Australian Government
Department of Agriculture

Cross-country Consistent Estimation of Agricultural Productivity

the Superlative vs. the Quantity-only Based Index Approach

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Yu Sheng (Eric) **ABARES**

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Introduction

Agricultural productivity growth is at the heart of dealing with global food security

- global agricultural total factor productivity grew at 1.0 pct a year between 1961 and 2010
- it accounted for a significant proportion of agricultural output growth and depressed global food price

However, agricultural productivity grows unevenly across countries

- No evidence of convergence in agricultural productivity between developed countries
- significant gap in productivity levels and growth between developed and developing countries

It is essential to measure and compare agricultural productivity across countries.

Introduction

The growth accounting based index method is widely used a tool to measure agricultural TFP at the industry level.

- initially developed by Jorgenson and Nishimizu (1978) and others
- large amount of literature including Ball et al. (2001, 2010), Fuglie (2010), Coelli and Rao (2005), Ludena et al. (2007) and Nin-Pratt and Yu (2009) etc.

Most of these studies can be categorised into two groups, depending on the index method that they have used

- the superlative index (i.e. Fisher or Törnqvist)
- the quantity-only based index approach (i.e. Malmquist)

Although the two methods should be equal theoretically (Fare 1994), it is not known which one performs better from an empirical perspective.

Introduction

This paper aims to apply both of these index methods to cross-country consistent data between the United States, Canada and Australia

- measure and compare agricultural TFP across countries
- examine the relative performance of the two methods

There are two contributions made to the literature

- provide a unique (national account based) dataset to compare agricultural production system across countries at the commodity and industry levels.
- examine the role of price information in constructing reliable index measure in international comparison.

The findings are not restricted to the three-country case, which has important policy implications for statistical agencies.

Methodology: TFP Measure

Agricultural TFP is measured as the ratio of gross output to total input such that

$$TFP^t = \frac{Y^t}{X^t} \quad (1)$$

$$\frac{dln(TFP^t)}{dt} = \frac{dln(Y^t)}{dt} - \frac{dln(X^t)}{dt} \quad (2)$$

where $Y^t = \sum_i y^t$ and $X^t = \sum_j x^t$ and y^t and x^t are output and input vectors.

How we aggregate different outputs and inputs into the corresponding quantity/volume index matters for the final results

- Form of transformation function (i.e. parametric vs. non-parametric)
- Weights to be used (i.e. real price vs. implicit price)

Methodology: the Superlative Index

The superlative index (i.e. Törnqvist) uses revenue shares as weights for output aggregation and cost shares as weights for input aggregation.

$$T_{TFP}^{t,t+1} = \frac{T_y^{t,t+1}(p^{t,t+1}, y^{t,t+1})}{T_x^{t,t+1}(w^{t,t+1}, x^{t,t+1})} \tag{3}$$

with

$$T_y^{t,t+1}(p^{t,t+1}, y^{t,t+1}) = \prod_{i=1}^{n} \left(\frac{y_i^{t+1}}{y_i^t}\right)^{\frac{1}{2}*[R_i^t + R_i^{t+1}]} \tag{4}$$

$$T_x^{t,t+1}(w^{t,t+1}, x^{t,t+1}) = \prod_{j=1}^{m} \left(\frac{x_j^{t+1}}{x_j^t}\right)^{\frac{1}{2}*[S_j^t + S_j^{t+1}]} \tag{5}$$

where $R_i^t = p_i^t y_i^t / \sum_i p^t y^t$ is the revenue share of the ith output and $S_j^t = w_i^t x_i^t / \sum_i w^t x^t$ is the cost share of the jth input at time t. Implicit in the formula are the price vectors of output p^t and of input w^t.

Methodology: the Quantity-only based Index

The quantity-only based index (i.e. Malmquist) uses implicit prices as weights for output and input aggregation

$$M_{TFP}^{t,t+1} = [M_0^t * M_0^{t+1}]^{1/2} = [\frac{D_0^t(x^{t+1},y^{t+1})}{D_0^t(x^t,y^t)} * \frac{D_0^{t+1}(x^{t+1},y^{t+1})}{D_0^{t+1}(x^t,y^t)}]^{1/2} \quad (7)$$

A distance function has been employed into the estimation of changes in aggregate input and output quantity

the measure could be further used to split the efficiency change component from a technical change component, implying that there could be off-frontier possibilities.

Methodology: Comparison of the Two

Following Kousmanen et al. (2004), the two index methods are equalised under certain conditions:

$$\frac{max_{p,w} \sum_{i=1}^{m} p_i y_{0i}}{\sum_{j=1}^{n} w_j x_{0j}}$$

s.t.

$$\sum_{i=1}^{m} p_i y_{ki} / \sum_{j=1}^{n} w_j x_{kj} \leq 1 \quad \text{with } k = 1, \dots, r$$

$$p_i, w_j \geq 0 \quad \text{with } i = 1, \dots, m; j = 1, \dots, n \qquad (11).$$

As in Coelli and Rao (2001), we need to impose the unit condition (sum $(w_j x_{kj})$=1) to solve Equation (11). This leads to a condition that equalize Equation (3) and to Equation (7), such that

$$D_x^t(x^t, y^t) = \max_{\rho,\omega} \{\frac{\rho y^t}{\omega x^t} : \frac{\rho y^t}{\omega x^t} \leq 1 \forall (y^t, x^t) \in L^t\} \qquad (12)$$

In particular, the retrieved implicit prices should be same as market prices and all observations located at the production frontier

Data Source

Agricultural input and output data are compiled based on the national accounts

- The United States: the US Census of Agriculture and the US Agricultural Resource and Management Survey
- Canada: the Statistics Canada CANSIM tables
- Australia: ABS Agricultural Census, ABARES Agricultural Commodity Statistics and ABARES Farm Surveys

Data are compiled at the commodity level

- there are 70 outputs and 28 inputs between 1960 and 2006
- both quantity and price variables are collection
- quality adjustment has been made for land, labour and some intermediate inputs

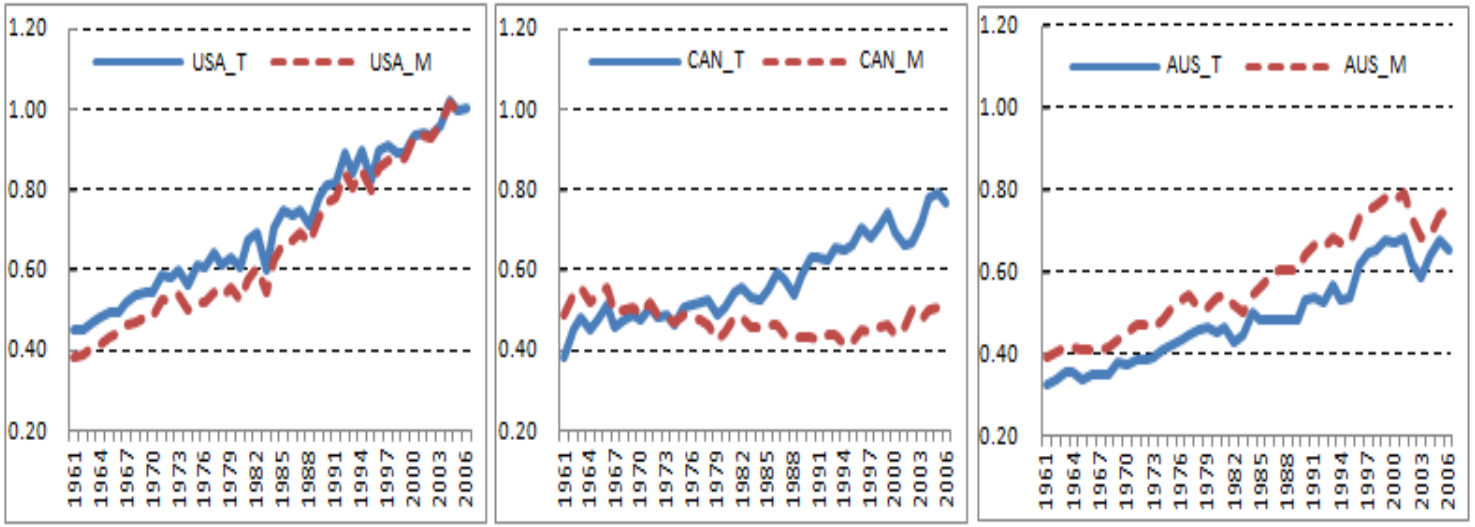
Empirical Results

The results obtained from this paper will be summarised in three areas

- Compare agricultural TFP estimates between the United States, Canada and Australia
- Examine difference in the results obtained from using the two methods and explore the potential reasons.
    - In particular, we need to compare the value shares used as weights for outputs and inputs in aggregation
    - This means we need to compare real prices to implicit prices, since the quantities are same.
- Explore the relative performance of the two methods at different aggregation levels
    - 2 outputs x 4 inputs
    - 6 outputs x 10 inputs
    - 16 outputs x 10 inputs

Figure 1 Cross-country consistent estimation of levels of agricultural TFP

(A) The United States (B) Canada (C) Australia



Note: The three figures display levels of agricultural TFP for the three countries. "USA", "CAN", and "AUS" denote the United States, Canada and Australia respectively. The last letter of each indicator, "_T" and "_M" stand for results from the Törnqvist and Malmquist index approaches respectively. Note that the level of agricultural TFP in the US in 2005 is set to one (as base country-year).

Compare Agricultural TFP between the United States, Canada and Australia

Agricultural TFP has been increasing in all the three countries over time

- The finding is consistent with our previous study
- It is consistent with literature using different methods and data.

The two index method will generate different agricultural TFP estimates across countries.

- The difference lies in agricultural TFP estimates for all countries
- The estimates obtained from the two approaches is opposite in direction for Canada

Reasons need to be provided to explain the difference in findings obtained from the two index methods

- The data are same so it will not cause the problem.

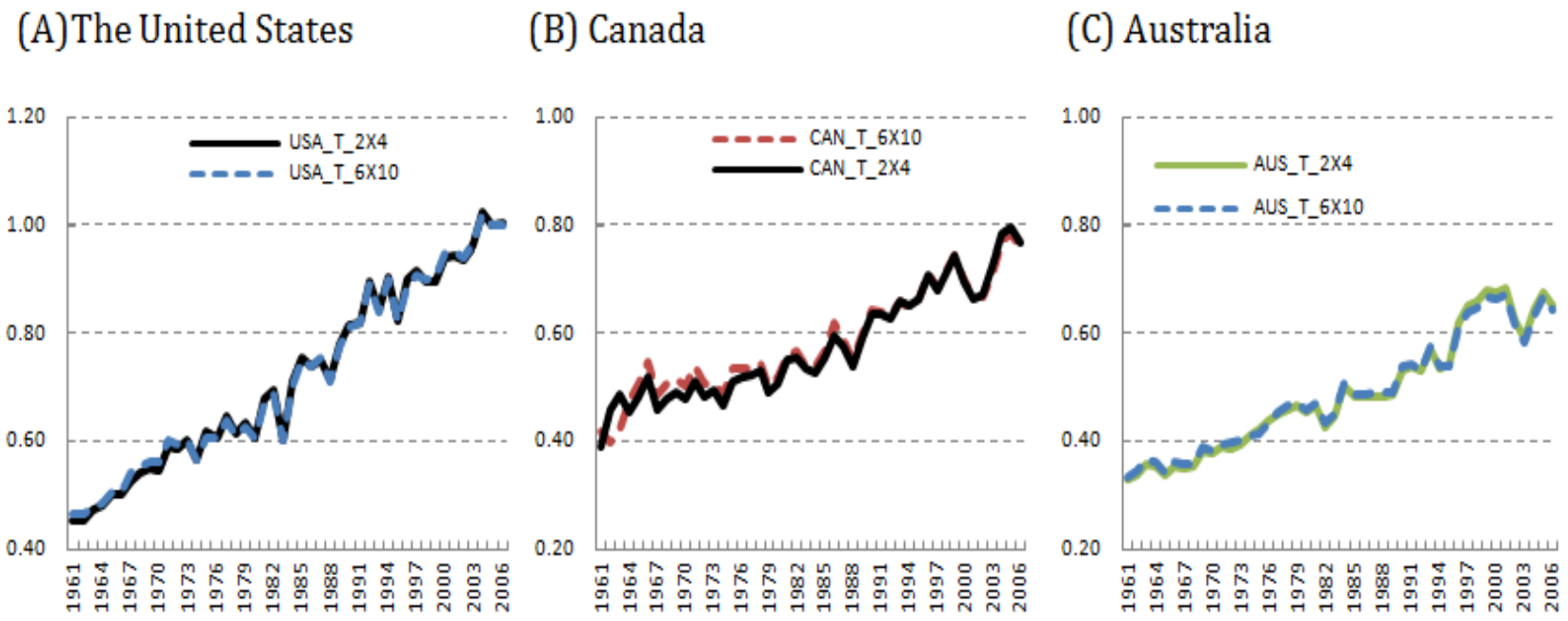
Table 1 Output/input share and real prices in the Törnqvist index: average between1960-2006

	USA	CAN	AUS	Real Price
Output Share in Total Revenue				
Crops Share (%)	55.2	52.0	49.5	1.022
Livestock Share (%)	44.8	48.0	50.5	0.724
Input Share in Total Expenditure				
Land Share (%)	8.6	8.8	10.2	0.432
Capital Share (%)	11.3	17.0	31.5	0.715
Labor Share (%)	24.8	18.3	19.9	0.298
Intermediate Inputs Share (%)	55.2	55.9	38.3	0.7

Table 2 Output/input share and implicit prices in the Malmquist index: average between1960-2006

	USA	CAN	AUS	Implicit Price
Output Share in Total Revenue				
Crops Share (%)	32.5	40.4	27.9	0.389
Livestock Share (%)	67.5	59.6	72.1	0.495
Input Share in Total Expenditure				
Land Share (%)	59.1	48.0	45.2	2.237
Capital Share (%)	19.9	18.3	20.8	2.472
Labor Share (%)	12.6	19.3	15.8	0.312
Intermediate Inputs Share (%)	8.4	14.4	18.3	0.741

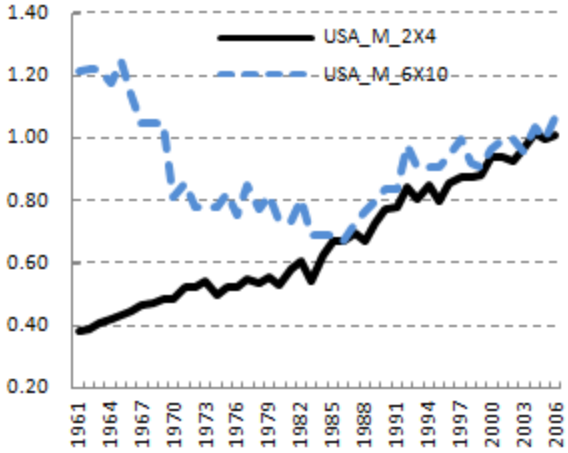
Figure 2 Comparison of estimated Törnqvist TFP growth: 2x4 model vs. 6x10 model



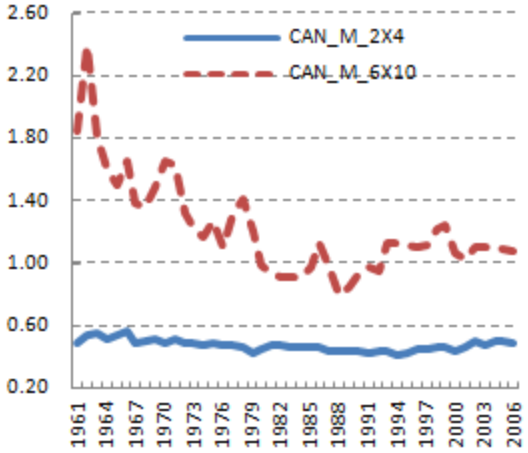
Note: The three figures display levels of agricultural TFP for the three countries. "USA", "CAN", and "AUS" denote the United States, Canada and Australia respectively. The last letter of each indicator, " _T", stands for the Törnqvist index. The number of each indicator, " _2x4" and "_6x10", denote results from 2-output and 4-input model and 6-output and 10-input model respectively. Note that the level of agricultural TFP in the US in 2005 is set to one (as base country-year).
Source: Authors' own estimation.

Figure 3 Comparison of estimated Malmquist TFP growth: 2x4 model vs. 6x10 model

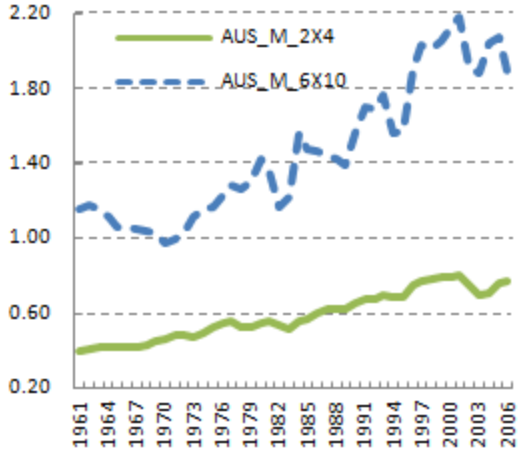
(A)The United States



(B) Canada



(C) Australia



Note: The three figures display levels of agricultural TFP for the three countries. “USA”, “CAN”, and “AUS” denote the United States, Canada and Australia respectively. The last letter of each indicator, “ _M”, stands for the Malmquist index. The number of each indicator, “ _2x4” and “_6x10”, denote results from 2-output and 4-input model and 6-output and 10-input model respectively. Note that the level of agricultural TFP in the US in 2005 is set to one (as base country-year).
Source: Authors' own estimation.

Conclusions

There are challenging issues both in the construction of cross-country consistent data as well as the choice of measurement methods.

We find that agricultural productivity in these three countries have generally been increasing during the period under study, though uneven across countries.

In terms of method comparison, agricultural TFP estimates obtained from using the superlative index outperforms those obtained from using the quantity-only based index.

Our finding points to the importance of price data collection work for cross-country consistent agricultural productivity comparison.

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Questions and Comments

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