factor productivity in the global agricultural economy: data evidence from FAO,” Chapter 4 in Alston, J. M., & Babcock, B. A., & Pardey, P. G. (eds.) *The shifting patterns of agricultural production and productivity worldwide*. The Midwest Agribusiness Trade Research and Information Center, Iowa State University, Ames pp. 64-95.

Glover-Amengor, M., & Tetteh, F.M. (2008) “Effect of pesticide application rate on yield of vegetables and soil microbial communities,” *West African Journal of Applied Ecology*, Vol. 12.

Griliches, Z. (1992) “The search for R&D spillovers,” *The Scandinavian Journal of Economics*, Vol. 94, 1992 Supplement, pp. 29-47.

Gu, W., & Kaci, M., & Maynard, J-P., & Sillamaa, M-A (2002) “The changing composition of the Canadian workforce and its impact on productivity growth” in Baldwin, J., & Harchaoui, T. (eds.) *Productivity growth in Canada-2002*. Catalogue no. 15-204-XIE2001000, Statistics Canada.

Hall, R.E., & Jones, C. I. (1999) “Why do some countries produce so much more output per worker tan others?” *Quarterly Journal of Economics*, Vol. 114, No. 1.

Harchaoui, T., & Kaci, M., & Maynard, J-P. (2001) “Appendix 1 – The Statistics Canada Productivity Program: concepts and methods” in Statistics Canada (2001) *Productivity growth in Canada*, Cat. No. 15-204-XIE, Statistics Canada. http://www.statcan.gc.ca/imdb-bmdi/document/1402_D3_T9_V1-eng.pdf.

Harchaoui, T., & Tarkhani, F. (2002) “A comprehensive revision of the capital input methodology for Statistics Canada’s multifactor productivity program” in Baldwin, J., & Harchaoui, T. (eds.) *Productivity growth in Canada-2002*. Catalogue no. 15-204-XIE2001000, Statistics Canada.

Hayami, Y., & Ruttan, V. W. (1970) “Agricultural productivity differences among countries,” *The American Economic Review*, Vol. 60, No. 5, pp. 895-911.

Headey, D., & Alauddin, M., & Rao, D. (2010) “Explaining agricultural productivity growth: an international perspective,” *Agricultural Economics*, Vol. 41, pp. 1-14.

Hulten, C. R. (1978) “Growth accounting with intermediate inputs,” *The Review of Economic Studies*, Vol. 45, No. 3.

ICP (2011) *Canada’s innovation imperative*, Institute for Competitiveness and Prosperity, Toronto.

James, J. S., & Pardey, P. G., & Alston, J. M. (2008) “Agricultural R&D policy: a tragedy of the international commons,” University of Minnesota, Department of Applied Economics, Staff Papers, No. 43094.

Jorgenson, D. W. (2001) “Information technology and the U.S. economy,” *American Economic Review*, Vol. 91, No. 1, pp. 1-32.

Jorgenson, D. W., & Stiroh, K. J. (2000) “Raising the speed limit: U.S. economic growth in the information age,” *Brookings Papers on Economic Activity*, Vol. 31 (2000-1), pp. 125-236.

Jorgenson, D. W., & Ho, M. S., & Stiroh, K. J. (2002) *Growth of U.S. industries and investments in information technology and higher education*, NBER Chapters, No. 10627.

Latruffe, L. (2010) “Competitiveness, productivity and efficiency in the agricultural and agri-food sectors,” OECD Food, Agriculture and Fisheries Working Paper No. 30, OECD, Paris.

Leeder, J. (2011) “Harvesting the truth about Canada’s farms,” The Globe and Mail, Wednesday, June 29.

Lemaitre, G. (1988) “A look at response errors in the labour force survey,” *Canadian Journal of Statistics*, Vol. 16 (Issue Supplement S1), pp. 127-141.

Lio, M., & Liu, M-C. (2008) “Governance and agricultural productivity: a cross-national analysis,” *Food Policy*, Vol. 33, pp. 504-512.

Lobell, D. B., & Schlenker, W., & Costa-Roberts, J. (2011) “Climate trends and global crop production since 1980,” *Science Magazine*, May.

Loureiro, M. L. (2009) “Farmers’ health and agricultural productivity,” *Agricultural Economics*, Vol. 40, pp. 381–388.

Lucas, R. (1988) “On the mechanics of economic development,” *Journal of Monetary Economics*, Vol. 22, pp. 3-42.

Makki, S., & Tweeten, L., & Thraen, C. (1999) “Investing in research and education versus commodity programs: implications for agricultural productivity,” *Journal of Productivity Analysis*, Vol. 12, pp. 77-94.

Mankiw, G., & Romer, D., & Weil, D. (1992) “A contribution to the empirics of economic growth,” *The Quarterly Journal of Economics*, Vol. 107, Issue 2, pp. 407-437.

Maynard, J. (2005) “Annual measure of the volume of work consistent with the SNA: the Canadian experience,” Economic Analysis Methodology Paper Series: National Accounts, Cat. No. 11F0026MIE, No.005. Statistics Canada, August. http://www.statcan.ca/english/research/11F0026MIE/11F0026MIE2005005.pdf.

Mosheim, R., & Knox Lovell, C. A. (2009) “Scale economies and inefficiency of U.S. dairy farms,” *American Journal of Agricultural Economics*, Vol. 91, No. 3, pp. 777-794.

Mullen, J. D. (2007) “Productivity growth and the returns from public investment in R&D in Australian broadacre agriculture,” *The Australian Journal of Agricultural and Resource Economics*, Vol. 51, pp. 359–384.

Mullen, J. D., & Cox, T. L. (1995) “The returns from research in Australian broadacre agriculture,” *Australian Journal of Agricultural Economics*, Vol. 39, No. 2, pp. 105-128.

Mullen, J. D., & Crean, J. (2007) *Productivity growth in Australian agriculture: trends, sources, performance*, Australian Farm Institute.

Oklahoma State University (2000) *Soil fertility research highlights 2000*, Oklahoma State University – Deparment of Plant and Soil Sciences, Stillwater.

OECD (2001) *Measuring productivity – Measurement of aggregate and industry-level productivity Growth*, OECD, Paris. http://www.oecd.org/dataoecd/59/29/2352458.pdf.

Rao, S., & Sharpe, A., & Smith, J. (2005) "An analysis of the labour productivity growth slowdown in Canada since 2000," *International Productivity Monitor*, Vol. 10, pp. 3-23.

Rayner, A. J., & Whittaker, J. M., & Ingersen, K. A. (1986) "Productivity growth in agriculture (revisited): a measurement framework and some empirical results," *Journal of Agricultural Economics*, Vol. 37, No. 2, pp. 127-150.

Savage, S. (2011) *A detailed analysis of US organic crops*, http://www.scribd.com/doc/47829728/A-Detailed-Analysis-of-US-Organic-Crops.

Sharpe, A. (2010a) "Unbundling Canada's weak productivity performance: the way forward," CSLS Research Report 2010-02, February. http://www.csls.ca/reports/csls2010-02.pdf.

Sharpe, A. (2006) "The relationship between ICT investment and productivity in the Canadian economy: a review of the evidence," CSLS Research Report 2006-05, December. http://www.csls.ca/reports/csls2006-05.pdf.

Sharpe, A. (2010b) "Can sectoral reallocations of labour explain Canada's abysmal productivity performance?" *International Productivity Monitor*, Vol. 19, Spring, pp. 40-45. http://www.csls.ca/ipm/19/IPM-19-sharpe.pdf.

Sharpe, A., & Arsenault, J. F. (2009) "New estimates for multifactor productivity growth for the Canadian provinces," *International Productivity Monitor*, Number 18, Spring, pp. 25-37. http://www.csls.ca/ipm/18/IPM-18-Sharpe-Arsenault.pdf.

Sharpe, A., & Thomson, E. (2010a) "New estimates of labour, capital, and multifactor productivity growth and levels for Canadian provinces at the three-digit NAICS level, 1997-2007," CSLS Research Report 2010-06, June. http://www.csls.ca/reports/csls2010-06.pdf.

Sharpe, A., & Thomson, E. (2010b) "Insights into Canada's abysmal post-2000 productivity performance from decompositions of labour productivity growth by industry and province," *International Productivity Monitor*, Number 20, Fall, pp. 48-67. http://www.csls.ca/ipm/20/IPM-20-Sharpe-Thomson.pdf.

Standing Committee on Agriculture and Agri-Food (2010) *Competitiveness of Canadian Agriculture*, May 2010.

Statistics Canada (2001) *Productivity Growth in Canada*, Cat. No.15-204-XIE, Statistics Canada. http://www.statcan.gc.ca/imdb-bmdi/document/1402_D3_T9_V1-eng.pdf.

Statistics Canada (2002) *Productivity Growth in Canada – 2002*, Cat. No. 15-204-XIE, Statistics Canada. http://www.statcan.gc.ca/pub/15-204-x/15-204-x2001000-eng.pdf.

Statistics Canada (2007) *North American Industry Classification System (NAICS) – Canada*, Cat. No.12-501-XIE, Statistics Canada, Standards Division. http://www.statcan.ca/english/freepub/12-501-XIE/12-501-XIE2007001.pdf.

Statistics Canada (2008) *Methodology of the Canadian Labour Force Survey*, Cat. No.71-526-X, Statistics Canada. http://www.statcan.gc.ca/pub/71-526-x/71-526-x2007001-eng.pdf.

Statistics Canada (2010) *The input-output structure of the Canadian economy*, Cat. No.15-201-X, Statistics Canada. http://www.statcan.gc.ca/pub/15-201-x/15-201-x2010001-eng.pdf.

Solow, R. (1957) "Technical change and the aggregate production function," *The Review of Economics and Statistics*, Vol. 39, No. 3, pp. 312-320.

*S*tewart, B., Veeman, T., and Unterschultz, J. (2009) "Crops and livestock productivity growth in the Prairies: the impacts of technical change and scale," *Canadian Journal of Agricultural Economics*, Vol. 57, No. 3, pp. 379–394.

Stewart, W.M. (2002) "Fertilizer contributions to crop yield," *News & Views*, Potash & Phosphate Institute.

Sweetman, A. (2002) "Working smarter: education and productivity," in *The Review of Economic Performance and Social Progress 2002: Towards a Social Understanding of Productivity*, Vol. 2, Centre for the Study of Living Standards & The Institute for Research on Public Policy.

STIC (2011) *State of the Nation 2010 – Canada's science, technology and innovation system: imagination to innovation – Building Canadian paths to prosperity*, Science Technology and Innovation Council.

Tang, J., Rao, S., and Li, M. (2010) "Sensitivity of capital stock and multifactor productivity estimates to depreciation assumptions: A Canada-U.S. comparison," *International Productivity Monitor*, Vol. 20, Spring, pp. 22-47. http://www.csls.ca/ipm/20/IPM-20-Tang-Rao-Li.pdf.

Tang, J., and Wang, W. (2004) "Sources of aggregate labour productivity growth in Canada and the United States," *Canadian Journal of Economics*, Vol. 37, No. 2, pp. 421-444.

The Conference Board of Canada (2009) Canada – Income per capita country ranking, July. http://www.conferenceboard.ca/hcp/details/economy/income-per-capita.aspx.

The Conference Board of Canada (2009). *Making milk: the practices, players, and pressures behind dairy supply management*, Research Report.

Transparency International (2010) *Corruption perceptions index 2010 results*. http://www.transparency.org/policy_research/surveys_indices/cpi/2010/results

Trichur, R. (2011) "Down on the Farm with Robo-Milker," The Globe and Mail, Thursday, March 17.

Trueblood, M., & Ruttan, V. (1992) "A comparison of multifactor productivity calculations of the U.S. agricultural sector," Staff Paper, P92-29, University of Minnesota. http://ageconsearch.umn.edu/bitstream/14165/1/p92-29.pdf.

Tweeten, L., & Gray, R., & Salcedo-Baca, S. (2002) "Structure of farming under freer trade among NAFTA countries," in Loyns, R.M.A., & Meilke, K., & Knutson, R. D., & Yunez-Naude, A. (eds.) *Structural change as a source of trade disputes under NAFTA*, Proceedings of the Seventh Agricultural and Food Policy Systems Information Workshop, pp. 98-128. http://www.farmfoundation.org/news/articlefiles/902-teal.pdf

van Ark, B. (2002) "Understanding productivity differentials among OECD countries: a survey," in Sharpe, A., & St-Hillaire, F., & Banting, K. (edited by) (2002) *The review of economic performance and social progress – Towards a social understanding of productivity*, Institute for Research and Public Policy and The Centre for the Study of Living Standards, pp. 69-92.

Veeman, T., & Gray, R. (2010) "The shifting patterns of agricultural production and productivity in Canada," Chapter 6 in Alston, J. M., & Babcock, B. A., & Pardey, P. G. (edited by) (2010) *The shifting patterns of agricultural production and productivity worldwide*. The Midwest Agribusiness Trade Research and Information Center, Iowa State University, Ames, pp 123-147.

Appendix 1: Productivity Concepts

There are several different concepts of productivity, each based on different measures of output and inputs. In this subsection, we define the input, output, and productivity measures used throughout this report:

- The **labour services input** is defined as total *quality adjusted* hours worked in a particular sector or in the market sector as a whole. It is the weighted sum of hours worked across different categories of workers, with the weights being equal to relative labour compensation shares.

- **Labour quality** (also known as **labour composition**) is defined residually as the difference between growth in labour services and growth in hours worked (*unadjusted* by quality). In Canada, the variables used to differentiate labour quality are education (four education levels), experience (proxied by seven age groups) and class of workers (paid employees versus self-employed workers). Overall, there are 56 different categories of workers.[38]

- The **capital services input** represents the flow of services provided by the capital stock. The difference between capital stock and capital services stems from the fact that not all forms of capital assets provide services at the same rate. Short-lived assets, such as a car or a computer, must provide all of their services in just a few years before they completely depreciate. Office buildings provide their services over decades. As a consequence, over a single year, a dollar's worth of a car provides relatively more capital services than a dollar's worth of a building. Thus, capital services growth is driven by: 1) increases in the level of **capital stock**; and 2) shifts in the **capital composition** caused by more investment in assets that provide relatively more services per dollar of capital stock (i.e. short lived assets). The capital input calculated by Statistics Canada's Canadian Productivity Accounts includes services provided by the stock of fixed reproducible business assets (equipment and machinery, buildings, and engineering structures), inventories, and land.

- **Capital intensity** is defined either as capital services per hour worked *or* capital stock per hour worked.

- Labour, land, and capital inputs are the **primary inputs** used in any production process. There are, however, other inputs which are either transformed or used up by the

[38] For more information on how Statistics Canada calculates labour quality, see Gu *et al.* (2002).

production process. These inputs are known as **intermediate inputs**, and Statistics Canada breaks them down into three main groups: energy, material, and services inputs.

- **Gross output** consists of all the goods and services produced by an economy, sector, industry or establishment during a certain period of time.

- **Gross domestic product (GDP)** measures the contribution of primary inputs to the production process. While gross output refers to an actual physical quantity, there is no physical representation of value added. Statistics Canada calculates three types of GDP estimates: 1) GDP at factor cost; 2) GDP at basic prices; and 3) GDP at market prices. The difference between GDP at factor cost and GDP at basic prices is that the latter includes net taxes *on factors of production* (such as property taxes, capital taxes, and payroll taxes). GDP at basic prices differs from GDP at market prices in that it does not include net taxes *on products* (e.g. sales taxes, fuel taxes). This report uses mainly estimates for GDP at basic prices.

- **Labour productivity** is defined either as real GDP per hour worked (*unadjusted* by quality) or gross output per hour worked (*unadjusted* by quality). It is important to keep in mind that labour productivity can be expressed either in growth rates or in levels. The economics literature largely focuses on productivity growth rates, which reflect increases in *real* output per hour. In this report we are also interested in making level comparisons. Ideally, productivity level comparisons are done in current dollars (i.e. using *nominal* GDP), as these estimates capture changes in relative prices. However, this frequently leads to confusion, as the growth rates (calculated using real output per hour) would not be consistent with the levels (calculated using nominal output per hour). To avoid this problem, focus was given to productivity levels calculated using real GDP (although nominal labour productivity levels are also discussed).

- **Intermediate input productivity** is defined as real gross output per unit of intermediate input used. Statistics Canada classifies intermediate inputs into three broad categories: energy, materials, 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, etc.), while the services input category aggregates several different subcategories of services.

- **Crop yields** are a measure of land productivity. They are calculated as the quantity produced of a certain crop per hectare of seeded area. In this report, crop yields are defined as kilograms per hectare of seeded area.

- **Multifactor Productivity (MFP)** growth is measured as the difference between real output growth and combined input growth. MFP reflects output growth that is not accounted for by input growth. Thus, MFP captures the residual effects of several elements of the production process, such as improvements in technology and organizations, capacity utilization, increasing returns to scale, among other factors. It also embeds errors due to the mismeasurement of inputs. This report provides two sets of MFP growth estimates, one calculated using a value added basis, and the other calculated using a gross output basis.

Appendix 2: Decomposing Labour Productivity Growth by Sector[39]

To begin we note that at any given point in time

$$P \equiv \frac{Q}{H} = \frac{\sum Q_i}{H} = \frac{\sum H_i P_i}{H} = \sum P_i\, h_i \qquad (1)$$

where

$P = Aggregate\ labour\ productivity\ level$
$P_i = Labour\ productivity\ level\ in\ sector\ i$
$H = Aggregate\ hours\ worked$
$H_i = Hours\ worked\ in\ sector\ i$
$h_i = Share\ of\ hours\ worked\ in\ sector\ i$
$Q = Aggregate\ real\ output$
$Q_i = Real\ output\ of\ sector\ i$

Equation (1) says that aggregate labour productivity P is equal to the weighted average of labour productivity in each of the sectors that make up the economy. The weight for each sector is its share of the total number of hours worked in the economy.

Because we are interested in how shifts in hours worked across sectors affect aggregate labour productivity growth, we must move beyond a single point in time. Equation (2) expresses the absolute change in aggregate labour productivity from period 0 to period 1, $\Delta P = P^1 - P^0$ where superscripts denote the period.

$$\Delta P = \sum h_i^0 \Delta P_i + \sum P_i^0 \Delta h_i + \sum \Delta h_i \Delta P_i \qquad (2)$$

In equation (2) h_i^0 and P_i^0 are respectively the share of total hours worked in sector *i* and the level of labour productivity in sector *i* in period 0, expressed in dollars.

In order to obtain economically meaningful sectoral contributions to aggregate productivity growth, we adjust the second term of equation (2) by subtracting the average level of labour productivity $\bar{P}^0$ from the level of labour productivity in each sector in period 0, P_i^0. In the third term, we subtract the average change in labour productivity $\Delta\bar{P}$ from the change in labour productivity in each sector, ΔP_i. The first adjustment ensures that an increase in the hours share in a sector with a below-average labour productivity level makes a negative contribution to aggregate labour productivity growth. The second adjustment also ensures that an increase in the hours share in a sector with below-average absolute growth in labour productivity makes a

[39] This appendix is an extract from Sharpe and Thomson (2010b).

negative contribution to aggregate labour productivity growth. The result of these adjustments is equation (3):

$$\Delta P = \sum h_i^0 \Delta P_i + \sum (P_i^0 - \bar{P}^0)\Delta h_i + \sum \Delta h_i (\Delta P_i - \Delta \bar{P}) \qquad (3)$$

We are able to subtract $\bar{P}^0$ from equation (2) because the terms $\Delta\bar{P}\Delta h_i$ and $\bar{P}^0\Delta h_i$ each sum to zero across all sectors, since $\bar{P}^0$ and $\Delta\bar{P}$ are constant and all changes in hours share Δh_i sum to zero across sectors.

The three terms in equation (3) represent respectively the within-sector, reallocation level and reallocation growth effects. The within-sector effect captures the change in labour productivity within a sector. The reallocation level effect indicates whether changes in hours share have favoured sectors with above- or below-average labour productivity levels. The reallocation growth effect is the sum of the product of the absolute change in the share of hours worked and the absolute change in the labour productivity level for each of the *i* sectors. It measures whether an economy is subject to a phenomenon akin to Baumol's cost disease, *i.e.* the tendency of labour to move towards sectors with relatively small absolute increases in labour productivity. A negative reallocation growth effect at the aggregate level means that labour is moving to sectors with relatively smaller absolute labour productivity increases.

There are some limitations to this analysis. First, the analysis assumes that differences in technological, institutional, and market structures across sectors lead to differences in average levels of labour productivity, even if marginal products are the same. It also assumes that when a sector loses or gains labour, the changes in output per hour are equal to the sector's average output per hour worked. Second, these results are sensitive to the level of disaggregation. For instance, we use 12 sectors at the two-digit level. If within a sector, resources shift from one subsector to another, and these subsectors have different levels of labour productivity, then the measured impact of the reallocation effect on aggregate labour productivity growth would be different.

Appendix 3: Sources of Labour Productivity (Value Added) Growth

The growth accounting framework used in this report assumes a Cobb-Douglas production function such that

$$Y = AK^{\alpha}L^{1-\alpha} \quad (1)$$

where Y is real output, K stands for capital services, L for labour input (quality adjusted hours), A for multifactor productivity and α is the share of output that takes the form of capital compensation. The labour input L can be decomposed into hours (H) and labour quality (QL):

$$L = H * QL \quad (2)$$

Capital services can be decomposed into capital stock (SK) and capital composition (QK):

$$K = SK * QK \quad (3)$$

Capital intensity (KI) is defined as:

$$KI = \frac{K}{H} \quad (4)$$

Using (1), (2), and (4), the components of labour productivity *growth* can be decomposed as follows:

$$\Delta LP = \Delta Y - \Delta H = [\Delta QL * (1-\alpha)] + [\Delta KI * \alpha] + \Delta A \quad (5)$$

where LP stands for labour productivity and Δ is the percentage change.