The Contribution of Productivity Growth to Net Farm Income in Canada and the United States

Sean A. Cahill

Research and Analysis Directorate
Agriculture and Agri-Food Canada

June 2013

Paper presented at the 2013 IATRC Symposium "Productivity and Its Impacts on Global Trade", June 2-4, Seville. The author thanks Eldon Ball, ERS, USDA for generously providing data for the United States. Any policy views, whether explicitly stated, inferred or interpreted from the contents of this paper should not be represented as reflecting the views of Agriculture and Agri-Food Canada.

1 Introduction

Agricultural productivity growth is typically associated with a wide range of bene…ts, including higher net farm incomes, overall economic growth, greater national food security, more a¤ordable food and resource conservation. The multiplicity of positive outcomes attributed to productivity growth has led governments to develop policies and programs that are designed to enhance this growth.

It is important, when considering the possible need for policy intervention, to …rst determine how signi…cant a role productivity growth plays in achieving these outcomes. In particular, productivity growth is commonly assumed to be an important contributor to net farm income (productivity growth will improve the 'prosperity of the farm sector'). Yet, to date, little research has been done to quantify this relationship.

This paper proposes a methodology that can be used to measure relationship between productivity growth and real net farm income growth. The methodology involves the use of Bennet price change and quantity change indicators, which are applied to data from agricultural production accounts for Canada and the United States. The next section outlines the methodology and the third section provides a brief description of the data. The fourth section presents the results from the decompositions. These results lead into the discussion in the last section, which posits a relationship between government policies that stimulate productivity growth and international market prices.

2 Methodology

The analysis is based on a national agricultural production account where, in each year, N inputs are used to produce M outputs. Countries vary in terms of the number and type of outputs produced, as well as in the number and type of inputs used, but the approach used to construct the accounts is the same across countries.

Individual output quantities, which are measured as gross outputs, are denoted as $y_{1;t}; y_{2;t}; ::::; y_{M;t}$ and the respective prices for these outputs in year t are denoted as $p_{1;t}; p_{2;t}; ::::; p_{M;t}$, where each price includes any subsidy

that is tied to production of that output. Individual input quantities are the variables $x_{1;t}; x_{2;t}; : : : ; x_{N;t}$: While the set of inputs varies between countries, the Nth input in each country is always essentially the same type of input both in its de…nition and the way in which it is measured. This commonality is important to this analysis because this input plays an important role in any country comparison. Nominal prices for all but the Nth input are denoted as the variables $w_{1;t}; w_{2;t}; : : : ; w_{N\,i\,1;t}$; where each price is adjusted by any rebate that is given for that input.[1]

In the production account, the total value of gross output must equal the total cost of all inputs, i.e.

$$\mathbf{X}_{\substack{M \\ i=1}} p_{i;t} y_{i;t} \acute{} \mathbf{X}_{\substack{N\,i\,1 \\ i=1}} w_{j;t} x_{j;t} + D_t \; ; \tag{1}$$

where D_t is a residual that interpreted as the value of services from the Nth input. D_t adjusts to ensure that the identity holds in each year. In the account, then, rearranging (1) and using more compact notation,

$$D_t = R_t \; ¡ \; C_t \; ; \tag{2}$$

where $R_t = \mathbf{P}_{\substack{M \\ i=1}} p_{i;t} y_{i;t}$ and $C_t = \mathbf{P}_{\substack{N\,i\,1 \\ i=1}} w_{j;t} x_{j;t}$ (the total cost of $N \; ¡ \; 1$ inputs):

For purposes of this analysis, the production accounts for Canadian and U.S. agriculture, input N is operator and unpaid family labour, i.e. this input is the claimant of the residual D_t. Thus, D_t can be interpreted as the nominal return to operator and unpaid family labour or, more simply, as nominal net farm income. Net farm income is assumed to be used by operators and unpaid family members to purchase consumer goods and services. Since the prices of these goods and services increase in aggregate at the rate of general in‡ation, nominal levels of net farm income (e.g. between $D_{t\,i\,1}$ and D_t) are converted into real terms. This is done by de‡ating (2), i.e.

$$D_t^r = D_t / h_t \; \acute{} \; R_t / h_t \; ¡ \; C_t / h_t \; ; \tag{3}$$

[1] Transfer payments made to farmers by governments – i.e. payments that are are decoupled from production – are not included in output prices: The payments may, nevertheless, be capitalized into asset values (particularly land), and therefore they may have an indirect impact on the account if they raise user costs of capital. This e¤ect, if it exists, is treated as exogenous, much in the same way that the e¤ects of other market forces on output and input prices are taken as given.

where h_t is the consumer price index (CPI) for all goods and services in year t; the CPI has a base year b so that the nominal value in any year t, when de‡ated by h_t is expressed in year b ('real') dollars. Unlike nominal values D_t; D_t^r can be compared over time and is interpreted as follows: if $D_t^r > D_{t-1}^r$, the quantity of goods and services that can be purchased with net farm income has increased.

Using (3), the growth in real net farm income between $t-1$ and t is:

$$D_t^{rg} = D_t^r - D_{t-1}^r \times (R_t/h_t - R_{t-1}/h_{t-1}) - (C_t/h_t - C_{t-1}/h_{t-1}); \quad (4)$$

i.e. this is the di¤erence between the growth in the total real value of gross output and the growth in the total real cost of $N-1$ inputs. Expression (4) is central to the analysis since the decomposition that follows shows how D_t^{rg} can be related to productivity growth.

The approach used to link D_t^{rg} to productivity growth is based on Diewert (2005), where it is shown that a change in the nominal value of revenue or cost can be expressed as the sum of an indicator of price change and a corresponding indicator of quantity change. There are several possible formulas for these indicators, and their properties can be assessed with a range of tests similar to those used to assess conventional index number formulas like the Fisher Ideal price index. Of the candidates, the Bennet indicators of price and quantity change are 'well-behaved' in that they satisfy all of the tests that are analogous to those met by the Fisher ideal price index. – see Diewert(2005, p.331, Prop. 2).

While Bennet indicators of price and quantity change are primarily used in the context of nominal changes in value, it is possible to adjust prices for in‡ation in one year when comparing data between two adjacent years – see Diewert(2005, p. 341). This adjustment accomplishes two things. First, the general in‡ation component in the Bennet indicators of price and quantity change – which would otherwise a¤ect the magnitude (and possibly sign) of these indicators – are removed. Second, the adjustment makes it possible to decompose growth in real net farm income into in‡ation-adjusted Bennet indicators of price and quantity change.

Diewert(2005, p. 342, expr. 81) shows that a change in the total nominal value of gross output between year $t-1$ and year t; i.e. $R_t - R_{t-1}$, using the de…nition of R_t given with expression (2) above – has the decomposition:

$$p_t \cdot y_t - p_{t-1} \cdot y_{t-1} = p_t \cdot y_t - p_t^* \cdot y_t + I_R(p_{t-1}; p_t^*; y_{t-1}; y_t) + V_R(p_{t-1}; p_t^*; y_{t-1}; y_t) \quad (5)$$

where: p_t is a $1 \times M$ matrix of output prices $[p_{1;t}; p_{2;t}; \ldots; p_{M;t}]$; y_t is a $1 \times M$ matrix of gross output quantities $[y_{1;t}; y_{2;t}; \ldots; y_{M;t}]$; p_t^* is a $1 \times M$ matrix of inflation-adjusted output prices $[p_{1;t}^*; p_{2;t}^*; \ldots; p_{M;t}^*]$; $p_{i;t}^* = p_{i;t}(h_{t-1}/h_t)$ is the inflation-adjusted price for output i; $i = 1; 2; \ldots M$;

$$I_R(p_{t-1}; p_t^*; y_{t-1}; y_t) = \sum_{i=1}^{M} y_{i;t}^a \left(p_{i;t}^* - p_{i;t-1} \right) \quad (6a)$$

is the inflation-adjusted Bennet indicator of output price change; $y_{i;t}^a$ is the arithmetic average of the quantity of output i in year t and in year $t-1$; i.e. $y_{i;t}^a = (y_{i;t} + y_{i;t-1})/2$;

$$V_R(p_{t-1}; p_t^*; y_{t-1}; y_t) = \sum_{i=1}^{M} p_{i;t}^{a*} (y_{i;t} - y_{i;t-1}) \quad (6b)$$

is the corresponding inflation-adjusted Bennet indicator of gross output quantity change; and $p_{i;t}^{a*}$ is the arithmetic average of the inflation-adjusted price of output i in t and the nominal price in $t-1$, i.e. $p_{i;t}^{a*} = (p_{i;t}^* + p_{i;t-1})/2$:

The term $p_t \cdot y_t - p_t^* \cdot y_t$ or, perhaps more obviously $(p_t - p_t^*) \cdot y_t$ is the part of the change in nominal value that is needed for the real value of total revenue to remain constant. Diewert(2005, p. 341) refers to this as the "value change due to general inflation". If, for example, there were no change in any output quantity ($y_t = y_{t-1}$) between $t-1$ and t (i.e. if $y_t = y_{t-1}$) and if all inflation-adjusted prices in t were the same as unadjusted prices in $t-1$ (i.e. if $p_t^* = p_{t-1}$); each unadjusted price in t would still have to increase at the rate of general inflation ($h_t/h_{t-1} - 1$) in order for real revenue to remain unchanged.

By the definition of inflation adjusted prices p_i^* and by the fact that each price is adjusted in the same way, $p_t^* = (h_{t-1}/h_t)p_t$: Substitution of this expression for p_t^* in (5) and rearrangement/elimination of terms gives:

$$(h_{t-1}/h_t)p_t \cdot y_t - p_{t-1} \cdot y_{t-1} = I_R(p_{t-1}; p_t^*; y_{t-1}; y_t) + V_R(p_{t-1}; p_t^*; y_{t-1}; y_t) \quad (5')$$

which, with multiplication through by $(1=h_{t\,i\,1})$;(5[0]) can be expressed as:

$$R_t^{gh} = R_t=h_t \;¡\; R_{t\,i\,1}=h_{t\,i\,1} \qquad (7)$$
$$´\; I_R\,(p_{t\,i\,1}; p_t^{¤}; y_{t\,i\,1}; y_t)=h_{t\,i\,1} + V_R(p_{t\,i\,1}; p_t^{¤}; y_{t\,i\,1}; y_t)=h_{t\,i\,1}\,:$$

Expression (7) shows that growth in the real value of total gross output between $t ¡ 1$ and t is equivalent to the sum of an in‡ation-adjusted Bennet indicator of output price change and an in‡ation-adjusted Bennet indicator of gross output quantity change, where both indicators are expressed in year b dollars:

It follows from the preceding derivations (dispensing with the intermediate steps) that the growth in the real (year b dollar) cost of $N ¡ 1$ inputs has the decomposition:

$$C_t^{gh} = C_t=h_t \;¡\; C_{t\,i\,1}=h_{t\,i\,1} \qquad (8)$$
$$´\; I_C(w_{t\,i\,1}; w_t^{¤}; x_{t\,i\,1}; x_t)=h_{t\,i\,1} + V_C(w_{t\,i\,1}; w_t^{¤}; x_{t\,i\,1}; x_t)=h_{t\,i\,1}\,;$$

where: w_t is a $1£N ¡ 1$ matrix of input prices $[w_{1;t}; w_{2;t}; : : : ; w_{N\,i\,1;t}]$; x_t is a $1£N ¡ 1$ matrix of input quantities $[x_{1;t}; x_{2;t}; : : : ; x_{N\,i\,1;t}]$; $w_t^{¤}$ is a $1£N ¡ 1$ matrix of in‡ation-adjusted input prices $[w_{1;t}^{¤}; w_{2;t}^{¤}; : : : ; w_{N\,i\,1;t}^{¤}]$; $w_{j;t}^{¤} = w_{j;t}\,(h_{t\,i\,1}=h_t)$ is the in‡ation-adjusted price for input j; $j = 1; 2; :::N ¡ 1$;

$$I_C\,(w_{t\,i\,1}; w_t^{¤}; x_{t\,i\,1}; x_t) = \sum_{j=1}^{N\,i\,1} x_{j;t}^{a} \left(w_{j;t}^{¤} \;¡\; w_{j;t\,i\,1} \right) \qquad (9a)$$

is the in‡ation-adjusted Bennet indicator of input price change; $x_{j;t}^{a}$ is the arithmetic average of the quantity of input j in year t and in year $t ¡ 1$ i.e. $x_{j;t}^{a} = (x_{j;t} + x_{j;t\,i\,1})=2$;

$$V_C\,(w_{t\,i\,1}; w_t^{¤}; x_{t\,i\,1}; x_t) = \sum_{j=1}^{N\,i\,1} w_{j;t}^{a¤}\,(x_{j;t} \;¡\; x_{j;t\,i\,1}) \qquad (9b)$$

is the corresponding in‡ation-adjusted Bennet indicator of output quantity change; and $w_{j;t}^{m¤}$ is the arithmetic average of the in‡ation-adjusted price in t and the nominal price in $t ¡ 1$, i.e. $w_{j;t}^{a¤} = (w_{j;t}^{¤} + w_{j;t\,i\,1})=2$:

Substitution of (7) and (8) into (4) gives the following decomposition of real net farm income growth:

$$D_t^{rg} = I_R(p_{t-1}; p_t^*; y_{t-1}; y_t)/h_{t-1} - I_C(w_{t-1}; w_t^*; x_{t-1}; x_t)/h_{t-1} + Z_t^{N-1}; \quad (10)$$

where

$$Z_t^{N-1} = V_R(p_{t-1}; p_t^*; y_{t-1}; y_t)/h_{t-1} - V_C(w_{t-1}; w_t^*; x_{t-1}; x_t)/h_{t-1}: \quad (11)$$

Z_t^{N-1} is the real value of 'in‡ation-adjusted N-1 factor productivity growth' that occurs between year $t-1$ and t. Notice that, unlike most productivity measures, Z_t^{N-1} is expressed in year b dollars, rather than as a percentage or proportion. This is an attractive feature of the decomposition approach since it can be used to estimate the value of productivity growth to the agricultural sector

Also notice that Z_t^{N-1} is de…ned over $N-1$, not N, inputs. It represents the di¤erence between growth in total gross output and growth in all inputs but the Nth. As such it is a partial, but almost complete, measure of total factor productivity growth; that is why the term 'in‡ation-adjusted $N-1$ factor productivity growth' is used to describe it.

Expression (10) shows that growth in real net farm income is comprised of three components: (i) an in‡ation-adjusted Bennet output price change indicator; minus (ii) an in‡ation-adjusted Bennet input price change indicator ; plus (iii) in‡ation-adjusted N-1 factor productivity growth. All three components are valued in year b dollars.

Note that (10) is similar to that for a Bennet decomposition of a change in pro…ts within a net output framework and where the in‡ation-adjusted N-1 factor productivity growth term is interpreted as a measure of overall e¢ciency – see Diewert(2000, p. 5, expr. 13). Expression (10) is also similar to the pro…t decomposition formula derived by Han and Hughes(1999, pp. 32-33), once the gross productivity and scale impacts in that framework are combined and terms are eliminated. For the decomposition in Han and Hughes, however, the measure of productivity change is total factor productivity growth, rather than in‡ation-adjusted N-1 factor productivity growth, since pro…t is the dollar amount of revenue in excess of the opportunity cost of all inputs in an account with no residual claimants. Where owners of …rms

pay a wage or salary to operators (e.g., as in a corporation with common shareholders), such 'pure pro…t' can exist, since it is disbursed as dividends to the owners once all inputs are assigned a price in the …rm's accounts. To measure the change in returns to a residual claimant or claimants, and to decompose this change, expression (10) is therefore more appropriate than the decomposition formulas in Diewert(2000) or Han and Hughes(1999).[2]

Similar decompositions to expression (10) have also been derived by Lawrence, Diewert and Fox (2004) and Gordon, Dupont, Fox and Grafton (2003). These studies, however, not only allow for pure pro…t, but also treat the change in net income as the ratio of net income in year t to that in year t ¡ 1; i.e. they use the ratio $D_t=D_{t\,i\,1}$ – see Lawrence, Diewert and Fox (2004, p. 4) and Gordon, Dupont, Fox and Grafton (2003, p. 3). Finally, in an article published by the U.K. Central Statistical O¢ce an approach similar in spirit to expression (10) was used, but in relation to a measure referred to as 'normal income' – see CSO(1961).

3 Data

The output and input data used to estimate expressions (10) and (11) are, as noted, from production accounts for Canadian and U.S. agriculture. The Canadian data (AAFC production account for Canadian agriculture) are documented in Cahill and Rich(2012), while the U.S. data are documented in Ball, Bureau, Nehring and Somwaru(1997). The CPI series for Canada are from Statistics Canada (CANSIM Table 326-0021) and for the U.S. from the Bureau of Labor Statistics (series ID CUUR0000SA0).

The production accounts for both countries comprehensively cover outputs and inputs (M and N are quite large in both cases). Rather than make the calculations across all inputs and outputs, aggregates were computed with both data sets so that M = 3 and N = 5. The three output aggregates are crops, livestock and secondary outputs. The …ve input aggregates are capital (machinery, buildings, livestock), land, hired labour, materials (purchased materials, within-sector produced materials, energy and

[2] Reference to a residual claimant, the owner of the "$N+1^{st}$" input is made in Diewert(2000,pp. 4,6). This approach can can be viewed as paying 'pure pro…t' to some …xed factor that does not enter the production account.

services) and operator/unpaid family labour. Prices for all outputs and for all inputs but operator and unpaid family labour are the constructed price indexes for these aggregates. Output and most input quantities other than operator and unpaid family labour are measured as constant dollar implicit quantities that correspond to the price indexes. The time period covered is 1961-2006.[3] Annex Tables 1a, 1b, 2a and 2b provide the complete Canadian and U.S. data sets used for the computations

4 Results

Expressions (2) and (4) are evaluated with data from Annex Tables 1a, 1b, 2a and 2b to obtain real net farm income series for Canada and the United States covering the period 1961-2006. Similarly, expressions (6a), (6b), (9a) and (9b) are used with the data to compute the de‡ated in‡ation-adjusted Bennet output price change and in‡ation-adjusted N-1 input price change indicator series for both countries. For each country, all four of these latter series are de‡ated by the CPI series for that country and are then used to evaluate expressions (10) and (11).

The estimated real net farm income series for Canada and the United States are presented in Figures 1 and 2 respectively. The patterns for both countries are quite similar. Both …gures show a substantial increase in real net farm income in the mid-1970s, followed by a general decline until the mid-1980s. There was a recovery in both countries until the early 1990's, after which real net farm income in both countries seemed to stabilize somewhat. The average level of real net farm income in the second half of the period 1961-2006 generally remained below the average level in the …rst half of the period. In fact, there was an average annual decline in real net farm income of 36 million 1996$C in Canada, while in the United States, the average annual decline was over 1.1 Billion 1996$US over the whole 1961-2006 period.

[3] Eldon Ball (ERS) provided a customized version of the U.S. data for this analysis. In particular, the measurement of U.S. land input di¤ers from that described in Ball, Bureau, Nehring and Somwaru(1997), since the service price of land is exogenous here, whereas it is endogenous (the price is based on the residual) in standard ERS account. Also, rather than valuing operator and unpaid family labour at opportunity cost, this is treated the same way as in the Canadian account, i.e. the value of this labour is determined residually as net farm income.

The results from the decomposition of real net farm income growth for Canada are presented in Table 1. The …rst component of the decomposition, the in‡ation-adjusted Bennet output price change indicator, averaged -511 million $1996 annually over the period. This result is due to nominal prices for all three types of output increasing at an average rate that was less than the average rate of general in‡ation; this added up to a large average negative impact on real net farm income growth.

The average annual value of the in‡ation-adjusted Bennet input price change indicator over 1961-2006 was -88 million $C1996. This re‡ects a average annual decline in the real prices of capital and materials that o¤set increases in the real prices of land and hired labour. This outcome had a positive e¤ect on real net farm income growth, but this was dwarfed by the e¤ect of decreasing real output prices; when combined, the contribution of in‡ation-adjusted net price change (the di¤erence between the output and input price components) was -423 million $C1996 annually.

In‡ation-adjusted N-1 factor productivity growth contributed an average 387 million $C1996 annually to real net farm income growth between 1961 and 2006. When viewed in isolation from the price changes this supports the notion referred to in the Introduction – productivity growth certainly increased real net farm income. The rub is in the output price changes, which more than negated the real bene…ts from productivity growth on average.[4]

The parallel set of results for the United States is presented in Table 2, where there is a pattern that is identical to Canada, although relative magnitudes are di¤erent across the four components. In particular, the in‡ation-adjusted Bennet output price change indicator, which averaged nearly -4521 million $US1996 annually between 1961 and 2006 was much larger than the in‡ation-adjusted Bennet input price change indicator, which was an average -280 million $US1996 annually over the period. The ratio of the two indicators was 16:1 on average, versus the ratio in Canada which was about 6:1.[5]

[4] It is important to recognize that, within the farm sector, some farms will have experienced positive real net farm income growth over certain periods and some will have experienced net farm income growth that was more negative than the annual average for the whole of Canada. Since the data are for the whole of Canada, this type of di¤erentiation cannot be made.

[5] Some of this di¤erence may be due to di¤erences in measurement – some inputs like

As in Canada, in‡ation-adjusted N-1 factor productivity growth made a large positive contribution to real net farm income in the United States, averaging 3073 million $US1996 annually over the 1961-2006 period. This growth, large as it was, did not o¤set the real price e¤ects, so that there was an average annual decline in real net farm income of 1169 million $US1996. This is consistent with results obtained by Ball, Färe, Grosskopf and Margaritis (2008, p.) who observe that total factor productivity growth and price change e¤ects "are apparently o¤setting " in their decomposition using a panel of U.S. state level production accounts.

The relative contribution of output price, input price and productivity growth elements are summarized in Figures 3 and 4 for Canada and the United States respectively. Data for (i) the in‡ation-adjusted Bennet output price change indicator, (ii) the negative of in‡ation-adjusted Bennet input price change indicator and (iii) in‡ation-adjusted N-1 factor productivity growth are each sorted in ascending order. Then each sorted series is presented side by side (data plots are ordered as sorted series (i)-(iii) going left to right). Observations that are above the x axis had a positive e¤ect on real net farm income growth, while those below the x axis had a negative e¤ect. What these two …gures illustrate is the importance of real output prices in determining the negative real net farm income growth. The in‡ation-adjusted Bennet output price change indicators are not only more frequently negative than positive but there are many more years with very large negative price e¤ects. The overall range of the output indicators show how volatile real output prices were over the period – much more so than either the input or productivity growth components.

The …gures also illustrate the fact that the negative of in‡ation-adjusted Bennet input price change indicator were more frequently positive than negative, but that the pattern of magnitudes was more evenly distributed than for output.

The in‡ation-adjusted N-1 factor productivity growth series both show similar patterns – positive e¤ects were not only more frequent but tended to be larger. The negative values are typical – irrespective of how it is measured, productivity growth can vary between positive and negative values from year

land, chemicals and hired labour are quality adjusted in the US account, whereas in the Canadian account no adjustments of this type are made.

to year. This reinforces the view that, when attempting to measure average productivity growth, it is important to use a time period that is long enough to remove random year over year variations.

5 Conclusion

The results presented in the previous section, while shedding some light on the link between productivity growth and real net farm income growth, do not explain why the potentially large positive impact of productivity growth has been so soundly negated in both countries. It would appear that there has been no lasting e¤ect of productivity growth on real net farm incomes, largely because of an overall decline in real output prices.

The fact that real net farm incomes have persistently declined in spite of substantial productivity growth suggests that more productivity growth may not help out on the income front. This does not mean that investments that stimulate productivity growth would not pay o¤ in some other way (see the list of other associated positive bene…ts given in the Introduction). It just means that there is a question mark regarding the wisdom of policies that seek to raise real net farm incomes through productivity growth.[6]

A more promising avenue for further investigation of the observed juxtaposition might be to measure the e¤ect of productivity growth on market prices. In particular, it seems likely that the output-expanding e¤ects of productivity growth have had a price-depressing e¤ect. Canada and the United States are large exporters of agricultural commodities and, while it is di¢cult to measure the overall importance of these two countries to international trade, it is certainly possible to determine their importance for speci…c commodities. For example, between 2002 and 2006, Canada and the United States together accounted for about 34% of world wheat exports, 58% of world corn exports and about 45% of world canola exports.[7] These numbers suggest that the impact of productivity growth must be measured

[6] There is a counterfactual argument for investments in productivity growth, of course. This says that real net farm incomes in both countries would have been lower without productivity growth. This argument, however, treats output prices as if they evolved independently of the output-stimulating e¤ect of productivity growth.

[7] These numbers are based on calculations with UNComtrade data. They are shares of world total trade volume in each case.

in terms of an open economy trade framework, so that nature and size of the inter-relationship between productivity growth and world market prices can be better understood.

References

[1] Ball, V.E., R. Färe, S. Grosskopf and D. Margaritis(2008). "R&D and U.S. Agricultural Productivity: A State Panel Approach", paper presented at the International Association of Agr-food Economics (AIEA2) meetings, Bologna, 19-21 June.

[2] Ball, V. E., J.-C. Bureau, R. Nehring and A. Somwaru (1997). "Agricultural Productivity Revisited", American Journal of Agricultural Economics, 79, 1045–1063.

[3] Cahill, S. A. and T. Rich (2012), "Measurement of Canadian agricultural productivity growth", in Fuglie, K. ,S.L. Wang and V.E. Ball (eds), Productivity Growth in Agriculture: An International Perspective, Wallingford: CABI

[4] CSO (1961). "Productivity Measurement in Agriculture", Economic Trends, No. 91 (a publication of the Central Statistical O¢ce, U.K.)

[5] Diewert, W.E. (2005). "Index Number Theory Using Di¤erences Rather than Ratios", The American Journal of Economics and Sociology, 64, 311-360.

[6] Diewert, W.E. (2000). "Productivity Measurement using Di¤erences Rather Than Ratios", Discussion Paper 2000/1, School of Economics, University of New South Wales.

[7] Gordon, D.V., D.P. Dupont, K.J. Fox and R.Q. Grafton (2003). "Pro…t and Price E¤ects of Multi-Species Individual Transferable Quotas", Discussion Paper 2003-08, Department of Economics, University of Calgary.

[8] Han, S.-H. and Hughes, A. (1999). "Pro…t Composition Analysis: A Technique for Linking Productivity Measurement & Financial Performance", Research and Information Paper TRP 99-5, New South Wales Treasury.

[9] Lawrence, D., W.E. Diewert and K.J. Fox (2004). "The Contributions of Productivity, Price Changes and Firm Size to Productivity", paper downloaded as a pdf from the worldwide web via the url: http://www.ipeer.ca/SSHRC.htm

Figure 1. Real Net Farm Income, Canada, 1961-2006

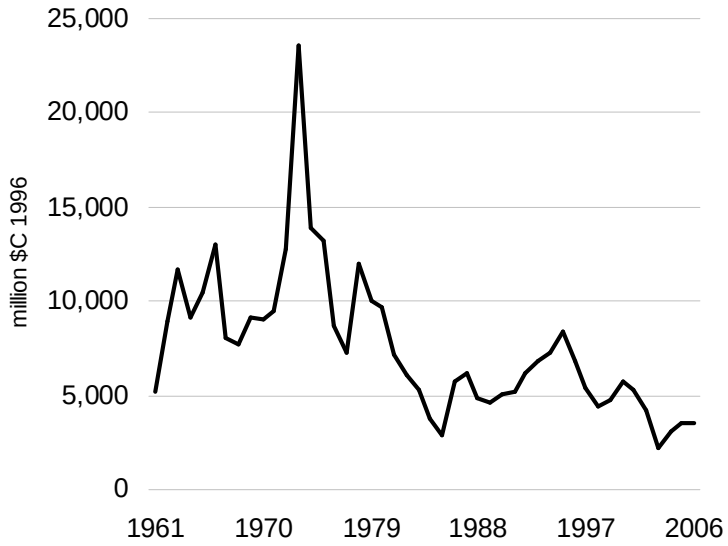


Figure 2. Real Net Farm Income, United States, 1961-2006

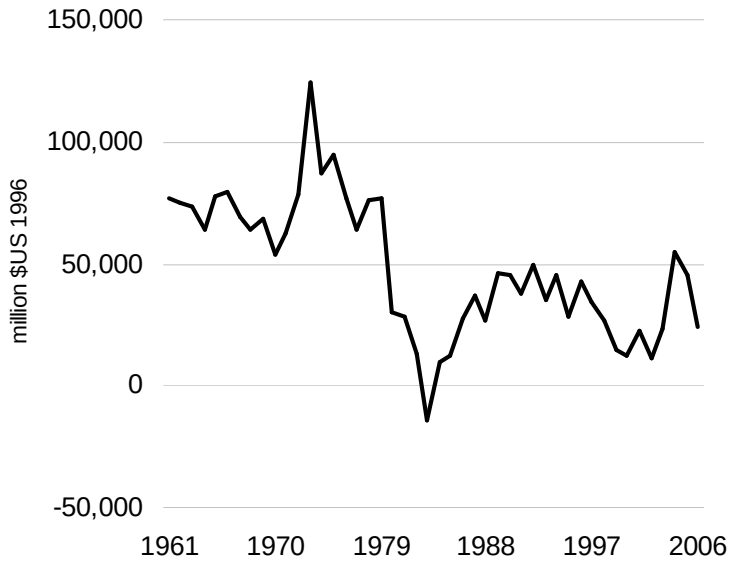


Table 1. Decomposition of Real Net Farm Income Growth, Canada, 1961-2006

Component	Average value 1961-2006 (million $C 1996)
A: Inflation-adjusted Bennet output price change indicator	-511
B: Inflation-adjusted Bennet N-1 input price change indicator	-88
C: Inflation-adjusted gross output quantity change indicator	801
D: Inflation-adjusted N-1 input quantity change indicator	414
Inflation-adjusted net price change (A-B)	-423
Inflation-adjusted N-1 factor productivity growth (C-D)	387
Net Farm Income Growth [(A-B)+(C-D)]	-36

Notes:

1. Components are derived using (11) and (12) with data from Annex Table 1a and Annex Table 1b.
2. All components are deflated and so are expressed in 1996 $US.

Table 2. Decomposition of Real Net Farm Income Growth, United States, 1961-2006

Component	Average value 1961-2006 (million $US 1996)
A: Inflation-adjusted Bennet output price change indicator	-4521
B: Inflation-adjusted Bennet N-1 input price change indicator	-280
C: Inflation-adjusted gross output quantity change indicator	4014
D: Inflation-adjusted N-1 input quantity change indicator	941
Inflation-adjusted net price change (A-B)	-4242
Inflation-adjusted N-1 factor productivity growth (C-D)	3073
Net farm income growth [(A-B)+(C-D)]	-1169

Notes:
1. Components are derived using (11) and (12) with data from Annex Table 2a and Annex Table 2b.
2. All components are deflated and so are expressed in 1996 $US.

Figure 3. Ascending Inflation-Adjusted Bennet Output Price Change Indicator, - Inflation-Adjusted Bennet Input Price Change Indicator and Inflation-Adjusted N-1 Factor Productivity Growth, Canadian Agriculture, 1961-2006

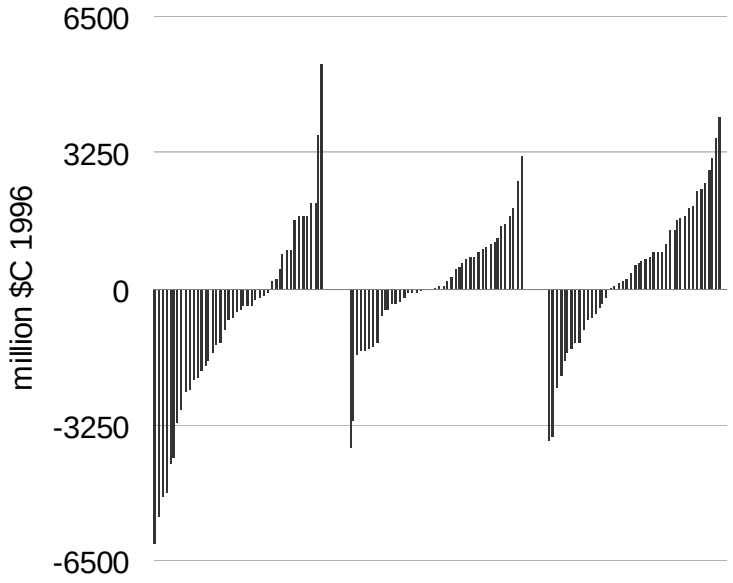
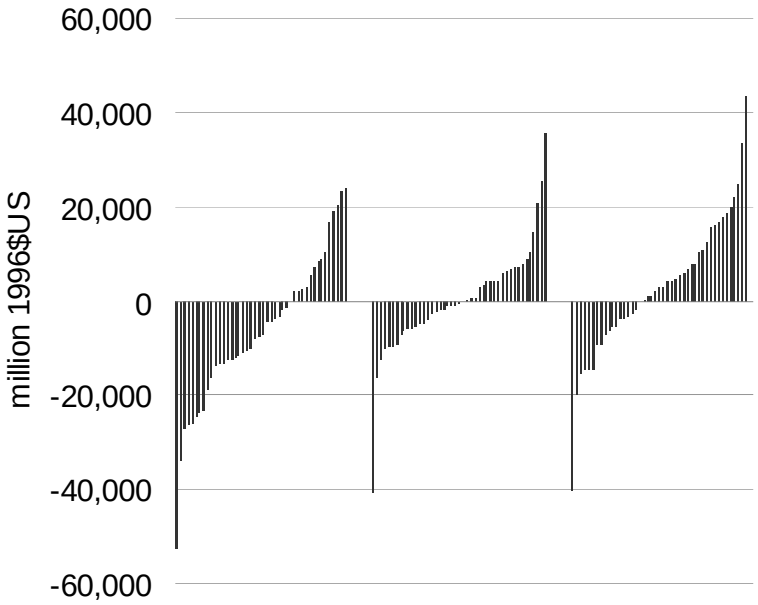


Figure 4. Inflation-Adjusted Bennet Output Price Change Indicator, - Inflation-Adjusted Bennet Input Price Change Indicator and N-1 Factor Productivity Growth, United States Agriculture, 1961-2006



Annex Table 1a. Production Account Data for Canadian Agriculture, Outputs,1961-2006
with CPI series

	output price indexes			constant dollar implicit output quantities			
year	crops	livestock	secondary	crops	livestock	secondary	CPI
	----------	1961=1	----------	----------	million 1961 $	----------	1996=1
1961	1.000	1.000	1.000	1610	2282	99	0.177
1962	0.971	1.062	1.025	2346	2276	99	0.179
1963	0.993	1.048	1.049	2683	2425	100	0.181
1964	1.018	1.020	1.075	2359	2483	98	0.184
1965	1.067	1.082	1.110	2582	2478	98	0.189
1966	1.070	1.192	1.178	3086	2605	97	0.197
1967	1.015	1.210	1.239	2555	2579	96	0.204
1968	0.921	1.231	1.291	2728	2557	98	0.211
1969	0.899	1.352	1.317	2909	2618	101	0.222
1970	0.940	1.331	1.347	2696	2823	103	0.228
1971	0.907	1.349	1.385	3146	2823	111	0.235
1972	1.268	1.542	1.455	2826	2954	114	0.246
1973	2.319	1.982	1.597	2985	2984	118	0.265
1974	2.400	2.074	1.837	2650	2879	113	0.295
1975	2.281	2.111	2.071	3113	2965	115	0.326
1976	2.004	2.097	2.237	3363	2937	121	0.350
1977	2.004	2.168	2.418	3496	2810	104	0.378
1978	2.353	2.668	2.685	3793	2914	89	0.412
1979	2.612	3.170	3.094	3469	3071	88	0.450
1980	3.095	3.194	3.447	3587	3202	97	0.495
1981	2.823	3.328	3.755	4124	3228	97	0.557
1982	2.625	3.424	3.969	4305	3278	99	0.618
1983	2.979	3.335	4.081	4083	3227	99	0.654
1984	3.018	3.501	4.210	3973	3280	112	0.682
1985	2.586	3.474	4.210	4341	3311	121	0.709
1986	2.484	3.620	4.123	4932	3301	133	0.738
1987	2.500	3.745	4.073	4692	3384	142	0.771
1988	2.855	3.685	4.138	3822	3573	150	0.801
1989	2.561	3.797	4.256	4489	3613	155	0.841
1990	2.229	3.809	4.395	5149	3646	178	0.882
1991	2.192	3.797	4.451	5060	3826	187	0.931
1992	2.417	3.831	4.567	4737	4073	198	0.945
1993	2.516	4.041	4.937	5299	3887	202	0.963
1994	2.794	4.065	5.184	5351	4145	221	0.964
1995	3.352	3.927	5.308	5393	4333	245	0.985
1996	3.125	3.938	5.482	5745	4486	274	1.000
1997	3.042	3.996	5.777	5376	4564	311	1.017
1998	2.789	3.843	5.873	5769	4850	312	1.027
1999	2.534	4.007	6.007	6305	4805	313	1.045
2000	2.650	4.427	6.290	5974	4979	310	1.073
2001	2.997	4.668	6.463	5124	5183	307	1.100
2002	3.320	4.445	6.709	4571	5505	310	1.125
2003	2.981	4.070	6.952	5856	5062	310	1.156
2004	2.667	4.101	6.933	6399	5308	301	1.178
2005	2.641	4.204	7.100	6646	5301	325	1.204
2006	3.007	4.308	7.134	6536	5056	324	1.227

Annex Table 1b. Production Account Data for Canadian Agriculture, Inputs,1961-2006

	input price indexes				constant dollar implicit output quantities				operator/ unpaid family
year	capital	land	hiredlabour	materials	capital	land	hiredlabour	materials	labour
	1961=1	1961=1	$/week	1961=1	m. 1961$	m. 1961$	m. weeks	m. 1961$	m. hours
1961	1.000	1.0000	42.330	1.000	689	179	4.809	2003	1644
1962	1.036	1.0430	44.250	1.043	691	180	4.671	2000	1603
1963	1.051	1.1230	46.180	1.038	710	180	4.325	1979	1561
1964	1.063	1.2390	48.110	1.043	739	181	4.111	2066	1518
1965	1.080	1.3990	50.030	1.070	777	181	4.311	2108	1475
1966	1.117	1.5720	53.520	1.111	823	180	3.977	2294	1430
1967	1.161	1.7930	57.010	1.118	859	179	3.972	2371	1382
1968	1.202	1.9910	60.500	1.084	872	178	3.925	2329	1334
1969	1.262	2.0180	63.980	1.068	876	177	3.761	2394	1285
1970	1.296	2.0410	67.470	1.077	857	176	3.832	2439	1236
1971	1.314	2.0700	82.770	1.101	859	176	3.842	2526	1186
1972	1.390	2.2670	98.070	1.177	892	175	3.627	2680	1161
1973	1.469	2.7700	113.370	1.616	960	175	3.417	2770	1136
1974	1.665	3.6590	128.670	2.079	1037	174	3.421	2711	1110
1975	1.815	4.6690	143.970	2.187	1132	174	3.687	2685	1083
1976	1.944	5.6040	154.400	2.166	1228	174	4.633	2799	1057
1977	2.090	6.4970	164.820	2.157	1295	174	4.539	2789	1028
1978	2.351	7.8070	175.240	2.280	1358	173	4.073	2957	1006
1979	2.698	9.7980	185.660	2.604	1438	173	4.255	3140	977
1980	3.017	12.5310	196.080	2.995	1470	173	4.536	3135	932
1981	3.267	14.1970	212.640	3.350	1497	172	4.125	3152	929
1982	3.418	14.3470	229.190	3.287	1477	172	4.305	3244	909
1983	3.591	13.8110	245.740	3.343	1443	172	4.937	3332	891
1984	3.707	13.2360	262.290	3.684	1414	171	5.226	3403	868
1985	3.801	12.3340	278.840	3.603	1357	171	5.716	3436	841
1986	3.957	11.4870	299.660	3.262	1298	170	5.900	3565	831
1987	3.998	10.9020	320.470	3.080	1243	170	6.030	3711	808
1988	4.069	11.0140	341.280	3.296	1190	170	5.520	3708	784
1989	4.188	12.2020	362.100	3.483	1143	170	5.553	3770	767
1990	4.267	13.0230	382.910	3.276	1093	169	5.327	3901	757
1991	4.242	13.0620	391.090	3.213	1049	169	6.029	3940	742
1992	4.385	12.7650	399.260	3.248	1010	169	5.945	4053	736
1993	4.636	12.9270	407.440	3.359	1002	169	6.320	4188	727
1994	4.930	13.6490	415.610	3.576	986	170	6.371	4520	698
1995	5.086	14.8680	423.790	3.896	975	170	6.360	4610	679
1996	5.195	15.9560	432.670	4.238	961	171	6.524	4669	667
1997	5.396	17.8220	441.540	4.092	975	171	6.134	4859	657
1998	5.590	19.0690	450.420	3.957	990	171	6.932	5093	641
1999	5.782	20.0430	459.300	3.788	980	170	6.945	5260	617
2000	5.818	20.9690	468.170	3.908	975	170	7.101	5413	604
2001	5.971	21.8290	483.120	4.276	962	170	6.670	5381	584
2002	6.094	23.3680	498.060	4.358	960	170	6.663	5485	577
2003	5.747	25.0030	513.010	4.585	959	170	6.633	5333	566
2004	5.768	26.6770	527.950	4.423	960	170	6.575	5379	555
2005	5.710	28.5320	542.890	4.323	959	170	7.111	5493	541
2006	5.667	30.6200	521.020	4.512	948	171	7.650	5494	533

Annex Table 2a. Production Account Data for United States Agriculture, Outputs,1961-2006
with CPI series

year	output price indexes			constant dollar implicit output quantities			
	crops	livestock	secondary	crops	livestock	secondary	CPI
	----------	2005=1	----------	----------	million 2005 $	----------	1996=1
1961	0.377	0.267	0.218	59424	78034	4919	0.191
1962	0.400	0.273	0.224	60393	78759	4712	0.192
1963	0.410	0.262	0.226	62798	80715	4897	0.195
1964	0.410	0.251	0.233	60753	81915	4387	0.198
1965	0.419	0.275	0.236	64555	80691	4334	0.201
1966	0.458	0.313	0.252	63036	82873	3980	0.207
1967	0.429	0.296	0.256	65892	84469	4029	0.213
1968	0.418	0.309	0.280	67996	84739	3754	0.222
1969	0.424	0.345	0.298	70513	85076	3514	0.234
1970	0.452	0.353	0.313	66883	87423	3168	0.247
1971	0.452	0.348	0.329	74833	90727	3245	0.258
1972	0.497	0.402	0.351	75177	92050	3290	0.266
1973	0.707	0.522	0.400	79979	92750	3640	0.283
1974	0.899	0.480	0.429	72650	89231	3723	0.314
1975	0.779	0.500	0.420	83128	85984	3858	0.343
1976	0.775	0.518	0.474	82542	90073	3819	0.363
1977	0.743	0.516	0.550	89526	91709	3720	0.386
1978	0.788	0.643	0.592	91868	91547	4069	0.416
1979	0.843	0.767	0.654	100615	92902	4230	0.463
1980	0.934	0.744	0.678	91584	94606	4224	0.525
1981	0.961	0.742	0.724	104615	94913	3624	0.579
1982	0.911	0.743	0.726	105729	94912	7435	0.615
1983	1.144	0.723	0.771	80888	96091	7323	0.635
1984	1.030	0.748	0.788	102364	95571	6733	0.662
1985	0.915	0.706	0.745	107367	97199	8582	0.686
1986	0.892	0.715	0.726	100824	98434	8376	0.699
1987	0.884	0.755	0.754	101150	100214	9224	0.724
1988	1.005	0.777	0.828	89175	101341	10582	0.754
1989	0.999	0.828	0.871	101683	101161	10888	0.790
1990	0.973	0.870	0.879	108687	103617	10509	0.833
1991	0.946	0.825	0.878	107587	105893	10934	0.868
1992	0.937	0.802	0.912	117931	108712	10263	0.894
1993	0.965	0.837	0.989	106309	109964	10321	0.921
1994	0.970	0.777	1.014	125591	115568	9979	0.945
1995	1.048	0.748	1.028	111645	117411	11355	0.971
1996	1.091	0.801	1.084	121284	114957	10813	1.000
1997	1.017	0.810	1.077	127428	118903	12232	1.023
1998	0.948	0.783	0.995	125627	120142	14226	1.039
1999	0.890	0.767	0.962	127033	124001	15246	1.062
2000	0.897	0.801	0.974	129420	123699	14366	1.098
2001	0.910	0.862	0.962	128924	123426	15616	1.129
2002	0.931	0.755	0.971	123629	124935	14870	1.147
2003	0.970	0.835	1.002	128723	126860	14001	1.173
2004	1.028	1.003	1.040	140928	124193	15174	1.204
2005	1.000	1.000	1.000	135503	126687	14781	1.245
2006	1.034	0.923	1.043	128620	129785	15900	1.285

Annex Table 2b. Production Account Data for United States Agriculture, Inputs,1961-2006

year	input price indexes				constant dollar implicit output quantities				operator/ unpaid family labour
	capital	land	hiredlabour	materials	capital	land	hiredlabour	materials	
		---- 2005=1				million 2005 $			m. hours
1961	0.158	0.0004	0.251	0.228	26391	1430379	12797	94807	6867
1962	0.167	0.0007	0.263	0.235	26238	1429390	12776	99775	6788
1963	0.167	0.0006	0.270	0.241	26411	1427343	12754	102858	6328
1964	0.182	0.0010	0.304	0.236	26791	1422698	11502	101683	5991
1965	0.182	0.0010	0.332	0.245	27182	1414268	10828	101224	5895
1966	0.198	0.0014	0.371	0.259	27913	1402157	9754	109300	5498
1967	0.200	0.0014	0.404	0.255	28794	1386605	9062	110432	5117
1968	0.221	0.0022	0.433	0.256	29882	1367958	8770	109673	5080
1969	0.233	0.0025	0.458	0.267	30423	1346784	8846	111898	4881
1970	0.261	0.0034	0.476	0.279	30758	1324068	8914	114286	4516
1971	0.263	0.0033	0.482	0.290	31056	1301817	8815	115487	4422
1972	0.275	0.0037	0.499	0.309	31428	1282357	8779	119434	4401
1973	0.309	0.0051	0.580	0.404	31931	1268016	8909	123192	4301
1974	0.351	0.0057	0.637	0.489	33386	1261019	9482	117574	4144
1975	0.309	0.0024	0.680	0.493	34853	1262358	9630	114769	3951
1976	0.329	0.0028	0.756	0.506	35682	1268526	9738	122333	3829
1977	0.383	0.0056	0.829	0.517	36609	1275034	9499	120312	3743
1978	0.389	0.0045	0.914	0.545	37523	1277391	8932	135183	3773
1979	0.459	0.0072	0.957	0.625	38243	1272532	9268	140369	3775
1980	0.567	0.0120	1.000	0.685	39979	1262330	9194	140102	3695
1981	0.719	0.0191	0.978	0.725	39698	1249857	9152	131883	3678
1982	0.799	0.0231	1.219	0.724	38988	1238136	8213	130719	3469
1983	0.882	0.0266	1.064	0.764	38155	1229415	9072	131438	3180
1984	0.972	0.0290	1.153	0.747	36552	1223078	8451	127150	3171
1985	0.971	0.0262	1.293	0.703	35849	1217873	7659	125594	2945
1986	0.909	0.0206	1.258	0.659	33772	1212626	7366	125383	3073
1987	0.903	0.0187	1.263	0.676	31755	1206274	7517	125539	3095
1988	0.943	0.0182	1.388	0.774	30661	1198172	7761	123254	3092
1989	0.958	0.0170	1.566	0.807	29817	1189206	7279	122074	3043
1990	0.978	0.0179	1.854	0.801	29216	1180697	7245	129776	2715
1991	0.966	0.0173	1.831	0.803	28914	1174177	7225	130554	2666
1992	0.958	0.0171	1.902	0.793	28164	1171175	6836	129305	2661
1993	0.986	0.0180	2.085	0.823	27509	1172668	6804	134147	2496
1994	1.033	0.0192	2.178	0.828	26640	1177070	6627	138169	3153
1995	1.071	0.0208	2.246	0.849	26299	1182373	6864	142025	3122
1996	1.076	0.0216	2.444	0.925	25515	1186867	6556	134032	2845
1997	1.110	0.0233	2.485	0.905	25332	1189071	6899	145247	2732
1998	1.093	0.0221	2.592	0.831	25133	1187898	7026	153236	2486
1999	1.173	0.0270	2.586	0.819	25028	1183333	7310	155204	2378
2000	1.236	0.0305	3.197	0.844	24833	1176259	6169	153560	2249
2001	1.152	0.0257	3.344	0.876	24763	1167679	6245	152657	2231
2002	1.133	0.0260	3.296	0.871	24841	1158797	6310	151476	2249
2003	1.129	0.0267	3.311	0.892	24786	1150720	6191	155003	2155
2004	1.061	0.0216	3.923	0.956	24967	1143189	5694	152788	2141
2005	1.000	0.0164	3.986	1.000	25737	1135817	5673	153097	2127
2006	1.072	0.0215	4.264	1.029	25994	1128306	5426	158206	1975