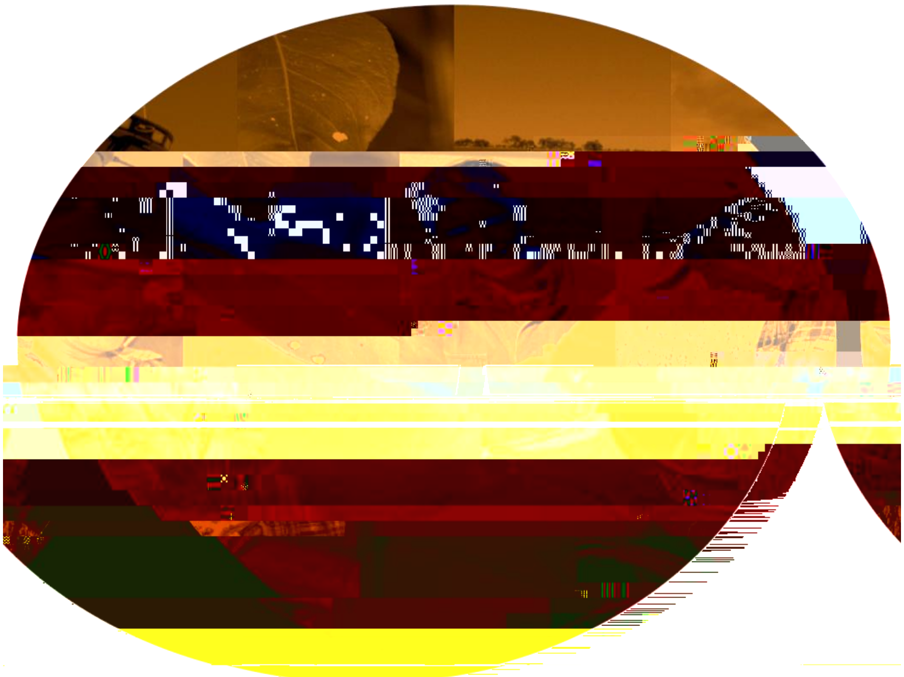
Yu Sheng, Eldon Ball and Xinpeng Xu

Publication series XXX



This paper constructs a novel cross-country consistent dataset built upon production accounts at the commodity level for inputs and outputs between Australia, Canada and the United States. Cross-country consistent agricultural productivity is then estimated and compared by using two most widely adopted methods in international comparison, namely the superlative index approach and the quantity-only based index approach. The results show that when price information is available, the superlative index approach always outperforms the quantity-only based index approach in accuracy and consistency of aggregation. This points to the importance

Agricultural total factor productivity (TFP) is measured as the ratio of total output ( ) to total input ( ); its growth is measured as the difference between output and input growth rates (estimated using logarithmic differentials with respect to time).

$$= — \qquad (1)$$

For example, using the Malmquist index to measure the TFP change between two consecutive

∑ =1 − 0 ≥ 0 with = 1, … ,

0 − ∑ =1 ≥ 0 with = 1, … ,

≥ 0 (10)

where represents observations defining production possibility set, represents m outputs and j represents inputs. The efficiency score obtained (

Production accounts for agriculture are compiled for the United States by the U.S. Department of Agriculture Economic Research Service (USDA ERS), for Canada by Agriculture and Agri-food Canada and for Australia by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES). These accounts are the primary sources of data that we use to construct our cross-country consistent dataset for t

Production data were not available for Canada, but were estimated from total income from sales to processors, consumers, exporters and farm households (including within-sector use, waste, dockage, loss in handling and changes in closing stocks). Output price data were available from Statistics Canada CANSIM tables. Some non-separable forestry outputs were included in aggregate output estimates.

Labour input was estimated as total number of hours worked, calculated by multiplying the number of workers by the average number of hours worked and the number of weeks. The average hours worked was obtained from the Australian Bureau of Statistics Population Census and it is assumed that there are 52 weeks a year.

Although the results obtained from using both index approaches display similar trend of TFP growth, there are marked differences in magnitudes of TFP levels between the Törnqvist TFP index and the Malmquist TFP index for the United States, Canada and Australia. This phenomenon deserves some further discussion. First, with the same data, the levels of the TFP index estimated based on the Malmquist index approach are generally lower than those estimated using the Törnqvist index approach for the United States while for Australia the results from the Malmquist index approach are generally higher than those from the Törnqvist index approach. For Canada, TFP estimates from the two approaches show a mixed pattern: levels of TFP based on the Törnqvist index approach are lower than those based on the Malmquist index approach for the initial years but higher for later years.

Second, the differences in estimated TFP levels using the two different approaches also lead to systematic differences in TFP growth. Over the period 1961 to 2006, the TFP growth rate estimated by using the Malmqu

1967	0.5250	0.4570	0.3510	0.5252	0.5336	0.3582	0.5252	0.5290	0.3566
1968	0.5420	0.4770	0.3530	0.5416	0.5571	0.3608	0.5416	0.5522	0.3592
1969	0.5490	0.4890	0.3830	0.5494	0.5711	0.3912	0.5494	0.5661	0.3895
1970	0.5460	0.4770	0.3770	0.5458	0.5570	0.3849	0.5458	0.5521	0.3832
1971	0.5880	0.5120	0.3880	0.5881	0.5980	0.3963	0.5881	0.5928	0.3946
1972	0.5840	0.4840	0.3860	0.5841	0.5651	0.3943	0.5841	0.5602	0.3925
1973	0.6040	0.4940	0.3930	0.6036	0.5765	0.4016	0.6036	0.5715	0.3998
1974	0.5660	0.4640	0.4110	0.5657	0.5420	0.4202	0.5657	0.5373	0.4184
1975	0.6170	0.5120	0.4220	0.6168	0.5981	0.4311	0.6168	0.5929	0.4292
1976	0.6070	0.5170	0.4380	0.6072	0.6036	0.4470	0.6072	0.5984	0.4451
1977	0.6460	0.5230	0.4490	0.6462	0.6104	0.4586	0.6462	0.6051	0.4566

1996	0.9010	0.7100	0.6200	0.9013	0.8281	0.6336	0.9013	0.8209	0.6308
1997	0.9150	0.6820	0.6520	0.9152	0.7956	0.6657	0.9152	0.7886	0.6628
1998	0.8970	0.7090	0.6580	0.8966	0.8280	0.6718	0.8966	0.8207	0.6689
1999	0.8950	0.7420	0.6790	0.8950	0.8664	0.6933	0.8950	0.8588	0.6902
2000	0.9390	0.6950	0.6740	0.9393	0.8108	0.6888	0.9393	0.8037	0.6858
2001	0.9430	0.6620	0.6830	0.9427	0.7730	0.6980	0.9427	0.7663	0.6949
2002	0.9370	0.6700	0.6240	0.9368	0.7817	0.6375	0.9368	0.7749	0.6347
2003	0.9650	0.7230	0.5910						

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inputs on average accounted for 38 per cent of total expenditure, followed by capital (32 per cent), labor (20 per cent) and land (10 per cent).

	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	0.700

Since the Malmquist index is a quantity-only based index which only uses information on quantity, prices of outputs and inputs and their corresponding revenue and cost shares in the Malmquist index are not directly available. To compare them with the real market prices of outputs and inputs as well as their revenue and cost shares from the Törnqvist index, we retrieve them by simulating the maximisation process with the corresponding quantity information. As shown in Table 8, the implicit output and input shares implicitly used by the Malmquist index showed significantly different patterns from the share estimated by using the market prices. On the output side, crop products only accounted for 30 to 40 per cent of total revenue for the three countries between 1961 and 2006. On the input side, land accounted for the largest share of total expenditure while intermediate inputs held the smallest share. The significant difference between the retrieved revenue/cost share from the Malmquist index (Table 9) and the real revenue/cost share estimated based on the Törnqvist index (Table 10) implies that the implicit prices of various outputs and inputs underlying the assumed distance function could be quite different from the corresponding market prices. These results suggest that cross-country TFP estimates and comparison using the quantity-only based index could be potentially biased.

	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

Figure 3 provides a visual plot of the estimated Törnquist TFP index that applies to two different levels of aggregation (2-output and 4-input versus 6-output and 10-input) for the three countries respectively. The estimated Törnquist TFP index series for both levels of disaggregation overlap substantially for all three countries, indicating that it is not sensitive to levels of disaggregation. We further report in Table 12 the average growth rate of Törnquist TFP. As the level of disaggregation increases (from 2-output and 4-input to 6-output and 10-input and then to 16-output and 10-input), the estimated annual Törnquist TFP growth rates become lower for all three countries. For example, the estimated annual Törnquist TFP growth rate in the 2-output and 4-input case is about 1.8 per cent while it decreases to 1.74 for in the 16-output and 10-input case for the United State. Are these decreases in estimated Törnquist TFP growth rates along with the levels of disaggregation significant or not for all three countries? A simple calculation of the root mean squared coefficient of variance gives a range between 0.02 to 0.06 (close to zero), implying that estimated Törnquist TFP for different levels of aggregation is quantitatively the same. The result suggests that Törnquist TFP index is aggregation consistent.

Table 13 Comparison of the estimated Törnqvist TFP growth with various levels of disaggregation

	USA	CAN	AUS

In contrast, the estimated Malmquist TFP and its growth rates for all three countries are not aggregation consistent. As plotted in Figure 4, the estimated Malmquist TFP index series for both levels of disaggregation diverge substantially, indicating that estimated Malmquist TFP index is very sensitive to levels of disaggregation.

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

Table 14 reports that

Table 15 Comparison of the estimated Törnqvist TFP growth with various levels of disaggregation

	USA	CAN	AUS
Malmquist 2x4	2.160	-0.300	1.610
Malmquist 6x10	0.900	-1.300	0.370
Malmquist 16x10	0.380	1.080	0.760
Root mean square coefficient of variation (RMSD)	0.80	6.89	0.69

International comparison of agricultural productivity has become one of the important issues for policymakers around the world. Yet, there are challenging issues both in the construction of cross-country consistent data as well as the choice of measurement methods. This paper first constructs a novel cross-country consistent dataset built upon production accounts at the commodity level for inputs and outputs for the estimation and comparison of agricultural TFP for Australia, Canada and the United States between 1961 and 2006. Using this cross-country consistent data, we estimate agricultural TFP across countries. We find that agricultural productivity in these three countries have generally been increasing during the period under study, though uneven across countries.

Second, we compare the performance of the two most widely adopted methods in cross-country productivity estimation, namely the superlative index method and the quantity-based index method. The quantity-only based index method has been widely used for measuring and comparing agricultural productivity growth across countries due to its advantage of requiring no priori price information. Yet, how well the method perform in providing reliable estimation of cross-country consistent agricultural TFP level and its growth is subject to debate. Our results suggest that TFP estimates obtained from using the superlative index outperforms those obtained from using the quantity-only based index. There are potentially two bias problems in the quantity-only based TFP index. One is that TFP estimates obtained from using the superlative index are more reliable relative to those obtained from using the quantity-only based index, and the other is that the superlative index TFP is more consistent in aggregation than the quantity-only based index TFP. Both problems are coming from the fact that the implicit prices of outputs and inputs (used by the quantity-only based index) could be significantly different from the market prices (used by the superlative index), rather than the choice of function form among others.

Our results suggest that the superlative TFP index method is still superior to the quantity-only based TFP index method in making international comparison of agricultural productivity. Our finding points to the importance of price data collection work for cross-country consistent agricultural productivity comparison.

Agricultural production account data are defined and collected consistently

Similarly, $X_n(\lambda_n)$, a vector of land characteristics associated with agricultural production, is the Box-Cox transformation of the continuous quality variable X_n where

$$X_n(\lambda_n) = f(x) = \begin{cases} (X_n^{\lambda_n} - 1)/\lambda_n, \lambda_n \neq 0 \\ \ln X_n, \lambda_n = 0 \end{cases} \quad \text{(A8)}$$

and D is a vector of country dummies used to control for external factors. For simplicity, it is approximated with a group of region and time dummy variables and not subject to transformation; λ, α and γ are unknown parameter vectors to be determined in the regression and ε is a stochastic disturbance term. This expression can assume linear, logarithmic and intermediate nonlinear functional forms depending on the transformational parameter.

To employ the hedonic model, regional land prices and land characteristics were observed for each country in 2005. Land characteristic data for 2005 were sourced from the USDA World Soil Resources Office and selected following Eswaran et al. (2003) and Sanchez et al. (2003). GIS mapping was used to overlay country and regional boundaries with land characteristics data according to particular soil categories, including soil acidity, salinity, and moisture stress. The three countries use more than 18 common variables to capture environmental attributes.

Two additional attributes affecting the price of agricultural land should be considered: irrigation and population accessibility. Irrigation (the percentage of cropland irrigated) was included as a separate indicator of production capacity in water-stressed areas, as well as an interaction term between irrigation and soil acidity. A population accessibility index could be used to control for the impact of urbanisation and economic development on land prices; however, it was not included in this analysis due to data constraints. Such indexes have been constructed in previous literature by using a gravity model of urban development, and provided a measure of accessibility to population concentrations (Shi et al. 1997).

Labour is defined as total hours worked by hired, self-employed and unpaid family workers. Because data were only available on agricultural employment, total hours worked was imputed by multiplying the number of workers by the average hours worked per week and the number of

Balk, B. M. (2007) ‘Measuring productivity change without neoclassical assumptions: a concept analysis’, EMG Workshop Working Paper.

Ball, V. E., J. Bureau, R. Nehring, and A. Somwaru (1997). “Agricultural Productivity Revisited.” American Journal of Agricultural Economics 79(4): 1045-1063.

Ball, V. E., A.

Ludena, C. E., T. W. Hertel, P. V. Preckel, K. Foster and A. Nin (2007) “Productivity growth and convergence in crop, ruminant, and nonruminant production: measurement and forecasts”, Agricultural Economics, 37: 1-17.

Nin-Pratt, A. C. Arndt, T.W. Hertel, P.V. Precket (2003) “Bridging the gap between partial and total factor productivity measures using directional distance functions”, American Journal of Agriculturel Economics, 85: 928-942.

Nin-Pratt, A. and B. Yu (2010) ‘Getting implicit shadow prices right for the estimation of the Malmquist index: the case of agricultural total factor productivity in developing countries’, Agricultural Economics, 41(3-4):349-360.

Szulc, BJ, 1964, Indices for multiregional comparisons, Statistical Review, vol.3, pp.239-254.