Measuring Output, Input and Total Factor Productivity in Australian Agriculture: An Industry-level Analysis

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Measuring Output, Input and Total Factor Productivity in Australian Agriculture: An Industry-Level Analysis

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[Abstract]

This paper uses the growth accounting approach to estimate total factor productivity in Australia's agriculture industry. In addition to employing international best practice to compile agricultural production accounts data, we compare various methods for deriving capital services and labour inputs. Agricultural productivity grew at an average rate of 2.1 per cent a year between 1949 and 2012, mainly driven by output expansion. The estimate provides a unique, long-term measure of the productivity performance of Australian agriculture, and contributes to the ongoing debate on the underlying estimation methods.

[Key Words]

Total Factor Productivity, Australian Agriculture, Capital Services

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C43, D24, Q18

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I. Introduction

Increasing productivity has long been recognised as the most important source of output growth and income improvement in the Australian farm sector. Although there are differences in methods and data, previous literature has generally reached the consensus that a significant proportion of agricultural output growth and almost all growth in farm profits in Australia have come from productivity growth over the past five decades (Mullen 2010; Productivity Commission 2011). Agricultural productivity growth in Australia also plays a particularly important role in increasing efficiency in production of the industry and maintaining international competitiveness in the face of declining terms of trade, increasing climate variability and tightening constraints on natural resource use. In some industries, changing community attitudes and values are also emerging as important factors governing farm production systems.

The total factor productivity (TFP) index is widely used to measure agricultural productivity performance because it provides a broad indication of how efficiently farmers combine all market inputs to produce total output. To measure TFP, researchers can aggregate various agricultural outputs (i.e. crop and livestock products) into an index of total output and compare this to an index of total input (i.e. land, labour, capital, and intermediate inputs). Specifically, the ratio of the two indexes gives the index of TFP, and movements in the TFP index over time reflect changes in productivity.

There are two groups of studies that have used index formulas (namely, the Fisher or Törnqvist indexes) to estimate agricultural TFP in Australia, and both are subject to certain limitations.[2] For instance, Knopke (1988), Mullen and Cox (1996), and Zhao *et al.* (2012) have used a gross output model and farm survey data to derive ‘bottom-up’ TFP measures for Australian broadacre and dairy industries. These industries currently cover around 70 percent of agricultural activities in Australia, and

[2] A brief review of this literature is presented in Appendix A

the TFP estimates begin from 1978. Survey data are not always available for all industries (such as horticulture) or for earlier periods, hence the usefulness of such TFP estimates for understanding the productivity performance of the agricultural industry as a whole is limited.

In contrast, Powell (1974), Productivity Commission (2005) and the Australian Bureau of Statistics (2007) have used the value-added and gross output models in conjunction with national accounts data to derive ‘top-down’ TFP measures for the combined agriculture, forestry and fishing sector. The value added (which excludes intermediate inputs) and gross output estimates, regularly published by the ABS, are now available from 1986 and 1995, respectively. These estimates are designed for cross-sector comparison of TFP growth, but have a limited capacity to reflect the long-term trend of agricultural productivity growth because of the short time series that is available and the relatively broad definition of the agriculture industry that is used limits their utility. In addition, these estimates are subject to limitations in the construction of the output measure, a lack of quality adjustments for land, and issues in the treatment of self-employed labour and intermediate inputs.

This paper uses the growth accounting approach to derive a TFP index for the Australian agriculture industry over a long period – 1949 to 2012. The approach is built on that used by the Economic Research Service of the US Department of Agriculture (ERS-USDA), and incorporates international best practice for using agricultural production accounts data.

This study features three distinct contributions to the literature. First, the TFP estimates obtained in the paper: focus on the agriculture industry as a whole (namely, on all agricultural sectors but excluding the forestry and fishing sectors); cover the past six decades; and uniquely, were derived in a transparent and replicable way. Second, the ‘ex ante’ and ‘ex post’ methods for deriving capital services (including land) and labour inputs are compared, which provides useful insights into the ongoing debate on underlying methods for agricultural TFP estimation. Third, we employ a series of quality adjustment procedures to reduce potential biases often associated with the measures of outputs and inputs.

Using both the ‘ex ante’ and ‘ex post’ methods, we find that agricultural TFP in Australia has grown at an annual rate of 2.1 per cent a year over the period 1949 to 2012. This estimate is comparable to that obtained in previous studies. This seemingly consistent estimate of productivity growth disguises some important differences in the measurement of individual inputs. The ‘ex post’ method underestimates the share of capital services in total input relative to the ‘ex ante’ method, particularly in the short run. This is because farmers’ investment decisions rely on the expected (‘ex ante’) rate of return, which is usually greater and only converges to the realised (‘ex post’) rate of return in the long run (when perfect foresight holds) (Oulton 2005).

A further analysis shows that a shift in outputs (from livestock to crop production), and an input mix adjustment (itself a consequence of technological progress and capital deepening) have played significant roles in driving the rapid industry-level productivity growth. The TFP estimate presented here, and the driver analysis that accompanies it, provides policy-makers with a comprehensive picture of the long-term productivity performance of the Australian agricultural industry.

The remainder of the paper is arranged as follows. Section II describes the growth accounting approach used to estimate agricultural TFP and its growth. Section III outlines the procedure for constructing outputs and inputs for the Australian agriculture industry, followed by a brief description of the data sources. Section IV discusses the agricultural TFP estimates and the related input and output shares. This section also contains a discussion of some potential drivers of productivity growth. Section V provides a robustness check. Conclusions are drawn in section VI.

II. The TFP Measure and Index Number Approach

TFP is defined as the residual of a production function, $\mathrm{F}(.,.)$, through which various inputs ($\mathrm{X_t}$) are combined to produce outputs ($\mathrm{Y_t}$), using specific technology ($\mathrm{A_t}$).

$$\mathrm{Y_t} = \mathrm{F}(\mathrm{X_t}, \mathrm{A_t}) \qquad (1)$$

Under strict neo-classical assumptions of separability and Hicks-neutrality of production technology, perfect competition and constant returns to scale, TFP measures technological progress (Balk 2008; OECD 2001).

A growth accounting based measure of TFP (TFP_t) in the agricultural industry can be derived as a gross agricultural output index ($\overline{\mathrm{Y_t}} = \sum \mathrm{Y_t}$) divided by a gross agricultural input index ($\overline{\mathrm{X_t}} = \sum \mathrm{X_t}$), such that

$$\mathrm{TFP_t} = \frac{\overline{\mathrm{Y_t}}}{\overline{\mathrm{X_t}}} \qquad (2).$$

Taking logarithmic differentials of Equation (2) with respect to time (t), yields

$$\widehat{TFP} = \widehat{\overline{Y_t}} - \widehat{\overline{X_t}} \qquad (3),$$

where $\widehat{TFP} = dTFP/dt$, $\widehat{\overline{Y_t}} = \mathrm{d}\overline{\mathrm{Y_t}}/\mathrm{dt}$ and $\widehat{\overline{X_t}} = \mathrm{d}\overline{\mathrm{X_t}}/\mathrm{dt}$. Therefore, TFP growth ($\widehat{TFP}$) is equal to the aggregate output growth rate ($\widehat{\overline{Y_t}}$) minus the aggregate input growth rate ($\widehat{\overline{X_t}}$).

To implement Equations (2) and (3), the analyst needs to decide how to aggregate individual inputs and outputs into their corresponding gross indexes. Using the index number approach, the direct or the indirect method can be used to aggregate outputs and inputs (Zhao *et al.* 2012). The direct method uses the index formula to aggregate output (or input) quantities, using the corresponding prices (or values) as weights. In contrast, the indirect method uses the index formula to obtain an average price (using the corresponding quantities as weights for aggregation), and then the volume index is derived indirectly by dividing total revenue (or cost) by the average price. Theoretically, the two methods are equivalent, but in practice, they can generate quite different results because most index formulas are not consistent in aggregation (Balk 2008).

In choosing between the two methods, Allen and Diewert (1981) suggested that if quantity ratios change more than price ratios, then the indirect method for deriving productivity indexes is more suitable, and vice versa. Agricultural production is dictated by highly variable climate conditions; hence the variation of quantity ratios is typically larger than that of price ratios. Accordingly, agricultural outputs and inputs should be aggregated using the indirect method. In addition, prices are more readily available and accurate (in statistics) than quantities.

Both the ERS-USDA (Ball 1985; Ball *et al.* 1997b) and Agriculture and Agri-Food Canada (Cahill and Rich 2012) deflate the output value and input expenditure by corresponding price indexes to derive quantities of agricultural output and input. In our paper, we apply the same method.

Regardless of which of these methods is used, the analyst must also choose the index formula for aggregating quantities, or for estimating the average price. Without knowing the true form of the production function, either the Fisher or the Törnqvist index can be used for this purpose, because they both provide second-order approximations to arbitrary production functions (Diewert 1976; Diewert 1992; Jorgenson 1986). However, only one index formula can be chosen, hence more criteria are required to choose between these alternatives.

To construct indexes of gross output and total input, the analyst must categorise agricultural outputs and inputs into sub-groups. This is because outputs and inputs within the same category may share similar characteristics in statistics. Furthermore, for data organisational reasons, the index aggregating process usually involves more than one-stage aggregation. To ensure the estimates obtained are consistent regardless of the level of aggregation used, the chosen index formula should satisfy the factor reversal test (Diewert 1992). Neither the Fisher nor Törnqvist index satisfies this requirement directly, but the former is preferred based on the second-order condition. Accordingly, we choose the Fisher index as the default method for deriving the price index. Finally, to minimise the so-called Laspeyres-Paasche spread and allow a closer match between production technologies in adjacent years, the chained rule has been applied to the Fisher indexes to construct time-series estimates.

The price indexes of output and input can be written as the geometric mean of the Laspeyres index and the Paasche index:

$$P_{t-1,t}^{F} = \left(P_{t-1,t}^{L} P_{t-1,t}^{P}\right)^{1/2} = \left(\frac{\sum_{i=1}^{N} p_{it} q_{i,t-1}}{\sum_{i=1}^{N} p_{i,t-1} q_{i,t-1}} \frac{\sum_{i=1}^{N} p_{it} q_{it}}{\sum_{i=1}^{N} p_{it-1} q_{it}} \right)^{1/2} \tag{4}$$

$$W_{t-1,t}^{F} = \left(W_{t-1,t}^{L} W_{t-1,t}^{P}\right)^{1/2} = \left(\frac{\sum_{j=1}^{M} w_{jt} x_{j,t-1}}{\sum_{j=1}^{M} w_{j,t-1} x_{j,t-1}} \frac{\sum_{j=1}^{M} w_{jt} x_{jt}}{\sum_{j=1}^{M} w_{jt-1} x_{jt}} \right)^{1/2} \tag{5}$$

where $P_{t-1,t}^{L} = \frac{\sum_{i=1}^{N} p_{it} q_{i,t-1}}{\sum_{i=1}^{N} p_{i,t-1} q_{i,t-1}}$ and $W_{t-1,t}^{L} = \frac{\sum_{j=1}^{M} w_{jt} x_{j,t-1}}{\sum_{j=1}^{M} w_{j,t-1} x_{j,t-1}}$ are the Laspeyres index and $P_{t-1t}^{P} = \frac{\sum_{i=1}^{N} p_{it} q_{it}}{\sum_{i=1}^{N} p_{it-1} q_{it}}$ and $W_{t-1t}^{P} = \frac{\sum_{j=1}^{M} w_{jt} x_{jt}}{\sum_{j=1}^{M} w_{jt-1} x_{jt}}$ are the Paasche index. p_{it-1}, p_{it}, w_{jt-1} and w_{jt} represent the prices of the ith output or jth input items in the base ($t-1$) and current periods (t), and q_{it-1}, q_{it}, x_{jt-1} and x_{jt} are the quantity of the ith or jth item in the two periods.

Assuming free entry, there will be no economic profits for the whole industry and total revenue should equal to total cost such that $R_t = C_t$ (Diewert and Morrison 1986; Hulten 2001). Equations (2) and (3) can thus be re-arranged (with the duality condition) as

$$\mathrm{TFP_t} = \frac{\mathrm{R_t/P_t}}{\mathrm{C_t/W_t}} = \frac{\mathrm{W_t}}{\mathrm{P_t}} \tag{6}$$

$$\ln\left(\frac{\mathrm{TFP_t}}{\mathrm{TFP_{t-1}}}\right) = \sum_j \mathrm{S_j} \frac{\mathrm{W_{j,t}}}{\mathrm{W_{j,t-1}}} - \sum_i \mathrm{R_i} \frac{\mathrm{P_{i,t}}}{\mathrm{P_{i,t-1}}} \tag{7}$$

where S_j and R_i are the revenue and cost share of output i and input j, and P_i and W_i are their prices (or price indexes).

III The Agricultural Production Account

We have constructed the production account of the Australian agriculture industry using international best practice (Ball *et al.* 1997b; Cahill and Rich 2012). Three categories of outputs (crops, livestock and other output related to on-farm activities) and four categories of inputs (capital, land, labour and intermediate inputs) define the multi-output and multi-input production system. Data used to construct the Australian agricultural production account are obtained from the ABS national accounts statistics and ABARES' farm surveys.[3]

<u>Output</u>

Agricultural outputs are defined to include all commodities (such as crop and livestock products) and services that are produced on farms and/or returns to on-farm activities. Physical quantities and market prices (at the farm gate) of each product and service are distinguished and collected or derived separately. These data are compiled using the ABS Agricultural Census, ABARES farm surveys and the ABS National Accounts statistics.

Using the growth accounting approach, physical quantities of all crop and livestock products should be estimated as the sum of 'commodities sold or transferred off farms', 'net additions to inventory' and 'quantities used on-farm for consumption and production'. In practice, this method is only applied to livestock products in Australia.

[3] A detailed list of variables is included in Appendix B.

For crops, physical quantities are indirectly derived by multiplying yield by the area sown. Furthermore, since no statistics on physical quantities of services produced on farm are available, volume measures, defined as total values of those services divided by corresponding price indexes, are used as substitutes.

Market prices of all crop and livestock products are directly collected in the ABARES farm survey, and are defined as the farmers' receipt price at the farm gate. When statistics are not available, either the unit value (defined as the sales value divided by the physical quantity sold) or an ABARES farm-survey based index of prices received by farmers for the same (or similar) products or services is used for imputation.

Market prices reflect the marginal value of outputs, and so the impacts of taxes and subsidies need to be addressed when designing the weights used for aggregating outputs. In principle, this suggests that taxes should be excluded and subsidies included in the weights. For example, market prices of wool and milk in Australia were once supported by the wool reserve price scheme and the milk exporting scheme respectively. As such, government indirect payments have been included in the output or price measure of these commodities. However, taxes levied on farmers by federal and state governments should be excluded. In Australia, these taxes include those related to drought support and rural adjustment scheme payments, among others. The treatment is consistent with the international standard (OECD 2001).

Intermediate Inputs

The process of measuring intermediate inputs is similar to that of outputs. These inputs were grouped in five categories, namely fuel, lubricants and electricity; fertilizer, chemicals and medicine; seeds, fodder and livestock purchases; repairs and maintenance; and other materials and services. Each of these categories is discussed in more detail below.

Data were obtained from several sources. From 1978 to the present, the ABARES series of ‘Major Components of Australian Farm Costs’ (ABARES Various issues-e) is used. For the period 1949 to 1978, statistics were obtained from ABARES’ ‘Historical Trends in Australian Agricultural Production, Exports, Incomes and Prices: 1952–53 to 1978–79’ (ABARES Various issues-d) and ABARES’ ‘Australian Rural Production, Exports, Farm Income and Indexes of Prices Received and Paid by Farmers: 1949–50 to 1970–71’ (ABARES Various issues-c).

Fuel, lubricants and electricity: quantities and prices of petrol, diesel, liquefied natural gas and electricity consumed are collected or derived separately and used for aggregation. Quantities are sourced from ABARES’ Agricultural Commodities database, while prices are sourced from ABARES’ Farm Commodity Price Survey (ABARES Various issues-a). Where these statistics are not available, the ABARES index of prices paid by farmers for ‘*fuel, lubricants and electricity’* is used as a substitute. The volume is obtained by dividing expenditure on these inputs by the imputed price index.

Fertilizers, chemical and medicines: to account for changes in quality, we construct the price index of this category using commodity-level prices and quantities. A Fisher price index is estimated using prices of 5 major fertilizers, 8 herbicides and numerous livestock medicines, with quantities consumed as weights. The volume of this category is then calculated as total expenditure divided by the price index. Where available, data on quantities and prices of individual commodities are sourced from the Agricultural Commodities database; otherwise, ABARES’ farm survey data are used for imputation.

Seed, fodder and livestock purchases: this group of inputs includes purchased feed crops and seed as well as those produced on-farm. It also includes livestock purchases and cross-farm transfers. Total expenditure on these items is obtained from ABARES’ Agricultural Commodities database. The price index of the category is sourced from

ABARES' farm survey data, and the volume is derived as total expenditure divided by the price index.

Repairs and maintenance: Total expenditure on these items is obtained from ABARES' Agricultural Commodities database. The price of the category is obtained from ABARES' farm survey data. The volume is derived as total expenditure divided by the price index.

Other materials and services: other purchased intermediate inputs include customised services, hire of plant and machinery, packaging and transportation, irrigation water purchases, among others. On average, they collectively account for around 5 per cent of total intermediate expenditure. There are no price statistics for the category, and so we use the price index for all intermediate inputs as a substitute. As is the case for other intermediate inputs, the implicit quantity of the category is also derived as total expenditure divided by the price index.

Measuring Capital Input

A three-step procedure is employed to measure the capital input. The first step is to construct the productive capital stock for each asset type. Following Ball *et al.* (1997b), Cahill and Rich (2012) and ABS (2007), total capital assets are split into three types, namely depreciable assets, land, and other non-depreciable assets. For depreciable assets, the perpetual inventory method is employed to derive the productive capital stock from investment data. For land and other non-depreciable assets, the productive capital stock is estimated by dividing total market value by a deflator.

The second step is to construct rental prices (or user costs). Ball *et al.* (1997b) suggests that this can be done by multiplying 'ex ante' rates by asset prices. However, in most other studies, 'ex post' rates are used instead. In this paper, we derive rental prices by analysing farmers' investment behaviour. The purpose is to investigate the potential differences in the estimation of capital services that arise when using ‘ex ante’ and ‘ex post’ rates, and to specify the circumstances when each should be used.

In the third step, we estimate total capital service from productive capital stocks and rental prices. Specifically, total capital service flows are defined as the sum of all individual capital services, which in turn are estimated by multiplying the productive capital stock by the applicable rental price. The total price index is aggregated from the rental rates for all types of assets, and the quantity is estimated by deflating the total capital services value by the price index.

Data on investments and purchase prices of each type of capital asset are sourced from the Australian National Accounts statistics for the combined Agriculture, Forestry and Fishing industry. The gross output value share of agriculture in these three sectors is used to distinguish investments in the agriculture sector from those in the forestry and fishing sectors. By doing this, it is implicitly assumed that farmers’ investment pattern in the agriculture sector is same as that of individuals in the forestry and fishing sectors, and the investment in each sector is proportional to their output value shares.

Capital Stock

Depreciable capital assets: depreciable assets include non-dwelling buildings and structures, plant and machinery, and transportation vehicles. Using the perpetual inventory method, we define the stock of capital at time t for each of these asset types, $K(t)$, as the sum of all past investments at the constant price, say $I(t-\tau)$, weighted by the relative efficiencies of capital goods of each age τ, namely $S(\tau)$.

$$K(t) = \sum_{\tau=0}^{\infty} S(\tau) I(t-\tau) \qquad (8)$$

To implement Equation (8), the efficiency of investment goods (or the need for replacement of productive capacity) must be specified. Following Ball (1985) and

Ball *et al.* (1997b), we use a rectangular hyperbola functional form to define the decay process of investment goods such that

$$S(\tau) = \frac{L-\tau}{L-\beta\tau} \quad \text{if} \;\; 0 \leq \tau \leq L$$

$$S(\tau) = 0 \qquad \text{if} \;\; \tau > L \tag{9}$$

where L is the service life of the asset and β the decay parameter. The aggregate efficiency function is thus constructed as the weighted sum of individual efficiency functions, where the weights are the rate with which decay occurs.

Each type of depreciable asset has a different service life. In this study, the average asset service lives for non-dwelling buildings and structures, plant and machinery, and transportation vehicles are assumed to be 40, 20 and 15 years respectively. This is based on the assumption (following Ball 1985) that the depreciation process is defined over a standard normal distribution truncated two standard deviations before and after the mean service life.

The decay parameter (β) is restricted to values between 0 and 1 following the assumption that efficiency declines more quickly in the later years of services (Penson *et al.* 1987; Romain *et al.* 1987). Although there is little empirical evidence to justify particular values of β, it is reasonable to assume that the efficiency of a capital asset declines smoothly(or continuously) over most of its service life. Furthermore, decay parameters are assumed to vary between assets. Consistent with previous literature for agriculture (Ball *et al.* 2001; Ball *et al.* 1997b), decay parameters are set to be 0.75 for non-dwelling buildings and structures, and 0.5 for other capital assets.

Land: compared to other capital assets, land is not homogeneous in quality across regions and can differ in its efficiency for agricultural production. To adjust for land quality differences, land areas operated and average unimproved value per hectare in 32 agricultural survey regions throughout Australia are collected. Furthermore, we distinguish between land used for cropping and grazing in each region. Land area data are obtained from the ABS Agricultural Census.[4] Unimproved land values per hectare are measured as the total market land value minus the value of buildings, structures and other improvements. Data on these variables are taken from the ABARES farm survey data. Total land stock is aggregated from different land types in each region, with unimproved land values per hectare used as weights.

Inventory and other non-depreciable assets: this category of capital assets includes the opening inventory of livestock and crops, as well as the stock of other cultivated biological resources (vines, trees, etc) and intellectual property. The number of cattle, sheep, pigs and other animals on farms are sourced from the ABARES publication 'Agricultural Commodity Statistics' (ABARES Various issues-b). Implicit quantities of opening stocks of crops, other cultivated biological resources and intellectual property are obtained from ABS National Accounts statistics.

Including the stock of other cultivated biological resources and intellectual property in the capital stock is a feature that is specific to the estimation of agricultural productivity in Australia. Although these two groups of assets provide a flow of services (similar to that provided by the stock of livestock and crops), they have not previously been accounted for in the US, Canadian or other studies.

Price of Capital Services

The rental price of capital goods is derived by analysing farmers' investments. Specifically, to maximise the net worth of capital assets, farmers continually increase their capital stock through investment. This investment process will continue as long as the present value of net revenue generated by an additional unit of capital exceeds its opportunity cost (or the purchase price).

$$P = \frac{\partial Y}{\partial K} = rW_K \sum_{t=1}^{\infty} W_K \frac{\partial R_t}{\partial K} (1+r)^{-t} = c \tag{10}$$

[4] Land used as conservation reserves are excluded from the area operated.

where P is the price of output, W_K is the price paid for a new unit of capital, R_t is replacement investment, r is the real discount rate and c is the rental rate of capital.

Equation (10) defines the rental price of capital in equilibrium, which consists of two components. The first term, rW_K, represents the opportunity cost associated with the initial investment. The second term, $\sum_{t=1}^{\infty} W_K \frac{\partial R_t}{\partial K}(1+r)^{-t}s$, is the present value of the cost of all future replacements required to maintain the productive capacity of the capital stock.

Let F_K denote the present value of the stream of capacity depreciation per unit of capital asset (K) according to the mortality distribution. It can be shown that $\sum_{t=1}^{\infty} \frac{\partial R_t}{\partial K}(1+r)^{-t} = \sum_{t=1}^{\infty} F_K^t = \frac{F_K}{1-F_K}$, and thus the rental rate of capital assets can be written as

$$c = \frac{rW_K}{1-F_K} \tag{11}$$

where F_K is defined by Equation (9) for depreciable assets; and for land and other non-depreciable assets, F_K is zero. Equation (11) shows that the rental rate (c) depends on the rate of return (r).

The standard method for estimating the rate of return is to use an ‘ex post’ method (Christensen and Jorgenson 1969; Jorgenson *et al.* 1987; Jorgenson and Griliches 1967). When using this method, the rate of return is derived using the condition that the sum of returns across all assets equals total observed profits (i.e. capital is the residual claimant). The ‘ex post’ method is based on investment theory with rational expectations, but an implicit assumption is that investors have perfect foresight – i.e. the rate of return that is calculated ex post is known by investors with certainty ex ante, or at least before making their capital investment decisions (Balk 2008; Oulton 2005).

The alternative method is to use the ‘ex ante’ method, in which case the rate of return is derived from external information, for example, from the financial market (Schreyer 2004; Schreyer *et al.* 2003). Relative to the ‘ex post’ method, the ‘ex ante’ method has a weaker theoretical foundation, but generates more flexible rates of return for deriving capital services across asset types and over time. Since this method does not require the assumption of perfect foresight, ‘ex ante’ rates can be quite different to ‘ex post’ rates, particularly in the short run.

In practice, both the ‘ex post’ and ‘ex ante’ methods are widely used to generate rates of return. It is not clear which method is most suitable, although Oulton (2005) proved that either ‘ex ante’ or ‘ex post’ rates could be close to the true measure under certain conditions. In this paper, we use both methods to estimate rates of return and capital services, and compare the results. Since farmers’ investment behaviour is more likely to be affected by expected rates of return (i.e. ‘ex ante’ rates) than by realised rates of return (i.e. ‘ex post’ rates), the ‘ex ante’ estimate is better than the ‘ex post’ estimate, particularly in the short run. In the long run, estimates obtained from both methods are expected to converge.

Regarding the specification of ‘ex ante’ rates, no consensus has been reached in the literature. Ball (1985) and Ball *et al.* (1997b) suggest that actual interest rates (i.e. nominal risk-free bond yields adjusted for inflation) should be used. Although this is common practice, Andersen *et al.* (2011) argue that the use of actual rates may disproportionally affect the estimation of rental rates for capital assets with different service lives. In particular, “assets with relatively longer (shorter) service lives are given relatively more weight in the indexing procedure when interest rates are increasing (decreasing)” (Andersen *et al.* 2011, p 723). Instead, they support the use of fixed interest rates.

The debate between Ball *et al.* (1997b) and Andersen *et al.* (2011) on the choice of ex ante rates can be further clarified through analysing Equations (8)-(11).[5] In sum, if F_K (the present value of the stream of capacity depreciation on one unit of capital asset K) is sensitive to rates of return, then fixed rates are preferred. Otherwise, actual rates are preferred. In our case, F_K (see Appendix C) derived from Equation (8) is only affected by the average rates of return over the service life of each capital asset. Thus, the estimate of capital services obtained when using fixed rates will follow that obtained when using the actual rate, as long as the fixed rate is equal to the mean of actual rates. Finally, we estimate the 'ex ante' rates using the actual rates, and compare a range of fixed rates as a robustness check.

Measuring Labour Inputs

The index of total labour input is aggregated from two types of labour distinguished by their employment status: employed and self-employed. The separation of these two types of labour is essential, as compensation for farm operators and their families is usually combined with farm profits, and could be quite different to the compensation paid to their hired counterparts (Powell 1974; Zhao *et al.* 2012). Failure to account for this issue would bias the estimated labour input index.

For each type of labour, the quantity of labour is defined as hours worked. The total quantity of labour used in production is estimated by multiplying the number of hired, self-employed and unpaid family labourers by the average number of hours worked by individuals in each of these groups. These data are sourced from ABARES' Agricultural Commodities database. Differences in labour quality are accounted for using a quality adjustment index provided by the ABS (2012). This index is estimated using Population Census Data, cross-classified by sex, age and education.[6]

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[5] A detailed derivation is shown in Appendix C.

[6] Age groups are: 15-24, 25-34, 25-44, 45-64. Education groups are: university degree, skilled labour and unqualified. All definitions are from ABS (2012).

Average hourly compensation for hired labour is derived by dividing the total payment to employed labour by the number of hours worked. The total payment to hired labour is sourced from the National Income and Expenditure (ABS 2012). Consistent with the methods used in the US and Canada, this treatment includes employers' contributions to social security, as well as unemployment compensation and other supplements to wages and salaries. From a producer's point of view, the supplement should be considered in the calculation of the marginal product of workers, in addition to wages and salaries.

Since average compensation data are not directly available for self-employed and unpaid family members, we use two different approaches to impute them, one for each of the approaches used to derive capital services. When the 'ex post' method is used to determine the rate of return for capital inputs, compensation for self-employed workers has to be imputed using the mean wage of hired workers with the same demographic characteristics. This is because there is only one degree of freedom for the production account implied by the assumed zero profit condition, and this is used to derive 'ex post' rates.[7] Conversely, when the 'ex ante' method is used, hourly compensation for self-employed workers can be imputed by dividing the gross value of output less the cost of capital services and intermediate inputs by the total number of hours worked. In this case, self-employed labour is the residual claimant and will therefore earn additional compensation for entrepreneurship.

IV Patterns of Agricultural Productivity and Its Determinants

Agricultural productivity in Australia and its growth are estimated using both the 'ex post' and 'ex ante' methods for the period 1949-2012. Using these results, we first illustrate the pattern of productivity and its growth over time (Tables 1 and 2). We

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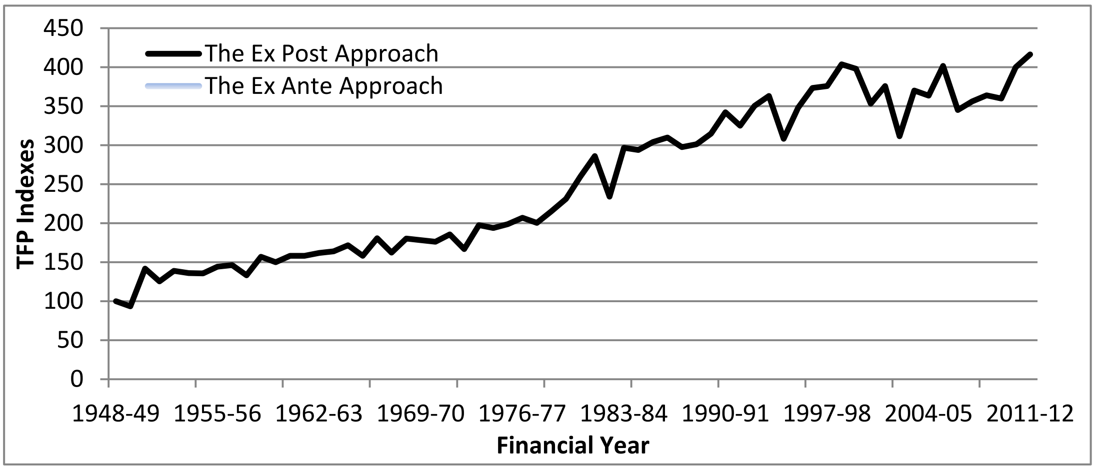
[7] Following the neoclassical assumption of free entry condition, profit for the whole industry is zero. When using the 'ex post' method, one can derive 'ex post' rates by dividing the gross value of output minus the cost of labour and intermediate inputs by the stock of capital (Balk 2005).

then compare the estimated capital services and labour inputs to reveal differences between the two methods (Tables 3 and 4). Thirdly, we decompose the growth in TFP into output and input to obtain some insight into potential drivers of productivity growth (Tables 5-7).

Agricultural TFP and Its Growth

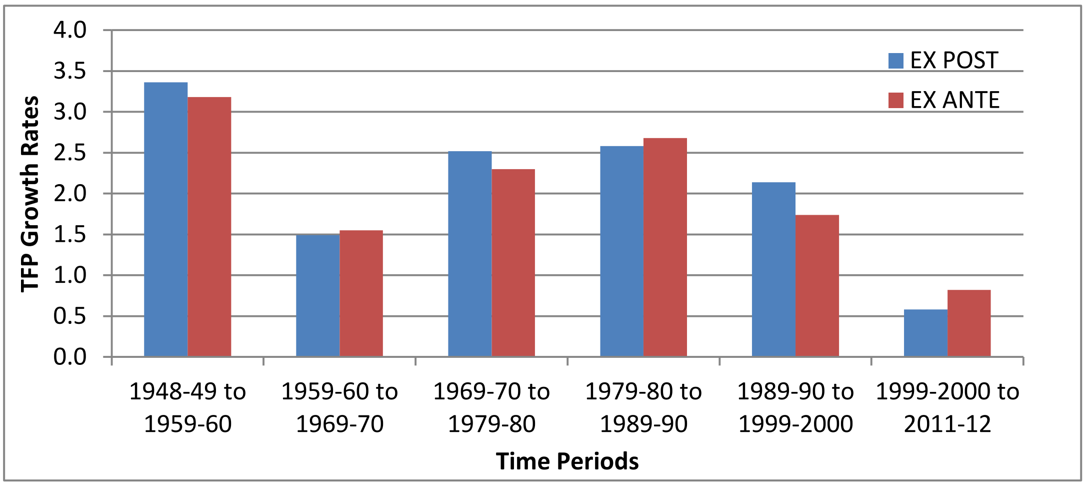
Australian agriculture has experienced rapid productivity growth from 1949 to 2012, reflecting continuous technology progress and on-farm innovation (Figure 1). The long-term growth rate of TFP is estimated to be 2.1 per cent a year over the period 1949 to 2012, after smoothing year-to-year fluctuations by regressing the logarithm of TFP against time. This rapid growth in TFP is mainly driven by significant output growth (2.6 per cent a year) and only mild input growth (0.5 per cent a year) (Tables 1 and 2). This suggests that productivity growth in Australian agriculture has followed an output expansion path rather than input saving path or output-input equal contribution path.

Figure 1 Agricultural TFP Index: 1949 to 2012 (1949=100)



Relative to the long-term growth, short-term productivity growth in Australian agriculture is also strong. When the whole period is split (arbitrarily) into six decade-long sub periods, productivity growth rates are positive in all periods. Furthermore, the average annual rate of growth exceeds (or is close to) 2.0 per cent a year in four out of the six periods (Figure 2). This result is consistent regardless of whether the ‘ex ante’ or ‘ex post’ method is used to estimate capital services.

Figure 2 TFP Growth over six decade-long sub-periods



However, a significant slow-down in productivity growth is observed in the most recent decade. Between 2000 and 2012, the annual growth rate of agricultural TFP is 0.6 per cent a year using the ‘ex post’ method and 0.8 per cent a year using the ‘ex ante’ method. This is much lower than the average of the remaining sub-periods, namely 2.4 per cent a year and 2.3 per cent a year respectively.[8] This phenomenon has been observed in previous studies and some potential reasons for the slow-down have been investigated (Sheng *et al.* 2011; World Bank 2007).

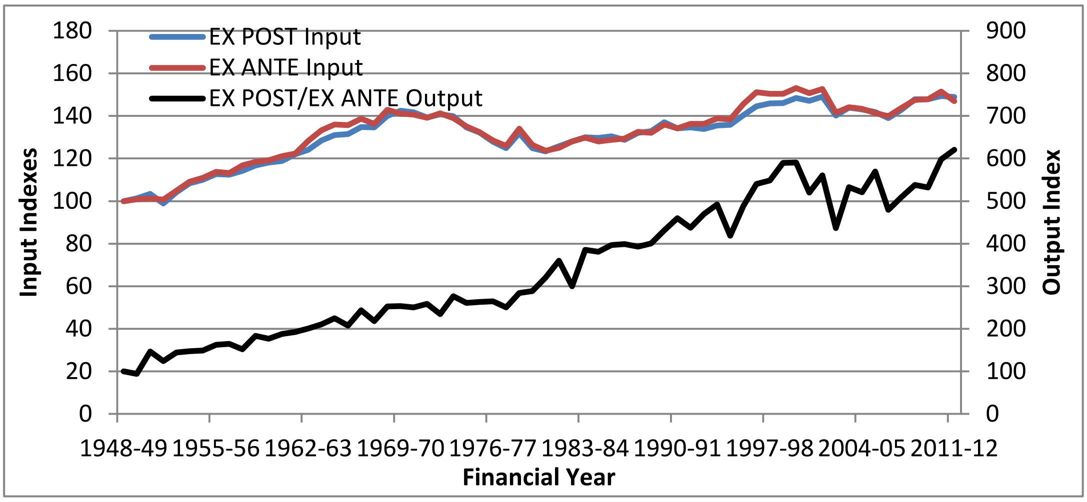
The estimated TFP indexes obtained using the ‘ex post’ and ‘ex ante’ methods closely track each other over time, and generate similar productivity growth rates for the whole period. However, in each of the sub-period comparisons, differences in TFP growth estimates obtained using the two methods are apparent.[9] In particular, noticeable differences between the aggregate inputs mainly occur in two time periods:

[8] The existence of a slow-down in TFP growth is further supported by CUMSQ tests conducted by the authors– results are available on request.

[9] The magnitude of the difference which exists in each period depends on the start and end point of the sub-period.

the early 1960s and the late 1980s (Figure 3). In both periods, the input series obtained when using the 'ex post' method is lower than that obtained when using the 'ex ante' method, and therefore the TFP estimate is higher when using the 'ex post' method. Since the 'ex post' and 'ex ante' methods differ only in the treatment of capital services and labour, estimates of these inputs are responsible for the disparity between the aggregate TFP indexes.

Figure 3 Aggregate Output and Input Index: 1949 to 2012 (1949=100)



<u>Capital Services and Labour Inputs: the Ex Post vs. the Ex Ante Approaches</u>

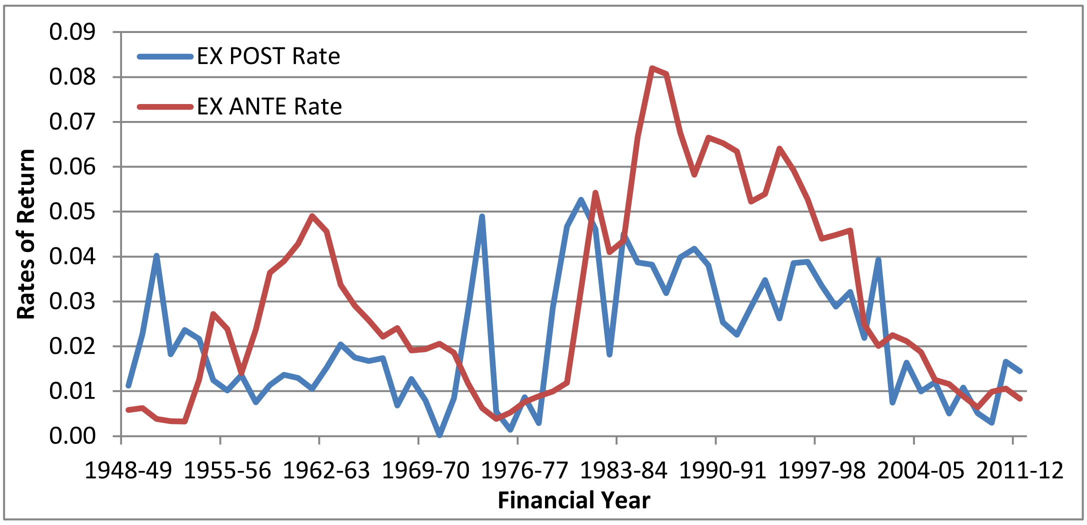
The use of different methods may generate different estimates of capital services and labour inputs. To ensure that TFP estimates are robust, we first compare the different estimates of capital services, and then consider the corresponding labour estimates.

Comparison of Capital Services

The estimate of capital services depends on the productive capital stock and the rental price. They are both sensitive to rates of return, and so our discussion starts with a comparison of these rates when using the 'ex post' and 'ex ante' methods (Figure 4).[10]

[10] The rental rates and capital service estimates for each class of asset that are obtained when using the 'ex post' and 'ex ante' methods are presented in tables 3A and 3B respectively.

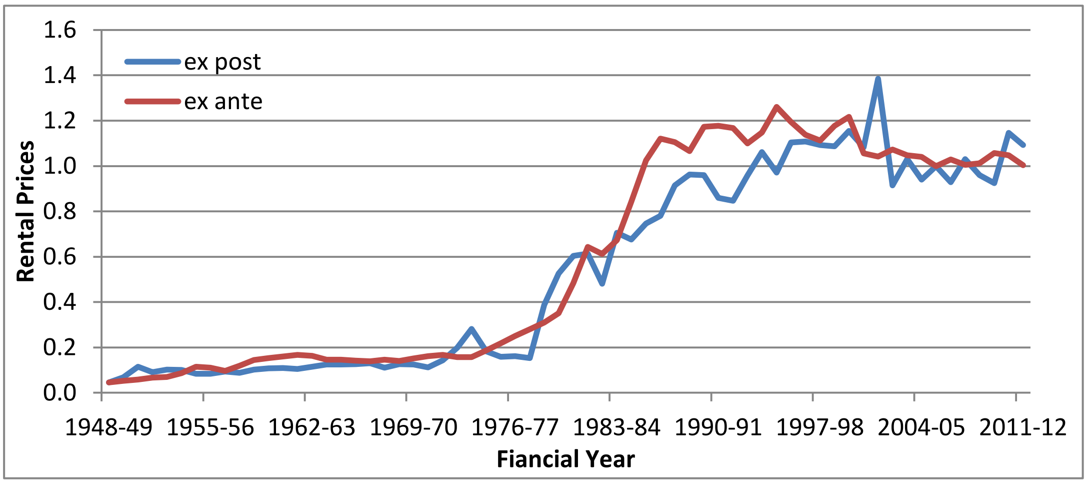
Figure 4 Comparison of ‘ex post’ and ‘ex ante’ rates



Over the period 1949 to 2012, the average rates of return estimated using the ‘ex post’ and ‘ex ante’ methods are 2.2 per cent and 3.0 per cent respectively. The difference between these two rates primarily reflects two time periods – the early 1960s and the late 1980s – when the ex ante rate is significantly higher than the ex post rate. A possible explanation is that money illusion, driven by strong inflation over these two periods (in particular, the early 1980s) drove expected rates of return higher than realised rates (Oulton 2005). In this case, the perfect foresight assumption is violated and the ‘ex ante’ method is better than the ‘ex post’ method. Specifically, rental prices of capital services estimated when using ‘ex ante’ rates are closer to the true measure, and are higher than those estimated using ‘ex post’ rates, particularly in the short run (Figure 5).

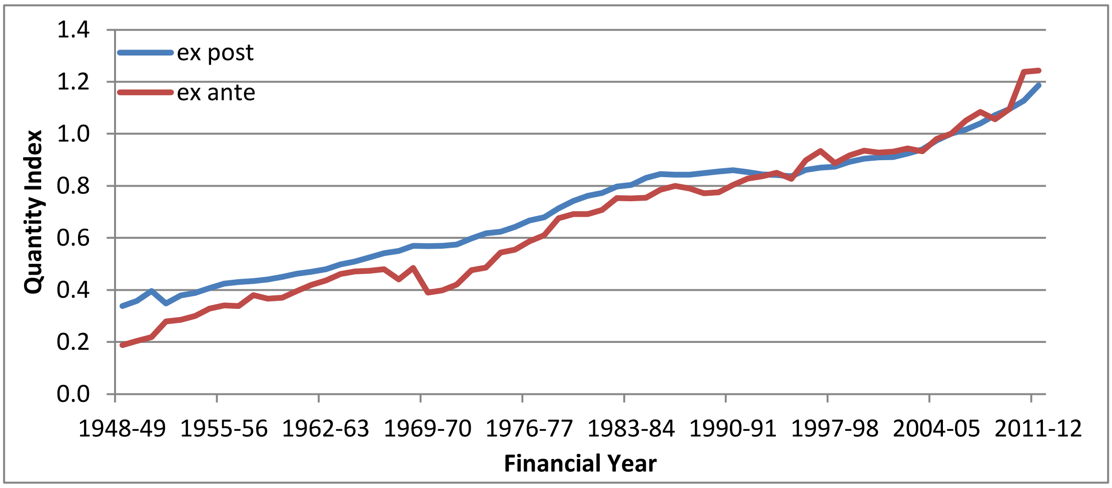
Overall, rental prices of capital services estimated when using ‘ex post’ rates grew at the rate of 5.3 per cent a year from 1949 to 2012, slightly slower than that obtained when using ‘ex ante’ rates, namely 5.4 per cent a year. Moreover, during the 1980s, the gap is more significant, with rental prices of capital services estimated using ‘ex ante’ rates around 20 per cent higher (on average) than those obtained when estimated using ‘ex ante’ rates. This concords with the timing of a divergence between the aggregate input series associated with each method.

Figure 5 Comparison of Rental Prices Index of Capital Service (2006 is the base year)



To extend our comparison of rental prices to the physical quantity of capital services, effects of different rates of return on farmers’ investment also need to be considered. As is shown in Equation (10), higher rental prices reflect farmers’ greater willingness to make investments replacing obsolete assets. This implies that realised investment will be greater than that predicted by the ‘ex post’ method, because the ‘ex post’ method generally underestimates rates of return relative to the ‘ex ante’ method. As such, it is not surprising to see that capital services estimated when using the ‘ex ante’ method increase more quickly than those obtained when using the ‘ex post’ method. Specifically, capital services grew at 2.4 per cent a year from 1949 to 2012 when using the ‘ex ante’ method, compared to 1.8 per cent a year when using the ‘ex post’ method (Figure 6).

Figure 6 Comparison of Capital Services (2006 is the base year)



In sum, relative to the ‘ex ante’ method, the ‘ex post’ method generally overestimates TFP growth by underestimating capital services, particularly in the short run.

Comparison of Labour Inputs

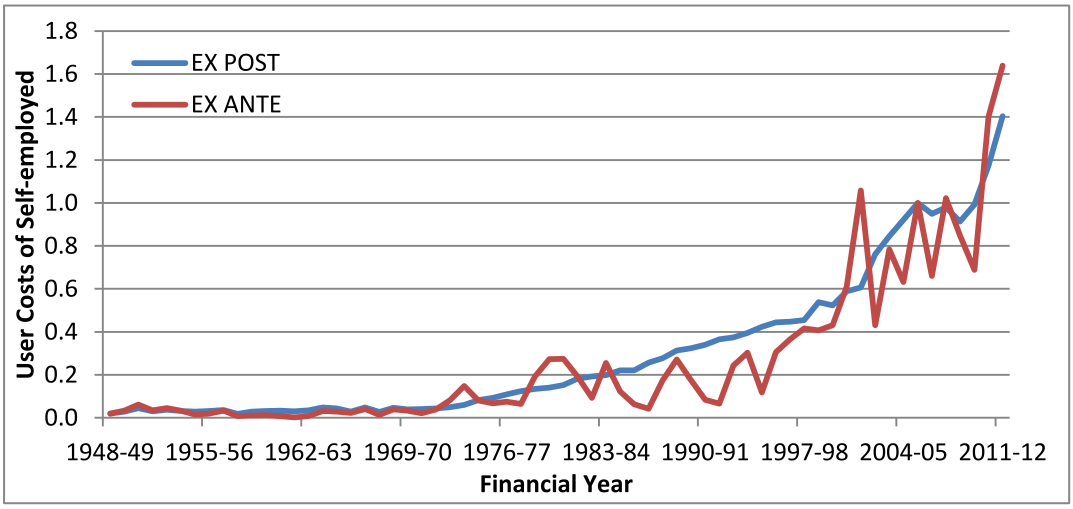
Corresponding to each of the methods used to estimate capital services, two different methods are used to estimate the labour input. The two methods differ only in the treatment of the user costs of self-employed workers, since other things – namely the quantities of hired and self-employed workers, and prices of hired workers are equal. As noted above, when using the ‘ex post’ method to estimate capital services, the per-hour user cost of self-employed workers is imputed using that of hired workers. Conversely, when the ‘ex ante’ method is used, the average user cost of self-employed workers is estimated by dividing the residual of total output value less the value of capital, intermediate and hired labour inputs by the total number of hours worked by self-employed workers.

Of these two sets of estimates, per-hour user costs of self-employed workers obtained when using the ‘ex ante’ method are slightly higher in the long run (Figure 7).[11]

[11] The annual estimates of labour inputs obtained when using the ‘ex post’ and ‘ex ante’ methods to estimate capital services are presented in table 4.

Specifically, when using the ‘ex ante’ method, the per-hour user costs of self-employed workers grew at 7.2 per cent a year from 1949 to 2012, slightly higher than that associated with the ‘ex-post’ method, namely 7.0 per cent a year. The difference in growth of the two estimates reflects the fact that farm owners and their family members should, in the long run, obtain additional compensation for their entrepreneurship even after accounting for their population characteristics.

Figure 7 User Costs of Self-employed Workers (2006 is the base year)



Moreover, per-hour user costs of self-employed workers are more variable over time when the ‘ex ante’ method is used than when the ‘ex post’ method is used (Figure 7). Specifically, the standard deviation of the series obtained when the ‘ex post’ method is used is 0.3 over the period 1949-2012, much lower than that associated with the ‘ex ante’ method. In particular, throughout the 1980s, the estimates derived from the ‘ex post’ method are consistently higher than the ‘ex ante’ estimates. This reflects the fact that of these two, the estimate obtained using the ‘ex ante’ method is more likely to capture the flexibility that farm owners have in the choice of short-term compensation for their labour input when making investment decisions, and in responding to external shocks (such as unexpected changes in climate conditions and the market prices of outputs and inputs).

The differences in per-hour user costs of self-employed workers estimated when using the two methods do not significantly affect estimates of aggregate labour inputs (Figures 8 and 9). Specifically, although there are short-term differences in the price of aggregate labour inputs between the two methods (which mainly preserve the pattern of per-hour user costs for self-employed workers), aggregate labour input quantities decline at 1.3 per cent a year over the period 1949-2012 when using both methods.

Figure 8 The price of aggregate labour inputs

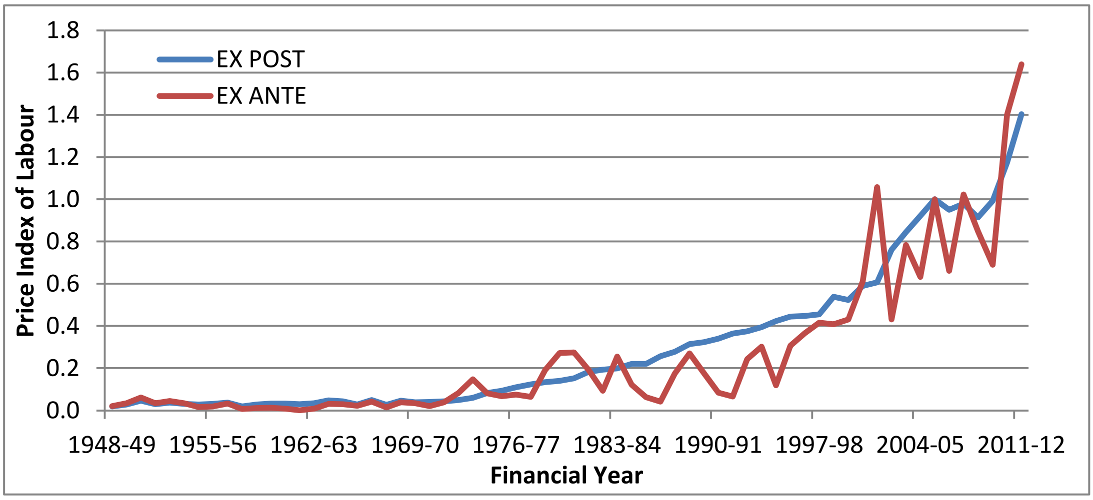
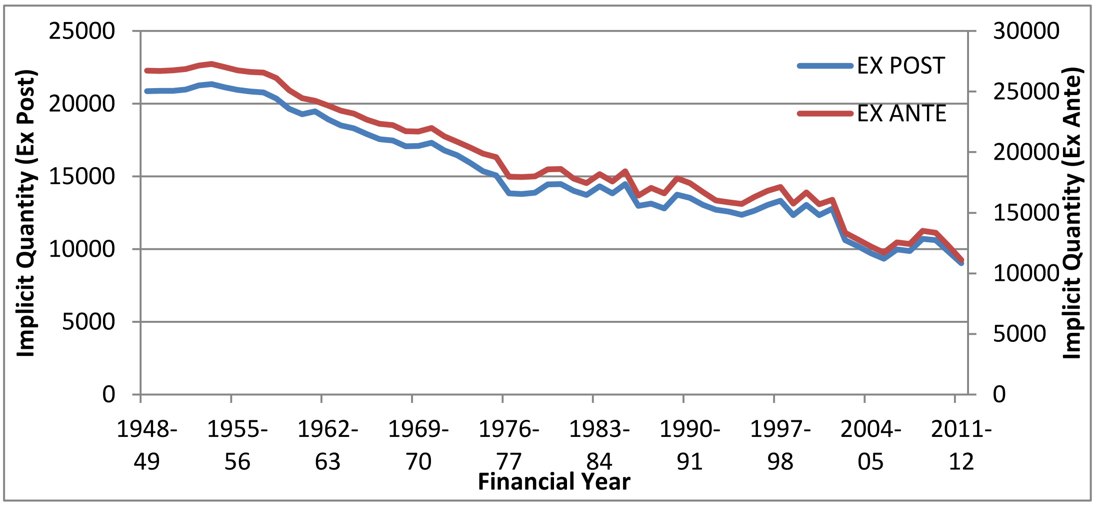
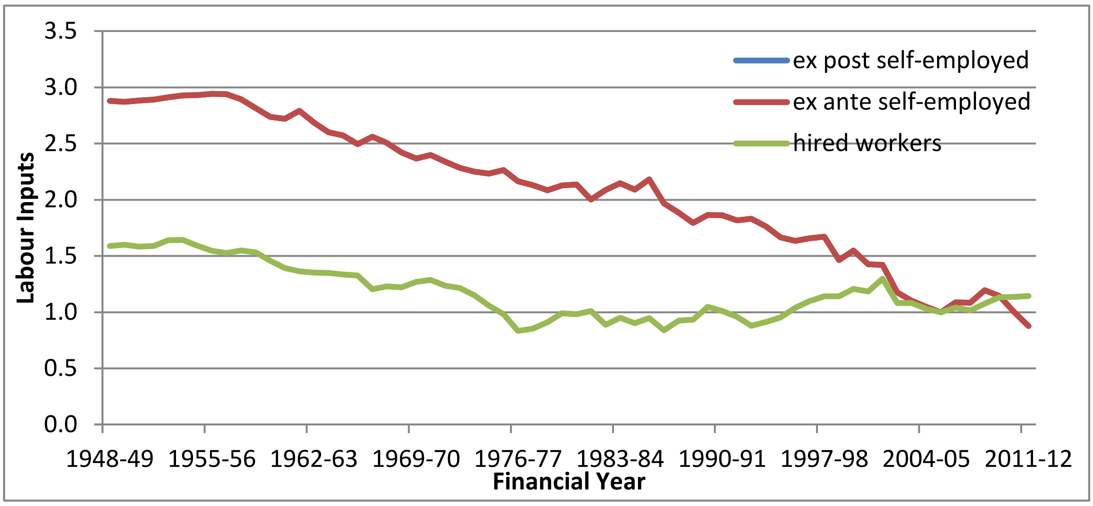


Figure 9 The quantity of aggregate labour inputs



Finally, it is interesting to note that both estimates show the labour inputs provided by self-employed workers declined at 1.7 per cent a year, much faster than the rate of decline for hired workers, namely 0.7 per cent a year. This result reflects a relative shift away from self-employed to hired labour in Australia's agricultural industry, although total labour inputs have been steadily declining over time (Figure 10).

Figure 10 Labour inputs of hired and self-employed (2006 is the base year)



Potential Drivers of Agricultural TFP Growth

How was agricultural productivity growth in Australia achieved over the past six decades? To answer this question, we decompose the gross output and input indexes into their components.[12] Three points can be made from this input-output analysis resulting from the decomposition:

First, rapid growth in crop production has driven up gross agricultural output (Table 5).[13] Over time, crop products as a whole grew at 4.0 per cent a year, which accounts for more than 70 per cent of gross output growth. In contrast, livestock products grew more slowly, at an average annual rate of 1.4 per cent a year. Reflecting the faster growth of crop production relative to that of livestock, the proportion of crop products in total output increased from 35 per cent to 54 per cent over the period 1949-2012. Although the precise reasons for this change in output structure are not well

[12] A decomposition of TFP growth is presented in table 7.

[13] The index of gross output and its disaggregation is presented in table 5.

understood, one possible explanation is higher productivity growth in cropping relative to that in livestock. In turn, this may reflect differences in their production processes, such as the longer production cycles associated with livestock production, and fewer opportunities to use capital intensive technologies (Mullen 2007).

Secondly, agricultural productivity growth in Australia is accompanied by a significant increase in the capital-labour ratio that can be inferred from the increase in the share of capital relative to that of labour (Table 6).[14] Overall, capital services increased at an average annual growth rate of 2.5 per cent year over the period 1949-2012. More specifically, service flows from 'non-dwelling buildings and structures' and 'plant and machinery' increased at an annual growth rate of close to 2.0 per cent a year, while service flows from 'transportation vehicles' increased by around 1.5 per cent a year. Over the same period, the labour input decreased at an average rate of 1.3 per cent a year, mainly driven by a decline in the use of self-employed labour. Together, these two changes caused a rapid increase in capital intensity, which in turn lead to an improvement in the efficiency of total input use, as it facilitated the use of advanced plant and machinery, and allowed farms access to the potential benefits of increasing returns to scale.

Thirdly, the use of intermediate inputs has increased modestly, and there has been a significant mixture change within this category (Table 6). From 1949 to 2012, the use of intermediate inputs increased at an annual growth rate of 0.9 per cent a year, a much lower rate than that of capital services. Increased use of 'crop chemicals and medicines', 'seed and fodder' and 'repair and maintenance services' were the main drivers of growth in total intermediate inputs. In addition to the benefits obtained from substitution between the broad categories of inputs, using more of particular intermediate inputs reflects input-augmented technology progress in the industry, which favours farms with a greater capacity to replace some inputs with others in

[14] The index of gross input and its disaggregation is presented in table 6.

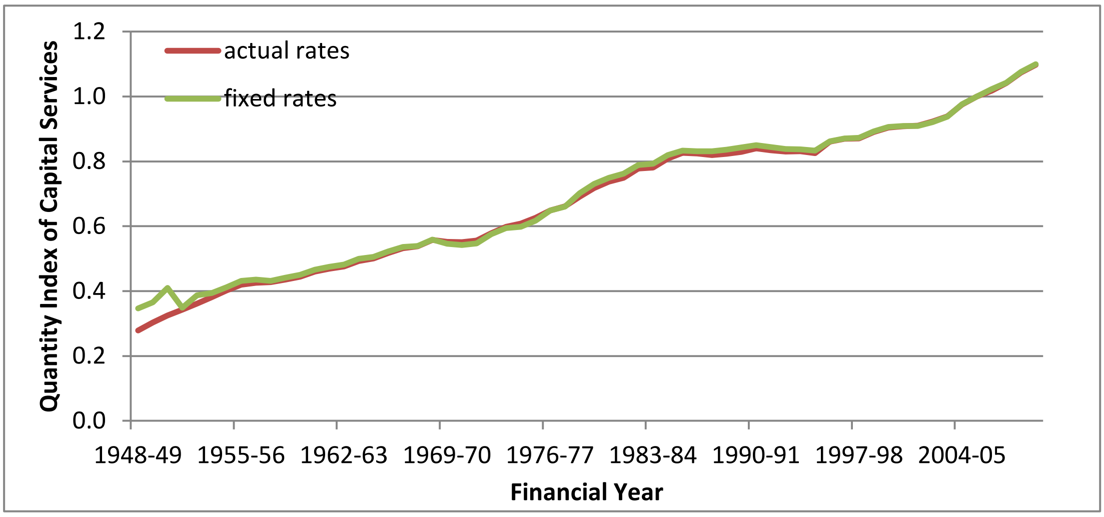
response to changes in relative input prices (Sheng *et al.* 2013). In turn, this contributed to the reallocation of resources to more efficient farms, and hence to aggregate industry-level productivity growth.

V Robustness Check

Comparison of different 'ex ante' rates

Using different 'ex ante' rates may generate different aggregate capital service estimates, since each capital asset may have its own service life (Andersen *et al.* 2011). As a robustness check, we compare the estimates of total capital services aggregated from three assets with different service lives (non-dwelling buildings and structures, plant and machinery and transportation vehicles) when using actual and fixed rates of return as 'ex ante' rates respectively. Comparing the results obtained from these two scenarios, we find that estimated capital services are quite similar (Figure 11). An important reason for this similarity is that we enforce the constraint that average actual rates of return over the whole period are equal to the fixed rate. This implies that capital service estimates are mainly sensitive to the mean rates of return that are applied, rather than short-term fluctuations.

Figure 11. Comparison of capital services estimated using different 'ex ante' rates



<u>Comparison with previous studies</u>

As a further check of robustness, we compare the TFP growth rate estimated in this paper to estimates obtained in previous studies. Specifically, we use the series obtained in this paper to estimate productivity growth rates over the periods examined in specific counterpart studies. The results, summarised in Table 8, show that the estimates of productivity growth obtained in this study are generally consistent with previous ABARES estimates of TFP growth in the broadacre agriculture sector (Zhao *et al*. 2012), and with ABS and Productivity Commission estimates of TFP growth in the Agriculture, Forestry and Fishing industry.

VI Concluding Remarks

This study provides a unique, long-term measure of productivity for the Australian agriculture industry. To obtain this measure, we used the growth accounting method and national accounts data compiled using international best practice. Various methods for deriving capital services and labour inputs (namely the 'ex ante' and 'ex post' methods) are compared to inform the method for TFP estimation.

We show that from 1949 to 2012, agricultural productivity growth in Australia was rapid, at an average growth rate of 2.1 per cent a year. Moreover, input-output analysis suggests that this rapid productivity growth was mainly driven by a strong output expansion and a mild input increase, as well as significant output and input structural changes.

The estimate of productivity growth obtained in this study is consistent with previous ABARES and ABS studies but is superior in terms of time series, sector coverage and methods. As such, this estimate provides policy-makers with a more comprehensive picture of productivity growth in Australian agriculture, and is suitable for a range of further economic analysis, including international comparison.

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Table 1 Aggregate output, input and TFP indexes: 1949-2012 (1949=100)

Year	The Ex Post Approach			The Ex Ante Approach		
	OUTPUT	INPUT	TFP	OUTPUT	INPUT	TFP
1948-49	100.0	100.0	100.0	100.0	100.0	100.0
1949-50	94.3	101.2	93.2	94.3	100.8	93.6
1950-51	146.5	103.3	141.8	146.5	101.2	144.7
1951-52	123.9	98.8	125.4	123.9	100.7	123.0
1952-53	144.6	104.1	138.9	144.6	104.9	137.9
1953-54	147.3	108.3	136.0	147.3	109.2	135.0
1954-55	149.0	110.0	135.5	149.0	110.9	134.3
1955-56	162.5	112.7	144.2	162.5	113.7	142.9
1956-57	164.6	112.4	146.4	164.6	113.2	145.4
1957-58	152.3	114.3	133.2	152.3	116.7	130.5
1958-59	183.4	116.8	157.0	183.4	118.3	155.0
1959-60	177.1	118.0	150.0	177.1	119.2	148.5
1960-61	188.2	118.9	158.3	188.2	121.1	155.4
1961-62	192.6	121.9	158.0	192.6	122.2	157.6
1962-63	201.0	124.1	161.9	201.0	128.3	156.7
1963-64	210.6	128.4	164.0	210.6	133.3	157.9
1964-65	224.8	131.0	171.6	224.8	136.0	165.3
1965-66	207.8	131.4	158.1	207.8	135.7	153.2
1966-67	243.5	134.8	180.6	243.5	138.7	175.5
1967-68	218.3	134.6	162.2	218.3	136.3	160.2
1968-69	252.3	140.0	180.3	252.3	142.9	176.6
1969-70	253.7	142.4	178.1	253.7	141.1	179.8
1970-71	250.0	141.7	176.4	250.0	140.6	177.7
1971-72	258.7	139.3	185.7	258.7	139.2	185.9
1972-73	234.9	140.8	166.8	234.9	141.3	166.3
1973-74	276.6	139.9	197.6	276.6	139.0	199.0
1974-75	260.8	134.6	193.7	260.8	135.0	193.1
1975-76	262.7	132.2	198.7	262.7	132.4	198.4
1976-77	264.6	127.9	207.0	264.6	128.4	206.1
1977-78	250.5	124.9	200.6	250.5	126.0	198.8
1978-79	284.0	131.9	215.3	284.0	134.0	211.9
1979-80	288.7	124.9	231.1	288.7	126.3	228.6
1980-81	320.4	123.3	259.8	320.4	123.6	259.1
1981-82	359.8	125.7	286.1	359.8	125.0	287.8
1982-83	299.6	128.0	234.1	299.6	128.0	234.1
1983-84	385.7	130.0	296.8	385.7	129.8	297.3
1984-85	381.0	129.6	294.0	381.0	128.0	297.8
1985-86	396.9	130.5	304.2	396.9	128.8	308.3

(to be continued…)

Table 1 Continued

Year	The Ex Post Approach			The Ex Ante Approach		
	OUTPUT	INPUT	TFP	OUTPUT	INPUT	TFP
1986-87	399.3	128.8	310.0	399.3	129.3	308.8
1987-88	392.8	132.1	297.4	392.8	132.5	296.5
1988-89	400.3	132.9	301.3	400.3	132.0	303.2
1989-90	431.3	137.0	314.9	431.3	135.9	317.4
1990-91	459.6	134.2	342.4	459.6	134.2	342.5
1991-92	437.3	134.6	325.0	437.3	136.3	320.9
1992-93	469.2	133.9	350.4	469.2	136.2	344.5
1993-94	492.3	135.5	363.4	492.3	138.8	354.6
1994-95	418.4	135.8	308.2	418.4	138.4	302.3
1995-96	488.4	140.3	348.0	488.4	145.6	335.5
1996-97	539.9	144.6	373.4	539.9	151.1	357.4
1997-98	548.2	145.9	375.8	548.2	150.4	364.6
1998-99	589.6	146.1	403.7	589.6	150.3	392.2
1999-2000	590.6	148.4	397.9	590.6	153.1	385.8
2000-01	519.7	147.2	353.1	519.7	150.7	344.9
2001-02	560.4	149.1	375.9	560.4	152.7	367.0
2002-03	436.6	140.2	311.4	436.6	141.5	308.6
2003-04	532.8	143.9	370.3	532.8	144.0	370.0
2004-05	520.4	143.1	363.7	520.4	143.4	362.9
2005-06	569.7	141.8	401.8	569.7	141.3	403.2
2006-07	479.7	139.0	345.0	479.7	139.8	343.0
2007-08	509.4	142.9	356.4	509.4	143.8	354.2
2008-09	537.9	147.8	363.9	537.9	147.5	364.6
2009-10	531.9	147.8	359.9	531.9	147.8	359.9
2010-11	597.8	149.4	400.1	597.8	151.5	394.6
2011-12	620.5	148.9	416.6	620.5	147.0	422.1

Table 2 TFP growth by 10 year sub-period: 1949-2012

	TFP Growth		Input Growth		Output Growth
	EX POST	EX ANTE	EX POST	EX ANTE	BOTH
1948-49 to 1959-60	3.36	3.18	1.65	1.83	5.01
1959-60 to 1969-70	1.49	1.55	1.89	1.83	3.38
1969-70 to 1979-80	2.52	2.30	-1.39	-1.17	1.13
1979-80 to 1989-90	2.58	2.68	0.84	0.74	3.42
1989-90 to 1999-2000	2.14	1.74	1.06	1.46	3.20
1999-2000 to 2011-12	0.58	0.82	0.10	-0.14	0.68
1948-49 to 2011-12	2.13	2.13	0.48	0.48	2.61

Table 3A Capital services estimated using the 'ex post' approach: 1949-2012[15]

year	EX POST rate	pkal	qkal	pbldg	kbldg	pmas	kmas	ptra	ktra	pinv	kinv	pkint	kint	pland	kland
1948-49	0.011	0.046	3577.2	0.038	31259.4	0.052	9578.8	0.052	2891.2	0.219	14820.4	-	-	0.048	183984.1
1949-50	0.023	0.068	3792.4	0.048	30912.5	0.056	11111.9	0.057	3450.3	0.219	14985.6	-	-	0.048	183984.1
1950-51	0.040	0.115	4187.8	0.060	30496.4	0.067	12674.6	0.068	3432.4	0.263	18575.3	-	-	0.045	187748.5
1951-52	0.018	0.092	3687.0	0.061	30012.3	0.080	14576.3	0.081	4149.2	0.415	10600.8	-	-	0.046	187455.2
1952-53	0.024	0.102	4005.5	0.060	29434.6	0.086	15508.8	0.087	4440.9	0.327	13500.3	-	-	0.049	187684.8
1953-54	0.022	0.101	4107.6	0.061	29831.8	0.087	16881.9	0.088	4914.2	0.362	12358.3	-	-	0.045	187434.9
1954-55	0.012	0.084	4311.2	0.062	30357.0	0.090	18204.0	0.091	5353.5	0.358	12447.2	-	-	0.055	182759.8
1955-56	0.010	0.083	4495.7	0.066	31006.7	0.092	19084.9	0.094	5590.0	0.333	13269.8	-	-	0.051	189486.2
1956-57	0.014	0.094	4554.4	0.067	31032.9	0.096	19607.5	0.098	5659.3	0.334	13157.2	-	-	0.055	191728.2
1957-58	0.008	0.088	4592.0	0.067	30837.5	0.103	20261.7	0.104	5792.7	0.364	12038.8	-	-	0.055	191287
1958-59	0.011	0.102	4665.7	0.067	31743.8	0.111	20529.6	0.112	5766.2	0.333	12596.7	-	-	0.051	189817.7
1959-60	0.014	0.108	4759.9	0.068	31770.9	0.112	21137.5	0.114	5881.6	0.331	12798.9	5.929	55.4	0.058	183125.1

To be continued…

[15] The variables in this table are: q = implicit quantity, p = rental price, kal = aggregate capital services, bldg = building and structures, mas = plant and machinery, tra = transportation vehicles, inv = inventory, int = intellectual property, land = land

Table 3A Continued

year	EX POST rate	pkal	qkal	pbldg	kbldg	pmas	kmas	ptra	ktra	pinv	kinv	pkint	kint	pland	kland
1960-61	0.013	0.109	4892.4	0.071	31879.9	0.114	21784.3	0.115	5974.9	0.311	13886.6	6.046	58.5	0.060	185357.5
1961-62	0.011	0.105	4974.7	0.071	32036.5	0.115	22334.4	0.117	5985.6	0.275	14306.2	5.759	61.1	0.062	185308.3
1962-63	0.015	0.114	5072.2	0.071	32372.6	0.116	23004.6	0.117	6100.5	0.278	14051.4	5.474	64.0	0.063	186321.2
1963-64	0.020	0.125	5274.1	0.073	32987.6	0.116	24075.6	0.118	6520.8	0.304	14071.0	5.272	67.4	0.064	186878.4
1964-65	0.018	0.125	5387.7	0.078	33637.6	0.120	25103.6	0.121	6843.0	0.359	12778.9	5.149	71.3	0.065	188064.1
1965-66	0.017	0.126	5554.7	0.079	34206.5	0.123	25936.4	0.125	6966.3	0.342	13634.6	5.098	74.7	0.062	188840.2
1966-67	0.017	0.130	5723.4	0.081	35066.0	0.126	26991.0	0.127	7249.9	0.359	13305.7	5.072	78.6	0.064	192788.8
1967-68	0.007	0.110	5821.7	0.084	35695.7	0.127	27873.5	0.130	7362.9	0.397	12265.3	5.004	82.4	0.064	191542.6
1968-69	0.013	0.127	6023.2	0.088	36687.8	0.133	28893.6	0.135	7579.0	0.372	12913.9	4.955	87.1	0.069	194691.1
1969-70	0.008	0.124	6017.1	0.092	37555.6	0.137	29485.2	0.139	7464.0	0.517	10631.9	5.024	92.2	0.071	193363.8
1970-71	0.000	0.112	6027.4	0.098	38241.6	0.146	29848.8	0.144	7234.4	0.497	9907.3	5.107	97.7	0.076	190783.4
1971-72	0.008	0.143	6075.8	0.106	39090.5	0.155	30248.4	0.152	7098.3	0.532	9946.9	5.261	102.8	0.076	191955.4
1972-73	0.028	0.199	6332.7	0.113	40440.7	0.160	31076.4	0.158	7343.4	0.527	11584.6	4.899	108.7	0.074	191208.5
1973-74	0.049	0.282	6537.3	0.129	42214.8	0.171	32001.5	0.169	7644.2	0.634	11761.3	4.251	114.4	0.082	191498.8
1974-75	0.005	0.183	6600.2	0.166	43390.3	0.212	32606.2	0.205	7727.3	0.470	10942.0	4.148	117.3	0.093	187445.8

To be continued…

Table 3A Continued

year	EX POST rate	pkal	qkal	pbldg	kbldg	pmas	kmas	ptra	ktra	pinv	kinv	pkint	kint	pland	kland
1975-76	0.001	0.159	6796.5	0.194	44595.7	0.241	33505.0	0.238	8003.5	0.505	11582.2	4.266	119.1	0.089	188721.1
1976-77	0.009	0.162	7055.9	0.217	45628.0	0.269	34542.1	0.265	8362.4	0.484	14321.2	4.208	117.5	0.086	184617.2
1977-78	0.003	0.154	7192.7	0.235	46649.7	0.299	35295.2	0.292	8496.2	0.530	14347.5	3.777	117.3	0.075	188003.4
1978-79	0.029	0.388	7549.7	0.252	48141.6	0.330	36455.4	0.321	8904.1	0.546	18623.9	2.995	116.8	0.113	187913.6
1979-80	0.047	0.526	7851.6	0.279	49719.9	0.363	37698.7	0.351	9338.7	0.625	19901.7	2.769	117.2	0.117	189854.9
1980-81	0.053	0.604	8054.9	0.314	51072.9	0.394	38838.8	0.379	9630.3	0.622	19979.5	2.322	118.8	0.182	190704.5
1981-82	0.046	0.614	8180.9	0.353	52277.2	0.423	39993.7	0.412	9869.3	0.645	18732.7	2.294	121.4	0.194	189282
1982-83	0.018	0.480	8434.6	0.404	53009.7	0.471	40488.0	0.444	9693.5	0.506	24595.8	2.424	124.5	0.232	187791.9
1983-84	0.045	0.705	8504.8	0.422	54199.5	0.492	41603.6	0.468	9985.5	0.679	20300.9	2.231	130.1	0.234	191351.9
1984-85	0.039	0.676	8789.4	0.449	55301.8	0.503	42835.6	0.480	10323.8	0.655	22090.1	2.216	143.6	0.247	189398.1
1985-86	0.038	0.747	8944.1	0.496	56235.5	0.560	43454.5	0.567	10103.8	0.577	24467.2	2.272	162.5	0.222	179314.4
1986-87	0.032	0.780	8916.2	0.535	57105.4	0.622	43725.7	0.660	9594.9	0.625	23773.8	2.253	191.7	0.211	179123.5
1987-88	0.040	0.914	8916.8	0.572	58060.8	0.657	44500.2	0.685	9441.9	0.826	20650.0	2.144	224.7	0.275	178918.7
1988-89	0.042	0.963	8979.8	0.613	58738.1	0.659	45533.8	0.676	9455.5	0.975	18852.1	2.041	261.4	0.425	178256.2
1989-90	0.038	0.960	9048.2	0.657	59458.9	0.677	46248.1	0.705	9325.2	0.894	18425.0	2.049	303.0	0.407	178112.2

To be continued…

Table 3A Continued

year	EX POST rate	pkal	qkal	pbldg	kbldg	pmas	kmas	ptra	ktra	pinv	kinv	pkint	kint	pland	kland
1990-91	0.025	0.859	9095.9	0.670	60183.6	0.707	46295.9	0.739	8848.0	0.731	21273.0	1.997	337.9	0.346	175021.4
1991-92	0.023	0.847	9023.3	0.639	61454.4	0.727	46168.3	0.777	8337.4	0.762	19973.4	1.850	378.3	0.358	172390.9
1992-93	0.029	0.958	8933.4	0.621	62486.0	0.774	45736.8	0.846	7742.5	0.739	20829.7	1.803	425.5	0.344	170533.4
1993-94	0.035	1.061	8901.4	0.627	63591.7	0.802	45413.1	0.900	7276.1	0.749	22534.0	1.729	484.2	0.340	177189
1994-95	0.026	0.971	8858.0	0.651	64651.4	0.798	44923.5	0.888	7326.2	0.791	20678.1	1.656	535.6	0.380	173580.2
1995-96	0.039	1.104	9117.1	0.673	66050.4	0.811	44611.8	0.889	7594.8	0.545	30129.7	1.558	597.4	0.392	176224.1
1996-97	0.039	1.109	9206.6	0.677	66808.7	0.809	44434.5	0.863	7912.4	0.598	31449.2	1.431	651.3	0.368	176936.6
1997-98	0.033	1.093	9240.7	0.700	68168.4	0.841	44400.9	0.907	8620.6	0.767	25986.2	1.357	707.9	0.431	176953.5
1998-99	0.029	1.088	9433.3	0.719	69728.1	0.908	44388.7	0.965	9180.1	0.722	28432.9	1.302	752.0	0.410	176370.3
1999-2000	0.032	1.154	9570.4	0.754	71398.8	0.916	44386.4	0.975	9688.7	0.774	28398.9	1.229	802.0	0.424	179903.9
2000-01	0.022	1.083	9627.2	0.774	72568.6	0.977	44890.0	1.045	9746.9	0.917	25784.9	1.240	848.6	0.464	177662.6
2001-02	0.039	1.385	9636.5	0.795	73769.5	1.022	45147.5	1.060	9635.2	1.034	23723.0	1.210	920.0	0.483	177855
2002-03	0.007	0.915	9774.1	0.816	75148.2	1.012	45825.3	1.053	9792.4	1.071	23066.3	1.156	962.1	0.621	179288.6
2003-04	0.016	1.031	9949.0	0.878	76981.5	0.969	46414.5	1.000	10040.8	1.050	23249.1	1.062	1021.3	0.756	181288.7
2004-05	0.010	0.940	10312.4	0.944	78988.0	0.979	47619.1	0.990	10716.5	0.930	26974.2	1.021	1092.7	0.941	184158.9

To be continued…

Table 3A Continued

year	EX POST rate	pkal	qkal	pbldg	kbldg	pmas	kmas	ptra	ktra	pinv	kinv	pkint	kint	pland	kland
2005-06	0.012	1.000	10579.8	1.000	81493.0	1.000	48721.0	1.000	11054.6	1.000	26509.0	1.000	1167.2	1.000	174160.2
2006-07	0.005	0.929	10758.4	1.086	84355.7	1.024	49286.4	1.015	10941.8	0.963	28865.2	0.977	1256.7	1.110	172382.4
2007-08	0.011	1.030	11003.9	1.140	87599.1	1.020	50161.0	0.974	11183.6	1.092	26559.0	0.968	1350.3	1.211	167637
2008-09	0.005	0.960	11346.5	1.140	91177.5	1.096	51564.4	1.000	11432.3	1.056	27116.3	0.969	1440.9	1.192	166498.2
2009-10	0.003	0.924	11588.8	1.111	94395.9	1.135	52742.0	0.940	11324.5	1.041	27010.5	0.945	1532.1	1.192	166498
2010-11	0.017	1.147	11925.0	1.140	98789.4	1.077	53694.8	0.919	11679.3	1.102	27343.9	0.926	1644.2	1.433	170407.3
2011-12	0.014	1.092	12551.2	1.160	105741.3	1.038	56297.4	0.904	12012.9	1.102	27618.2	0.912	1757.6	1.466	170751.1

Table 3B Capital services estimated by using the 'ex ante' approach: 1949-2012[16]

	EX ANTE rate	pkal	qkal	pbldg	kbldg	pmas	kmas	ptra	ktra	pinv	kinv	pkint	kint	pland	kland
1948-49	0.006	0.045	1520.2	0.001	31259.4	0.006	9578.8	0.008	2891.2	0.001	14820.4	-	-	0.022	2309.0
1949-50	0.006	0.052	1653.5	0.002	30912.5	0.006	11111.9	0.009	3450.3	0.001	14985.6	-	-	0.024	2309.0
1950-51	0.004	0.059	1773.2	0.002	30496.4	0.007	12674.6	0.010	3432.4	0.001	18575.3	-	-	0.014	2356.2
1951-52	0.003	0.067	2268.2	0.002	30012.3	0.008	14576.3	0.012	4149.2	0.001	10600.8	-	-	0.012	2352.5
1952-53	0.003	0.069	2316.1	0.002	29434.6	0.009	15508.8	0.013	4440.9	0.001	13500.3	-	-	0.013	2355.4
1953-54	0.013	0.087	2437.6	0.003	29831.8	0.010	16881.9	0.014	4914.2	0.005	12358.3	-	-	0.045	2352.3
1954-55	0.027	0.115	2659.2	0.003	30357.0	0.011	18204.0	0.016	5353.5	0.010	12447.2	-	-	0.119	2293.6
1955-56	0.024	0.110	2763.1	0.003	31006.7	0.011	19084.9	0.016	5590.0	0.008	13269.8	-	-	0.096	2378.0
1956-57	0.014	0.097	2745.9	0.003	31032.9	0.011	19607.5	0.016	5659.3	0.005	13157.2	-	-	0.061	2406.2
1957-58	0.024	0.119	3083.0	0.003	30837.5	0.012	20261.7	0.017	5792.7	0.009	12038.8	-	-	0.104	2400.6
1958-59	0.036	0.144	2971.7	0.004	31743.8	0.014	20529.6	0.020	5766.2	0.012	12596.7	-	-	0.148	2382.2
1959-60	0.039	0.153	3003.3	0.004	31770.9	0.015	21137.5	0.020	5881.6	0.013	12798.9	0.231	55.4	0.180	2298.2

To be continued…

[16] The variables in this table are: q = implicit quantity, p = rental price, kal = aggregate capital services, bldg = building and structures, mas = plant and machinery, tra = transportation vehicles, inv = inventory, int = intellectual property, land = land

Table 3B Continued

	EX ANTE rate	pkal	qkal	pbldg	kbldg	pmas	kmas	ptra	ktra	pinv	kinv	pkint	kint	pland	kland
1960-61	0.043	0.160	3209.2	0.005	31879.9	0.015	21784.3	0.021	5974.9	0.013	13886.6	0.259	58.5	0.205	2326.2
1961-62	0.049	0.167	3397.6	0.005	32036.5	0.016	22334.4	0.022	5985.6	0.013	14306.2	0.282	61.1	0.242	2325.6
1962-63	0.046	0.162	3543.5	0.005	32372.6	0.016	23004.6	0.022	6100.5	0.013	14051.4	0.250	64.0	0.228	2338.3
1963-64	0.034	0.146	3742.8	0.004	32987.6	0.015	24075.6	0.021	6520.8	0.010	14071.0	0.178	67.4	0.173	2345.3
1964-65	0.029	0.146	3824.9	0.004	33637.6	0.015	25103.6	0.021	6843.0	0.010	12778.9	0.150	71.3	0.151	2360.2
1965-66	0.026	0.141	3837.7	0.004	34206.5	0.015	25936.4	0.021	6966.3	0.009	13634.6	0.131	74.7	0.127	2369.9
1966-67	0.022	0.139	3890.2	0.004	35066.0	0.015	26991.0	0.021	7249.9	0.008	13305.7	0.112	78.6	0.114	2419.5
1967-68	0.024	0.146	3568.0	0.004	35695.7	0.015	27873.5	0.022	7362.9	0.010	12265.3	0.120	82.4	0.122	2403.8
1968-69	0.019	0.141	3935.9	0.004	36687.8	0.016	28893.6	0.022	7579.0	0.007	12913.9	0.094	87.1	0.104	2443.4
1969-70	0.019	0.152	3166.5	0.004	37555.6	0.016	29485.2	0.023	7464.0	0.010	10631.9	0.097	92.2	0.109	2426.7
1970-71	0.021	0.161	3230.0	0.005	38241.6	0.017	29848.8	0.024	7234.4	0.010	9907.3	0.105	97.7	0.125	2394.3
1971-72	0.019	0.167	3415.7	0.005	39090.5	0.018	30248.4	0.025	7098.3	0.010	9946.9	0.098	102.8	0.113	2409.0
1972-73	0.012	0.158	3858.9	0.005	40440.7	0.018	31076.4	0.025	7343.4	0.006	11584.6	0.057	108.7	0.069	2399.6
1973-74	0.006	0.158	3936.9	0.005	42214.8	0.018	32001.5	0.026	7644.2	0.004	11761.3	0.027	114.4	0.041	2403.3
1974-75	0.004	0.187	4405.7	0.006	43390.3	0.022	32606.2	0.031	7727.3	0.002	10942.0	0.016	117.3	0.028	2352.4

To be continued…

Table 3B Continued

	EX ANTE rate	pkal	qkal	pbldg	kbldg	pmas	kmas	ptra	ktra	pinv	kinv	pkint	kint	pland	kland
1975-76	0.005	0.218	4503.5	0.007	44595.7	0.026	33505.0	0.036	8003.5	0.003	11582.2	0.022	119.1	0.037	2368.4
1976-77	0.008	0.250	4762.4	0.009	45628.0	0.029	34542.1	0.041	8362.4	0.004	14321.2	0.032	117.5	0.052	2316.9
1977-78	0.009	0.280	4949.1	0.010	46649.7	0.033	35295.2	0.045	8496.2	0.005	14347.5	0.034	117.3	0.053	2359.4
1978-79	0.010	0.310	5484.0	0.010	48141.6	0.036	36455.4	0.050	8904.1	0.005	18623.9	0.030	116.8	0.090	2358.3
1979-80	0.012	0.351	5609.6	0.012	49719.9	0.040	37698.7	0.056	9338.7	0.007	19901.7	0.033	117.2	0.111	2382.7
1980-81	0.033	0.484	5607.9	0.018	51072.9	0.050	38838.8	0.066	9630.3	0.020	19979.5	0.076	118.8	0.473	2393.3
1981-82	0.054	0.643	5743.2	0.027	52277.2	0.061	39993.7	0.079	9869.3	0.035	18732.7	0.124	121.4	0.837	2375.5
1982-83	0.041	0.612	6111.1	0.027	53009.7	0.063	40488.0	0.080	9693.5	0.021	24595.8	0.099	124.5	0.757	2356.8
1983-84	0.044	0.673	6093.2	0.029	54199.5	0.067	41603.6	0.086	9985.5	0.030	20300.9	0.097	130.1	0.811	2401.4
1984-85	0.067	0.842	6122.9	0.040	55301.8	0.078	42835.6	0.097	10323.8	0.044	22090.1	0.148	143.6	1.311	2376.9
1985-86	0.082	1.025	6368.4	0.051	56235.5	0.094	43454.5	0.122	10103.8	0.047	24467.2	0.186	162.5	1.447	2250.4
1986-87	0.081	1.121	6484.5	0.054	57105.4	0.104	43725.7	0.141	9594.9	0.050	23773.8	0.182	191.7	1.355	2248.0
1987-88	0.068	1.105	6405.3	0.051	58060.8	0.103	44500.2	0.139	9441.9	0.056	20650.0	0.145	224.7	1.480	2245.4
1988-89	0.058	1.066	6255.7	0.050	58738.1	0.098	45533.8	0.132	9455.5	0.057	18852.1	0.119	261.4	1.973	2237.1
1989-90	0.066	1.173	6283.0	0.058	59458.9	0.105	46248.1	0.142	9325.2	0.059	18425.0	0.136	303.0	2.156	2235.3

To be continued…

Table 3B Continued

	EX ANTE rate	pkal	qkal	pbldg	kbldg	pmas	kmas	ptra	ktra	pinv	kinv	pkint	kint	pland	kland
1990-91	0.065	1.177	6514.7	0.058	60183.6	0.109	46295.9	0.148	8848.0	0.048	21273.0	0.130	337.9	1.799	2196.5
1991-92	0.063	1.168	6712.3	0.055	61454.4	0.111	46168.3	0.155	8337.4	0.048	19973.4	0.117	378.3	1.809	2163.5
1992-93	0.052	1.099	6785.0	0.047	62486.0	0.111	45736.8	0.161	7742.5	0.039	20829.7	0.094	425.5	1.431	2140.2
1993-94	0.054	1.148	6895.1	0.048	63591.7	0.116	45413.1	0.172	7276.1	0.040	22534.0	0.093	484.2	1.462	2223.7
1994-95	0.064	1.261	6710.3	0.056	64651.4	0.122	44923.5	0.177	7326.2	0.051	20678.1	0.106	535.6	1.939	2178.4
1995-96	0.059	1.194	7290.5	0.055	66050.4	0.121	44611.8	0.174	7594.8	0.032	30129.7	0.092	597.4	1.850	2211.6
1996-97	0.053	1.138	7571.9	0.052	66808.7	0.116	44434.5	0.164	7912.4	0.032	31449.2	0.075	651.3	1.548	2220.5
1997-98	0.044	1.113	7197.8	0.048	68168.4	0.115	44400.9	0.166	8620.6	0.034	25986.2	0.060	707.9	1.512	2220.7
1998-99	0.045	1.177	7438.3	0.050	69728.1	0.125	44388.7	0.178	9180.1	0.032	28432.9	0.058	752.0	1.463	2213.4
1999-2000	0.046	1.217	7582.4	0.053	71398.8	0.127	44386.4	0.180	9688.7	0.035	28398.9	0.056	802.0	1.546	2257.8
2000-01	0.025	1.055	7522.5	0.041	72568.6	0.119	44890.0	0.176	9746.9	0.023	25784.9	0.031	848.6	0.919	2229.6
2001-02	0.020	1.042	7556.9	0.039	73769.5	0.120	45147.5	0.174	9635.2	0.021	23723.0	0.024	920.0	0.775	2232.1
2002-03	0.022	1.073	7660.5	0.041	75148.2	0.121	45825.3	0.175	9792.4	0.024	23066.3	0.026	962.1	1.112	2250.1
2003-04	0.021	1.048	7563.7	0.044	76981.5	0.115	46414.5	0.165	10040.8	0.022	23249.1	0.022	1021.3	1.275	2275.2
2004-05	0.019	1.040	7959.8	0.045	78988.0	0.114	47619.1	0.162	10716.5	0.017	26974.2	0.019	1092.7	1.402	2311.2

To be continued…

Table 3B Continued

	EX ANTE rate	pkal	qkal	pbldg	kbldg	pmas	kmas	ptra	ktra	pinv	kinv	pkint	kint	pland	kland
2005-06	0.013	1.000	8110.4	0.043	81493.0	0.112	48721.0	0.159	11054.6	0.013	26509.0	0.013	1167.2	1.000	2185.7
2006-07	0.012	1.028	8528.3	0.046	84355.7	0.114	49286.4	0.160	10941.8	0.011	28865.2	0.011	1256.7	1.026	2163.4
2007-08	0.009	1.005	8792.2	0.046	87599.1	0.111	50161.0	0.152	11183.6	0.010	26559.0	0.009	1350.3	0.855	2103.8
2008-09	0.006	1.012	8563.4	0.044	91177.5	0.118	51564.4	0.154	11432.3	0.007	27116.3	0.006	1440.9	0.606	2089.5
2009-10	0.010	1.057	8884.8	0.046	94395.9	0.125	52742.0	0.147	11324.5	0.010	27010.5	0.009	1532.1	0.935	2089.5
2010-11	0.011	1.048	10043.9	0.048	98789.4	0.119	53694.8	0.144	11679.3	0.012	27343.9	0.010	1644.2	1.210	2138.6
2011-12	0.008	1.003	10079.9	0.046	105741.3	0.113	56297.4	0.141	12012.9	0.009	27618.2	0.008	1757.6	1.239	2142.9

Table 4 Labour inputs estimated using the 'ex post' and 'ex ante' approaches: 1949-2012

	EX POST						EX ANTE					
	All labour		Hired Workers		Self-employed Workers		All labour		Hired Workers		Self-employed Workers	
Year	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity
1948-49	0.021	20875.7	0.022	6000.2	0.020	15985.8	0.022	26723.0	0.022	6000.2	0.020	22827.7
1949-50	0.028	20879.1	0.022	6045.9	0.028	15945.5	0.034	26706.6	0.022	6045.9	0.034	22770.1
1950-51	0.043	20895.0	0.028	5977.6	0.046	16008.8	0.059	26760.0	0.028	5977.6	0.062	22860.4
1951-52	0.033	20969.1	0.034	6006.1	0.030	16059.4	0.037	26851.4	0.034	6006.1	0.035	22932.7
1952-53	0.039	21260.5	0.038	6198.7	0.037	16165.8	0.047	27160.2	0.038	6198.7	0.045	23084.7
1953-54	0.036	21348.3	0.042	6202.4	0.031	16258.0	0.038	27285.3	0.042	6202.4	0.034	23216.3
1954-55	0.035	21130.3	0.046	6012.5	0.028	16280.6	0.024	27023.3	0.046	6012.5	0.016	23248.6
1955-56	0.038	20958.2	0.048	5839.0	0.032	16345.7	0.028	26766.8	0.048	5839.0	0.020	23341.5
1956-57	0.043	20854.3	0.051	5768.2	0.037	16325.6	0.040	26637.0	0.051	5768.2	0.033	23312.9
1957-58	0.029	20784.9	0.053	5846.5	0.019	16076.1	0.018	26583.1	0.053	5846.5	0.007	22956.5
1958-59	0.037	20367.0	0.053	5784.8	0.028	15623.6	0.021	26116.2	0.053	5784.8	0.011	22310.4
1959-60	0.037	19659.3	0.044	5506.3	0.032	15206.4	0.021	25128.8	0.044	5506.3	0.013	21714.6
1960-61	0.039	19272.5	0.047	5261.2	0.033	15099.9	0.018	24455.7	0.047	5261.2	0.008	21562.5

To be continued…

Table 4 Continued

	EX POST						EX ANTE					
	All labour		Hired Workers		Self-employed Workers		All labour		Hired Workers		Self-employed Workers	
Year	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity
1961-62	0.037	19468.0	0.050	5152.3	0.030	15503.6	0.012	24250.0	0.050	5152.3	0.001	22139.0
1962-63	0.042	18925.6	0.054	5105.4	0.035	14916.5	0.019	23859.8	0.054	5105.4	0.008	21300.7
1963-64	0.053	18506.1	0.057	5099.8	0.048	14440.4	0.040	23436.3	0.057	5099.8	0.032	20620.8
1964-65	0.051	18307.5	0.060	5048.1	0.043	14281.5	0.039	23185.0	0.060	5048.1	0.029	20393.9
1965-66	0.039	17915.5	0.062	5008.7	0.028	13855.6	0.033	22683.4	0.062	5008.7	0.022	19785.7
1966-67	0.058	17560.8	0.071	4551.3	0.049	14223.1	0.052	22329.3	0.071	4551.3	0.041	20310.6
1967-68	0.041	17477.4	0.074	4647.5	0.027	13917.5	0.028	22237.0	0.074	4647.5	0.014	19874.0
1968-69	0.057	17078.6	0.077	4612.3	0.046	13447.9	0.051	21737.6	0.077	4612.3	0.039	19203.5
1969-70	0.052	17102.9	0.076	4800.5	0.039	13140.3	0.046	21708.4	0.076	4800.5	0.033	18764.2
1970-71	0.053	17323.9	0.077	4860.3	0.040	13314.4	0.035	21988.6	0.077	4860.3	0.021	19012.9
1971-72	0.056	16794.8	0.079	4671.1	0.044	12983.1	0.051	21313.8	0.079	4671.1	0.039	18539.7
1972-73	0.064	16452.7	0.093	4596.9	0.049	12679.9	0.093	20860.5	0.093	4596.9	0.083	18106.8
1973-74	0.079	15929.7	0.118	4339.9	0.060	12491.0	0.154	20383.1	0.118	4339.9	0.148	17837.1

To be continued…

Table 4 Continued

	EX POST						EX ANTE					
	All labour		Hired Workers		Self-employed Workers		All labour		Hired Workers		Self-employed Workers	
Year	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity
1974-75	0.106	15365.3	0.152	4001.5	0.083	12399.3	0.103	19891.5	0.152	4001.5	0.081	17706.2
1975-76	0.121	15078.8	0.177	3713.4	0.093	12567.2	0.095	19590.0	0.177	3713.4	0.067	17945.9
1976-77	0.141	13840.3	0.203	3147.6	0.110	12024.7	0.107	17981.8	0.203	3147.6	0.075	17171.2
1977-78	0.156	13790.5	0.215	3220.5	0.124	11830.3	0.100	17942.2	0.215	3220.5	0.065	16893.6
1978-79	0.166	13883.2	0.218	3442.2	0.134	11573.7	0.218	18010.7	0.218	3442.2	0.192	16527.2
1979-80	0.174	14460.9	0.228	3738.8	0.141	11806.3	0.293	18574.6	0.228	3738.8	0.272	16859.4
1980-81	0.192	14465.1	0.262	3709.6	0.153	11860.3	0.302	18621.4	0.262	3709.6	0.275	16936.4
1981-82	0.229	14016.9	0.312	3813.8	0.182	11117.3	0.238	17822.0	0.312	3813.8	0.193	15875.5
1982-83	0.252	13731.9	0.369	3352.3	0.192	11587.4	0.159	17457.0	0.369	3352.3	0.093	16546.7
1983-84	0.260	14325.5	0.379	3586.9	0.199	11916.9	0.313	18198.3	0.379	3586.9	0.255	17017.2
1984-85	0.287	13829.7	0.414	3410.9	0.220	11602.5	0.196	17583.3	0.414	3410.9	0.123	16568.4
1985-86	0.302	14469.1	0.474	3583.8	0.221	12108.6	0.151	18413.4	0.474	3583.8	0.063	17291.0
1986-87	0.350	12967.9	0.547	3175.0	0.256	10931.2	0.145	16415.2	0.547	3175.0	0.041	15609.7

To be continued…

Table 4 Continued

	EX POST						EX ANTE					
	All labour		Hired Workers		Self-employed Workers		All labour		Hired Workers		Self-employed Workers	
Year	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity
1987-88	0.374	13126.0	0.571	3495.3	0.278	10474.7	0.271	17044.8	0.571	3495.3	0.175	14957.7
1988-89	0.427	12796.6	0.665	3530.2	0.314	9955.7	0.373	16604.4	0.665	3530.2	0.271	14216.7
1989-90	0.429	13751.2	0.643	3957.6	0.324	10361.8	0.289	17850.7	0.643	3957.6	0.176	14796.6
1990-91	0.434	13517.2	0.617	3812.5	0.340	10333.2	0.206	17451.4	0.617	3812.5	0.084	14755.7
1991-92	0.453	13050.0	0.616	3620.7	0.365	10081.2	0.191	16718.5	0.616	3620.7	0.067	14395.8
1992-93	0.479	12708.9	0.687	3326.7	0.375	10168.6	0.363	16024.6	0.687	3326.7	0.243	14520.7
1993-94	0.501	12584.9	0.708	3452.8	0.395	9781.7	0.421	15866.1	0.708	3452.8	0.303	13968.1
1994-95	0.523	12360.1	0.708	3599.6	0.424	9245.9	0.261	15739.6	0.708	3599.6	0.118	13203.1
1995-96	0.536	12646.3	0.698	3922.2	0.445	9072.3	0.412	16298.6	0.698	3922.2	0.306	12955.2
1996-97	0.544	13045.5	0.719	4147.0	0.448	9198.4	0.464	16801.6	0.719	4147.0	0.366	13135.2
1997-98	0.540	13326.4	0.691	4308.1	0.455	9284.5	0.495	17138.9	0.691	4308.1	0.416	13258.2
1998-99	0.609	12325.5	0.727	4308.1	0.539	8123.8	0.499	15765.0	0.727	4308.1	0.408	11600.7
1999-2000	0.594	13048.0	0.712	4561.9	0.524	8598.3	0.511	16689.0	0.712	4561.9	0.430	12278.3

To be continued…

Table 4 Continued

	EX POST						EX ANTE					
	All labour		Hired Workers		Self-employed Workers		All labour		Hired Workers		Self-employed Workers	
Year	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity	Price Index	Implicit quantity
2000-01	0.651	12336.6	0.751	4475.7	0.589	7915.7	0.653	15714.5	0.751	4475.7	0.611	11303.5
2001-02	0.637	12784.3	0.686	4906.0	0.606	7881.2	0.950	16065.7	0.686	4906.0	1.057	11254.3
2002-03	0.772	10618.3	0.789	4090.7	0.761	6528.6	0.543	13337.4	0.789	4090.7	0.431	9322.8
2003-04	0.842	10192.0	0.838	4082.0	0.844	6108.7	0.801	12796.5	0.838	4082.0	0.783	8723.2
2004-05	0.903	9715.9	0.876	3894.5	0.921	5820.4	0.710	12198.2	0.876	3894.5	0.631	8311.5
2005-06	1.000	9330.3	1.000	3778.0	1.000	5552.3	1.000	11706.7	1.000	3778.0	1.000	7928.7
2006-07	0.941	9979.9	0.928	3937.3	0.949	6041.5	0.746	12543.5	0.928	3937.3	0.661	8627.2
2007-08	0.969	9869.8	0.955	3839.8	0.979	6027.6	1.004	12417.6	0.955	3839.8	1.022	8607.4
2008-09	0.924	10701.8	0.943	4060.3	0.913	6639.3	0.879	13506.6	0.943	4060.3	0.848	9480.8
2009-10	0.950	10613.4	0.885	4275.3	0.993	6345.8	0.751	13354.0	0.885	4275.3	0.689	9061.8
2010-11	1.087	9820.9	0.959	4295.4	1.174	5582.4	1.247	12265.6	0.959	4295.4	1.401	7971.7
2011-12	1.221	9039.0	0.976	4319.7	1.403	4861.8	1.404	11105.6	0.976	4319.7	1.638	6942.7

Table 5 Gross output and its disaggregation: 1949-2012

	Aggregate Outputs		Output share		
Year	Price index 2005-06=1.00	implicit quantity	Crops	Livestock	others
1948-49	0.1793	6797.2	33.6	63.3	3.1
1949-50	0.2465	6411.5	33.4	64.2	2.4
1950-51	0.2377	9959.7	21.7	76.4	1.9
1951-52	0.2286	8424.5	32.1	65.4	2.5
1952-53	0.2374	9828.4	30.8	67.1	2.1
1953-54	0.2319	10013.5	29.9	67.9	2.2
1954-55	0.2182	10127.5	28.5	69.2	2.3
1955-56	0.2096	11043.0	31.1	66.7	2.3
1956-57	0.2283	11188.9	25.5	72.3	2.1
1957-58	0.2182	10348.8	27.9	69.8	2.4
1958-59	0.2015	12465.8	34.5	63.3	2.2
1959-60	0.2190	12034.5	28.5	69.3	2.2
1960-61	0.2128	12789.9	36.3	61.5	2.2
1961-62	0.2071	13093.7	34.1	63.6	2.3
1962-63	0.2169	13662.7	34.4	63.3	2.3
1963-64	0.2355	14314.7	33.4	64.4	2.2
1964-65	0.2220	15281.5	35.8	62.0	2.2
1965-66	0.2323	14123.8	32.6	65.1	2.4
1966-67	0.2292	16549.0	40.3	57.6	2.1
1967-68	0.2226	14839.5	34.8	62.8	2.4
1968-69	0.2278	17152.5	40.8	57.1	2.1
1969-70	0.2167	17242.0	36.8	61.0	2.2
1970-71	0.2110	16991.6	39.3	58.3	2.3
1971-72	0.2258	17585.1	37.9	59.8	2.3
1972-73	0.3108	15967.3	29.6	68.1	2.3
1973-74	0.3411	18799.9	42.5	55.4	2.1
1974-75	0.3314	17725.7	52.2	45.5	2.3

To be continued…

Table 5 Continued

	Aggregate Outputs		Output share		
Year	Price index 2005-06=1.00	implicit quantity	Crops	Livestock	others
1975-76	0.3455	17859.5	50.4	47.4	2.3
1976-77	0.3756	17986.9	45.0	52.8	2.2
1977-78	0.4102	17025.4	41.1	56.4	2.5
1978-79	0.5285	19306.6	46.1	51.9	2.0
1979-80	0.5996	19621.0	45.2	52.9	1.9
1980-81	0.6372	21777.6	52.5	45.2	2.3
1981-82	0.6175	24453.5	55.6	42.3	2.1
1982-83	0.6974	20363.4	50.7	47.2	2.2
1983-84	0.6870	26218.7	59.4	38.9	1.8
1984-85	0.6998	25900.6	56.2	41.8	2.0
1985-86	0.7109	26979.0	56.4	42.0	1.6
1986-87	0.7302	27138.2	49.7	48.2	2.1
1987-88	0.8596	26696.8	44.4	53.7	1.9
1988-89	0.9532	27206.8	47.3	51.0	1.8
1989-90	0.9131	29317.9	46.9	51.2	1.9
1990-91	0.7858	31237.4	48.5	49.3	2.2
1991-92	0.8254	29727.0	53.0	44.8	2.2
1992-93	0.8207	31895.6	54.9	43.0	2.1
1993-94	0.8395	33461.6	55.0	42.9	2.1
1994-95	0.9742	28442.7	52.0	45.7	2.3
1995-96	0.9504	33199.5	59.5	38.5	2.0
1996-97	0.8879	36697.8	60.7	37.2	2.1
1997-98	0.8799	37264.2	58.2	39.5	2.3
1998-99	0.8290	40079.7	59.5	38.1	2.4
1999-2000	0.8704	40144.6	59.4	38.4	2.2
2000-01	0.9846	35322.9	52.9	45.2	1.9
2001-02	1.0468	38093.1	52.2	45.9	1.9

To be continued…

Table 5 Continued

Year	Aggregate Outputs		Output share		
	Price index 2005-06=1.00	implicit quantity	Crops	Livestock	others
2002-03	1.1198	29677.8	45.8	51.7	2.5
2003-04	1.0307	36217.8	53.5	44.3	2.2
2004-05	1.0323	35369.9	48.9	48.8	2.3
2005-06	1.0000	38723.0	51.6	46.0	2.4
2006-07	1.1235	32603.8	47.5	49.8	2.7
2007-08	1.2637	34622.9	53.3	44.6	2.1
2008-09	1.1469	36559.4	52.4	45.7	1.9
2009-10	1.0971	36152.4	51.1	46.7	2.2
2010-11	1.1751	40633.1	54.1	44.1	1.8
2011-12	1.1564	42179.4	54.2	44.0	1.8

Table 6 Gross input and its disaggregation: 1949-2012

	EX POST		Input share				EX ANTE		Input share			
Year	Price index 2005-06=1.00	implicit quantity	land	capital	labour	intermediate	Price Index	Implicit Quantity	land	capital	labour	intermediate inputs
1948-49	0.0446	27311.9	8.2	13.6	36.6	41.7	0.0445	27403.1	4.2	5.7	48.4	41.7
1949-50	0.0572	27642.1	12.7	16.3	36.9	34.1	0.0572	27612.0	3.5	5.4	57.0	34.1
1950-51	0.0839	28219.6	14.4	20.4	38.0	27.3	0.0854	27742.1	1.4	4.4	67.0	27.3
1951-52	0.0713	26988.4	8.2	17.5	35.6	38.7	0.0698	27602.3	1.5	7.9	52.0	38.7
1952-53	0.0820	28441.0	9.3	17.6	35.8	37.4	0.0812	28743.5	1.3	6.9	54.5	37.4
1953-54	0.0785	29582.0	7.9	17.8	32.9	41.4	0.0776	29914.5	4.6	9.2	44.9	41.4
1954-55	0.0736	30031.2	5.7	16.5	33.2	44.7	0.0727	30399.2	12.4	13.8	29.1	44.7
1955-56	0.0752	30767.0	4.2	16.1	34.6	45.1	0.0743	31157.1	9.9	13.1	31.9	45.1
1956-57	0.0832	30703.8	5.6	16.8	35.2	42.4	0.0824	31013.2	5.8	10.4	41.4	42.4
1957-58	0.0723	31207.7	3.5	17.9	27.1	51.5	0.0706	31973.9	11.0	16.2	21.2	51.5
1958-59	0.0788	31897.5	4.4	18.9	29.7	47.1	0.0775	32428.6	14.1	17.1	21.8	47.1
1959-60	0.0817	32239.6	5.5	19.6	27.8	47.2	0.0807	32664.1	15.7	17.4	19.8	47.2
1960-61	0.0839	32460.6	5.3	19.6	27.3	47.8	0.0821	33173.8	17.5	18.9	15.8	47.8
1961-62	0.0814	33302.8	4.5	19.2	26.5	49.8	0.0809	33497.2	20.8	18.9	10.5	49.8

To be continued…

Table 6 Continued

	EX POST		Input share				EX ANTE		Input share			
Year	Price index 2005-06=1.00	implicit quantity	land	capital	labour	intermediate	Price Index	Implicit Quantity	land	capital	labour	intermediate inputs
1962-63	0.0874	33904.3	6.0	19.6	26.8	47.6	0.0843	35154.4	18.0	19.4	15.0	47.6
1963-64	0.0961	35074.6	7.3	19.6	29.3	43.9	0.0923	36540.2	12.0	16.2	27.9	43.9
1964-65	0.0948	35783.4	6.3	19.8	27.3	46.6	0.0910	37268.4	10.5	16.4	26.5	46.6
1965-66	0.0914	35897.1	5.9	21.3	21.4	51.3	0.0883	37173.2	9.2	16.5	23.0	51.3
1966-67	0.1030	36819.4	5.7	19.6	26.8	47.9	0.0998	38017.0	7.2	14.2	30.6	47.9
1967-68	0.0898	36769.9	2.5	19.4	21.7	56.3	0.0885	37346.2	8.9	15.8	19.0	56.3
1968-69	0.1022	38226.4	4.4	19.5	25.1	51.0	0.0998	39166.7	6.5	14.2	28.3	51.0
1969-70	0.0961	38897.6	2.9	20.0	23.6	53.5	0.0966	38669.3	7.1	12.8	26.5	53.5
1970-71	0.0926	38709.7	0.1	18.8	25.5	55.6	0.0930	38539.6	8.3	14.5	21.5	55.6
1971-72	0.1044	38042.1	3.1	21.8	23.6	51.5	0.1041	38134.1	6.8	14.4	27.3	51.5
1972-73	0.1290	38462.2	8.0	25.4	21.1	45.5	0.1282	38710.6	3.3	12.2	38.9	45.5
1973-74	0.1678	38219.4	11.9	28.7	19.6	39.7	0.1684	38079.7	1.5	9.7	49.1	39.7
1974-75	0.1598	36766.3	1.6	20.5	27.8	50.0	0.1587	37007.3	1.1	14.0	34.8	50.0
1975-76	0.1708	36116.5	0.4	17.5	29.5	52.6	0.1700	36285.7	1.4	15.9	30.1	52.6

To be continued…

Table 6 Continued

	EX POST		Input share				EX ANTE		Input share			
Year	Price index 2005-06=1.00	implicit quantity	land	capital	labour	intermediate	Price Index	Implicit Quantity	land	capital	labour	intermediate inputs
1976-77	0.1934	34921.8	2.0	16.9	29.0	52.1	0.1920	35183.9	1.8	17.6	28.5	52.1
1977-78	0.2048	34109.5	0.6	15.8	30.8	52.8	0.2023	34524.4	1.8	19.9	25.6	52.8
1978-79	0.2833	36023.4	6.0	28.7	22.5	42.8	0.2778	36728.1	2.1	16.7	38.5	42.8
1979-80	0.3448	34121.0	8.8	35.1	21.4	34.7	0.3399	34608.5	2.2	16.7	46.3	34.7
1980-81	0.4120	33682.4	13.1	35.1	20.1	31.7	0.4095	33882.9	8.2	19.5	40.6	31.7
1981-82	0.4397	34341.6	11.2	33.3	21.3	34.2	0.4408	34256.2	13.2	24.5	28.1	34.2
1982-83	0.4063	34959.1	5.6	28.5	24.4	41.5	0.4049	35074.4	12.6	26.3	19.6	41.5
1983-84	0.5074	35495.8	11.2	33.3	20.7	34.8	0.5066	35556.6	10.8	22.8	31.6	34.8
1984-85	0.5120	35398.4	10.0	32.8	21.9	35.4	0.5169	35064.9	17.2	28.4	19.0	35.4
1985-86	0.5382	35636.0	7.9	34.8	22.8	34.5	0.5436	35284.6	17.0	34.0	14.5	34.5
1986-87	0.5633	35176.4	6.1	35.1	22.9	35.9	0.5592	35435.8	15.4	36.7	12.0	35.9
1987-88	0.6362	36070.1	8.5	35.5	21.4	34.6	0.6321	36304.3	14.5	30.8	20.1	34.6
1988-89	0.7146	36288.3	12.2	33.4	21.1	33.4	0.7169	36172.6	17.0	25.7	23.9	33.4
1989-90	0.7156	37410.0	10.3	32.4	22.0	35.2	0.7188	37243.1	18.0	27.5	19.2	35.2

To be continued…

Table 6 Continued

	EX POST		Input share				EX ANTE		Input share			
Year	Price index 2005-06=1.00	implicit quantity	land	capital	labour	intermediate	Price Index	Implicit Quantity	land	capital	labour	intermediate inputs
1990-91	0.6695	36661.3	6.3	31.8	23.9	38.0	0.6675	36772.8	16.1	31.2	14.7	38.0
1991-92	0.6677	36749.2	5.7	31.1	24.1	39.1	0.6571	37341.4	16.0	32.0	13.0	39.1
1992-93	0.7157	36576.8	6.4	32.7	23.3	37.6	0.7013	37329.2	11.7	28.5	22.2	37.6
1993-94	0.7592	37000.5	7.4	33.6	22.5	36.5	0.7383	38046.1	11.6	28.2	23.8	36.5
1994-95	0.7473	37079.8	6.2	31.0	23.3	39.4	0.7305	37930.7	15.2	30.5	14.8	39.4
1995-96	0.8232	38332.1	8.4	31.9	21.5	38.2	0.7909	39893.8	13.0	27.6	21.3	38.2
1996-97	0.8252	39484.9	7.8	31.3	21.8	39.1	0.7870	41400.3	10.6	26.4	23.9	39.1
1997-98	0.8230	39842.2	7.8	30.8	22.0	39.4	0.7958	41204.9	10.2	24.4	25.9	39.4
1998-99	0.8329	39891.1	6.3	30.9	22.6	40.2	0.8065	41198.4	9.7	26.3	23.7	40.2
1999-2000	0.8619	40537.5	7.0	31.6	22.2	39.2	0.8328	41955.2	10.0	26.4	24.4	39.2
2000-01	0.8653	40191.6	5.2	30.0	23.1	41.8	0.8424	41283.9	5.9	22.8	29.5	41.8
2001-02	0.9793	40719.3	8.5	33.5	20.4	37.6	0.9530	41841.8	4.3	19.7	38.3	37.6
2002-03	0.8677	38298.2	2.5	26.9	24.7	45.9	0.8572	38770.2	7.5	24.7	21.8	45.9

To be continued…

Table 6 Continued

	EX POST		Input share				EX ANTE		Input share			
Year	Price index 2005-06=1.00	implicit quantity	land	capital	labour	intermediate	Price Index	Implicit Quantity	land	capital	labour	intermediate inputs
2003-04	0.9500	39294.6	6.0	27.5	23.0	43.5	0.9458	39467.5	7.8	21.2	27.5	43.5
2004-05	0.9343	39080.6	4.7	26.5	24.0	44.7	0.9293	39291.3	8.9	22.7	23.7	44.7
2005-06	1.0000	38723.0	5.4	27.3	24.1	43.2	1.0000	38723.0	5.6	20.9	30.2	43.2
2006-07	0.9647	37970.7	2.6	27.3	25.6	44.5	0.9560	38317.9	6.1	23.9	25.5	44.5
2007-08	1.1209	39035.4	5.0	25.9	21.9	47.2	1.1104	39403.5	4.1	20.2	28.5	47.2
2008-09	1.0387	40366.1	2.4	26.0	23.6	48.0	1.0371	40427.8	3.0	20.7	28.3	48.0
2009-10	0.9826	40367.8	1.5	27.0	25.4	46.1	0.9795	40492.9	4.9	23.7	25.3	46.1
2010-11	1.1703	40802.8	8.5	28.6	22.4	40.5	1.1503	41509.1	5.4	22.0	32.0	40.5
2011-12	1.1991	40678.8	7.4	28.1	22.6	41.9	1.2108	40282.9	5.4	20.7	32.0	41.9

Table 7 Decomposition of TFP growth: 1949-2012

	EX ANTE		EX POST	
	Growth Rate	Share (%)	Growth Rate	Share (%)
Total Factor Productivity Index	2.13		2.13	
Gross Output Growth	2.61	100.0	2.61	100.0
Crops	3.97	44.4	3.97	44.4
grains	3.23	58.1	3.23	58.1
oilseeds	7.37	1.8	7.37	1.8
vegetables and melons	4.73	12.0	4.73	12.0
fruits and nuts	2.03	11.0	2.03	11.0
cotton, tobacco and other horticulture	4.78	6.3	4.78	6.3
other crops	1.20	10.8	1.20	10.8
Livestock	1.43	53.4	1.43	53.4
red meat	2.45	41.4	2.45	41.4
poultry	5.92	5.0	5.92	5.0
egg	0.89	3.8	0.89	3.8
wool	-0.26	32.0	-0.26	32.0
milk and dairy products	0.94	17.5	0.94	17.5
other livestock products	0.81	0.3	0.81	0.3
Other output	3.79	2.2	3.79	2.2
Gross Input Growth	0.48	100.0	0.48	100.0
Land	-0.19	8.9	-0.21	6.4
Capital	2.45	19.7	1.77	25.3
non-dwelling building and structures	3.29	28.4	1.60	46.7
plant and machinery	2.32	53.0	2.08	39.2
transportation vehicles	1.54	17.5	1.46	9.4
others	1.57	1.1	1.54	4.7

To be continued…

Table 7 Continued

	EX ANTE		EX POST	
	Growth Rate	Share (%)	Growth Rate	Share (%)
Labour	-1.28	28.6	-1.31	25.6
hired labour	-0.70	42.0	-0.70	38.9
self-employed labour	-1.70	58.0	-1.70	61.1
Intermediate Inputs	0.89	42.7	0.89	42.7
fuel, lubricants and electricity	0.01	10.0	0.01	10.0
fertilizer	0.82	9.5	0.82	9.5
chemicals and medicine	4.20	5.7	4.20	5.7
Seeds, fodder and livestock purchases	1.36	20.6	1.36	20.6
marketing and packaging	0.00	20.9	0.00	20.9
repairs and maintenance	1.50	13.3	1.50	13.3
plant hire	0.47	3.8	0.47	3.8
other materials and services	0.45	16.1	0.45	16.1

Table 8 Comparison of agricultural TFP estimates with previous literature

	TFP Growth in literature (%)	TFP Growth in this paper (%)	Industrial Coverage	Data Source	Time Period Covered
ABS VA	2.8	1.6	Agriculture, Forestry and Fishing	ABS National accounts	1984-85 to 2010-11
PC VA	2.5	1.9	Agriculture, Forestry and Fishing	ABS National accounts	1974-75 to 2007-08
ABS GO	1.2	1.5	Agriculture, Forestry and Fishing	ABS National accounts	1994-95 to 2009-10
ABARES	1.3	1.8	the broadacre agriculture	ABARES Farm Survey	1977-78 to 2009-10
Mullen and Cox (1995)	2.4-2.6	2.2	the broadacre agriculture	ABARES Farm Survey	1952-53 to 1993-94
Knopke (1995)	2.7	2.3	the broadacre agriculture	ABARES Farm Survey	1977-78 to 1994-95
Coelli and Rao (2005)	1.8	2.1	Agriculture for Australia	FAO data	1980 to 2000 (1980-81 to 2000-01)
Fuglie (2010)	1.4	1.6	Agriculture for Australia	FAO data	1961 to 2006 (1961-62 to 2006-07)

Note: the estimate of TFP growth labelled "TFP Growth in this paper" relates to the estimation period of the corresponding study in the table.

Appendix A: A Brief Literature Review of Agricultural TFP Measurement

While the concept of agricultural TFP is reasonably straightforward, using the index method to measure it in practice is still a challenging task. Previous studies differ from each other mainly in three aspects: choice of aggregation methods, definition of inputs/outputs and use of data sources. This appendix provides a brief but comprehensive review on representative studies of using the index method to measure agricultural TFP in the US (Ball 1985; Ball *et al.* 1997b; Ball *et al.* 1999; ERS-USDA 2009) and in Australia (ABS 2007; Knopke 1988; Mullen and Cox 1996; Powell 1974; Zhao *et al.* 2012). The objective is to inform our study in terms of methodology and data. A list of these studies is presented in Table A1.

International studies: single-country agriculture

The ERS-USDA was the first agency to use index methods to measure agricultural TFP in the United States. It has done so since the 1960s, and this model has now been applied to other countries (Fuglie *et al.* 2012). In the development of this model, improvements on data and methods were mainly proposed by Ball (1985), Ball *et al.* (1997) and ERS (2009).

In the study by Ball (1985), the production account was defined in terms of the gross value of six categories of outputs, and inputs included labour, capital and intermediate inputs such as fertilizer and chemicals. Data describing the prices and quantities of each of these outputs and inputs were constructed using a combination of existing surveys and models. This construction of the production account is in contrast to the 'value added' model used by the ERS-USDA at the time, in which output was defined as the real value added in US agriculture, and inputs only included capital and labour.

Although it represents a significant improvement from previous studies, there are at least two shortcomings of Ball's (1985) model. First, it does not satisfy the determination test because the Törnqvist index is indeterminate if the components of the output/input vector are zero. Secondly, it does not satisfy the factor reversal test because the value of the implicit quantity index is different from the value of the direct quantity index.

To deal with these and other concerns, the ERS-USDA subsequently adopted the Fisher index to approximate the output/input aggregation function when measuring agricultural TFP (Ball *et al.* 1997b). The specification of the production account was also altered in two ways relative to previous ERS-USDA work. First, the definition of output was changed to cover gross production leaving the farm (as opposed to real value added). Second, the definition of inputs was widened to include not only capital and labour, but also land and intermediate inputs. This is known as the gross output model.

Since the adoption of these modifications, the method used by the ERS-USDA to estimate agricultural TFP has remained largely unchanged, with only modest revisions necessitated by the adoption of new data sources (ERS-USDA 2009). For example, in their recent update of national-level agricultural TFP estimates, the only changes made to the estimation model were shifting the base year from 1996 to 2005, and using data from the decennial Census of Population and the annual Current Population Survey to impute the labour input from self-employed and unpaid family workers.

Nowadays, although some disagreements remain about the treatment of the interest rate and its related capital services (Andersen *et al.* 2012; Anderson and Nelgen 2012), the ERS-USDA method for estimating agricultural TFP has become a standard. For example, this approach has been the basis of methods used to measure agricultural productivity in other countries, such as Canada (Cahill and Rich 2012). The method has also been used for performing country-specific case studies (Fuglie *et al.* 2012), and has been extended for comparison of agricultural TFP across countries (Ball *et al.* 1997a; Ball *et al.* 2010).

Australian studies: various data sources

Index methods have also commonly been used to estimate agricultural TFP in Australia. Over the past three decades, various studies in Australia have employed a range of different production accounts, aggregation methods and data sources. These studies are discussed in two groups, distinguished by their use of data sources.

Using Farm Survey Data

Using data from the Australian Sheep Industry Survey, Lawrence and McKay (1980) estimated TFP growth in the Australian sheep industry over the period 1952–53 to 1976–77. In this study, a gross output model was used, and output was specified to include crops, wool, other sheep products, cattle and other outputs, and input is defined to include livestock, materials and services, labour, capital and land. A Törnqvist index was used as the aggregation function. Average annual TFP growth of the Australian sheep industry was estimated to be 2.9 per cent a year, mainly driven by the capital deepening process.

In a subsequent study, Knopke (1988) used an adjusted Törnqvist index (one which accounted for increasing returns to scale) to estimate TFP growth in the Australian dairy industry over the period 1967–68 to 1982–83. Using data from the Australian Dairy Industry Survey, the production account was defined in a similar way to that used by Lawrence and McKay (1980). After accounting for the potential effects of farm support (namely a price subsidy), the results showed that the average TFP growth of dairy farms was 1.5 per cent a year and that there were significant differences between regions.

Males *et al.* (1990), Knopke *et al.* (1995) and Mullen and Cox (1996) all used data from the Australian Agricultural and Grazing Industry Survey to estimate TFP growth in Australia’s non-irrigated (broadacre) agriculture sector. All of these studies used the Tornqvist index as the aggregation function, although Mullen and Cox also compared some alternative aggregation indexes such as the Fisher and the Malmqvist (Chavas and Cox 1994).

Males *et al.* (1990) found the average rate of productivity growth was 2.2 per cent a year from 1977-78 to 1988-89. Knopke *et al.* (1995) estimated TFP growth over the period 1977-78 to 1993-94, and found an average annual growth rate of 2.7 per cent. Mullen and Cox (1996) restricted their sample to only include farmers with more than 200 sheep, and hence were able to extend their sample to include data from earlier surveys of the sheep industry. Using this data, Mullen and Cox found that average

TFP growth in the Australian broadacre agriculture industry was 2.4 to 2.6 per cent a year over the period 1952-53 to 1993-94.

In all these studies the production account was defined to include 72 output items categorised into 4 groups (crops, livestock sales, wool and other farm income) and 23 input items categorised into 5 groups (capital, livestock purchases, labour, materials and services). In addition, to avoid a sample rotation problem caused by entry and exit of farms in the survey, a weighting strategy was employed when aggregating the various inputs and outputs by industry and survey region.

A similar method was also applied in Knopke *et al.* (2000) to measure TFP growth in the Australian grains industry, disaggregated by the Grain Research and Development Commission (GRDC) geographic region and farm type (i.e. size and profitability) between 1977–78 and 1998–99.

Recently, Zhao et al. (2012) summarized previous studies that had used index methods and farm survey data to measure agricultural TFP in Australia, and developed a general empirical framework for measuring and analysing TFP and its growth in Australian broadacre and dairy industries from 1977-78 to the present. In this framework, outputs and inputs were aggregated using the Fisher index, and the production account was constructed using the gross output model. Output comprised 16 items and input comprised 23 items (grouped into four categories including land, capital, labour, materials and services). Between 1977-78 and 2010-11, average annual growth rate of TFP in Australian broadacre industry was found to be 1.4 per cent a year.

An important limitation of all the Australian studies listed above is that they only relate to specific agricultural industries (such as broadacre or dairy industries), and hence do not provide any insight into productivity changes in the Australian agriculture industry as a whole. Furthermore, although using farm survey data when estimating agricultural productivity has some advantages (for example it provides comprehensive information which is useful when constructing the production account), there are also some disadvantages.

First, reflecting the limited coverage of farm surveys in Australia, TFP estimates can only be constructed for the broadacre and dairy industries from around 1977–78 onwards. Such estimates cannot provide insight into the productivity performance of the agriculture industry in Australia as a whole. Second, the quantity of service flows from durable inputs (such as land, machinery and non-dwelling construction) is taken to be proportional to the market-valued quantity of the stock of such inputs, which is known to be an inaccurate measure (Yotopoulos 1967). Third, an adjustment for the quality of inputs such as land and intermediate inputs is typically not made appropriately.

Using National Accounts Data

An alternative approach is to use national accounts data and index methods to measure agricultural TFP in Australia. In these studies, the aggregation index method is similar to that applied to farm survey data, but the data required to construct the production account is less comprehensive. Specifically, total output is derived by deflating the total value of output by a readily available output price index. On the input side, capital and labour are comprehensively measured, but there is little information about intermediate inputs.

Powell (1974) combined the index method with national accounts data to measure multi-factor (total factor) productivity growth in Australian agriculture between 1920–21 and 1969–70. In this study, the production account is defined using the value-added model, and the agriculture industry is defined by combining data for the agriculture, forestry and fishing sectors. Specifically, output is derived as value-added deflated by a producer price index; while input is defined to include three types of capital and three types of labour. The results showed that the Australian agriculture industry experienced productivity growth of around 2.0 per cent a year from 1920–21 to 1969–70, reflecting significant technology progress over this period.

Similarly, the Australian Bureau of Statistics (ABS 2001) developed its own growth accounting based index method to measure TFP growth in 16 market sectors of the Australian economy, one of which is the combined agriculture, forestry and fishery industry. Using this approach, the ABS produces annual estimates of productivity in each sector. Two models are used when calculating these estimates: value added and gross output. For each of these models, data is drawn from national accounts and input-output tables. The data required to apply the value added model is available from 1984-85 onwards, while the data required to estimate the gross output model is available from 1994-95.

The agricultural TFP estimate obtained by the ABS using the value-added model was later extended by PC (2005) to cover the period 1970-71 to 2002-03. In this latter study, one departure from that of ABS (2001) was that the PC (2005) used a more complex perpetual inventory method when calculating the flow of capital services. Recently, extensions such as ABS (ABS 2007) and Wei (2011) have further improved the method for estimating TFP by introducing a better procedure for performing an adjustment to account for differences in labour quality when estimating the labour input quantity.

Compared to using farm survey data, one advantage of using national accounts data to measure agricultural TFP is that it allows cross-industry estimates to be obtained. However, this approach has several shortcomings. First, data constraints mean an independent, long-term TFP estimate for the agriculture industry (separated from the forestry and fishing activities) cannot be obtained.

Second, these studies obtain output quantities by deflating the gross output value (or the value added) by an output price index which is not transparently constructed. This means that little information can be obtained about the output side of the production account. Third, given the limited data about intermediate inputs that is collected in the national accounts, the accuracy with which these inputs are estimated in agriculture is a problematic issue. Together, these concerns have prevented estimates of TFP obtained using this data from being a widely accepted measure of productivity performance in the Australian farm sector.

In sum, the methods and data employed in this paper are based on best practice, which has been developed in the international and domestic studies summarised in this review.

Table A1. A List of Literature on Country-level Agricultural TFP Estimation

Authors/Year	Country	Method	Data	Features
International Literature: single-country agriculture				
Ball (1985)	the US	the Törnqvist index/value-added model	National accounts data	Agricultural TFP estimates
Ball (1997)	the US	the Fisher index/gross output model	National accounts data	Agricultural TFP estimates
Ball (1999)	the US	the Fisher index/gross output model	National accounts data	State-level agricultural TFP
Ball et al. (2001)	EU 9 countries/the US	the Törnqvist index/value-added model	National accounts data	cross-country TFP level comparison
ERS (2009)	the US	the Fisher index/gross output model	National accounts data	Agricultural TFP estimates
Ball et al. (2010)	EU 15 countries/the US	the Fisher index/gross output model	National accounts data	cross-country TFP level comparison
Fuglie et al. (2012)	12 countries	the grow accounting method	country-specific national accounts data/farm survey data	Agricultural TFP estimates
Domestic Literature: Farm survey data				
Knopke (1988)	Australia	an adjusted Törnqvist index	Farm survey data	dairy industry TFP
Knopke (1995)	Australia	the Törnqvist index	Farm survey data	sheep and beef industry TFP
Mullen and Cox (1995)	Australia	various index methods	Farm survey data	broadacre agriculture TFP
Knopke (2000)	Australia	the Fisher index	Farm survey data	crop industry TFP
Zhao et al. (2012)	Australia	the Fisher index	Farm survey data	broadacre and dairy industry TFP

To be continued…

Table A1 Continued

Authors/Year	Country	Method	Data	Features
Domestic Literature: National accounts data				
Powell (1974)	Australia	the growth accounting approach/value-added model	National accounts data	Agriculture, Forestry and Fishery TFP
Williams (1990)	Australia	statistics	National accounts data	inputs and outputs in Agriculture, Forestry and Fishery
ABS (2001, 2007)	Australia	the index method/ both value-added and gross output models	National accounts data	Market sector TFP
Productivity Commission (2005)	Australia	the index method/ value-added model	National accounts data	R&D investment and Agriculture, Forestry and Fishery TFP
Shank and Zheng (2006)	Australia	the index method/ value-added model	National accounts data	Market sector TFP
Wei (2011)	Australia	the hedonic approach	National accounts data	Market sector TFP and labour quality adjustment

Appendix B Agricultural Production Account and Data Sources

Detailed data on prices and quantities of various outputs and inputs are required when the index method is used to estimate agricultural TFP. This appendix briefly describes the main data sources used, namely national accounts statistics (provided by ABS) and farm surveys (provided by ABARES). A list of outputs and inputs are presented in Table B1.

Outputs consist of 72 products and product groups. The quantity and value of agricultural commodities are obtained from the Agricultural Commodity Database which was developed by ABARES and ABS. This database contains data from the ABS Agricultural Census and from ABARES farm surveys such as the Australian Agricultural and Grazing Industry Survey, the Australian Dairy Industry Survey and the Horticultural Industry Survey. When the quantity variables are not available, they are derived by deflating the value variables by the appropriate prices. The price of each output is drawn from the ABS Agricultural Census, and if not available for early years, the ABARES price paid and received index for the same groups of products is used for imputation.

Inputs consist of 23 items, which are classified into 4 categories, namely capital, land, labour and intermediate inputs. Specifically, there are five types of capital assets (non-dwelling building and structure, plant and machinery, transportation vehicles, livestock and other cultivated biological resources, inventory and intellectual property); two types of land (crop and pasture) at the state level with a quality adjustment; two types of labour (hired and self-employed) by gender, age and education; and 14 intermediate inputs classified into 9 groups (fuel and lubricant, electricity, fertilizer and chemicals, seed and fodder, repairs and maintenance, marketing costs, plant hire, livestock purchase and other materials and services). Data for all inputs are obtained from various data sources including Agricultural Commodity Database, ABS national accounts database and farm surveys. As is the case for outputs, when the real price is not available for the product/service or the product/service group, a price index is used as a substitute.

Finally, the output and input structure are described in Table B1:

Table B1 Outputs and inputs

Outputs					Inputs			
Crops			Livestock	Other outputs	Land	Capital	Labour	Intermediate inputs
Grains and oilseeds	*Fruits and Nuts*	*Vegetables*	*Livestock*	*On farm activities*	*Land*	*Capital*	*Labour*	*Materials and services*
Barley	Almonds	Asparagus (fresh, processing)	Cattle and Calves	Marketing	Land services	Buildings and structures (non-dwelling)	Employers and self-employed	Fuel, lubricant and electricity
Canola	Apples			Packaging				
Caster	Apricots	Snap beans	Ducks	Processing			Wage and salary earners	Fertiliser, chemicals and medicine
Cottonseed	Avocados	Beans (dry, processing)	Chickens and broilers			Plant and machinery		
Flaxseed	Bananas			*Services*			Contributing family workers	
Hay and silage	Cherries (sweet)	Broccoli	Eggs	Contract services		Transportation and other vehicles		Seed, fodder and livestock purchases
Maize	Cherries (tart)	Cauliflower	Hogs					
Oats	Cranberry	Cabbage	Milk, butter, cheese	Machinery hire				
Peanut	Dates	Capsicum		Land lease				Repairs and maintenance
Rice	Figs	Celery	Sheep and lambs	Other services				
Rye	Grapefruit	Cucumber (fresh, processing)						Other materials and services (marketing, packaging and transportation, plant and machinery hire, water purchases)
Safflower	Grapes		Sheep					
Sorghum	Hazelnuts	Corn (fresh, processing)	Turkey					
Soybean	Lemons and limes		Wool					
Sunflower	Macadamias	Honeydew						
Triticale	Mandarins	Lettuce						
Wheat	Mangoes	Lentils						
	Nectarines	Onions						
Other crops	Olives	Peas (dry, green)						
Cotton lint	Oranges	Potatoes						
Tobacco	Peaches	Rock melon						
Horticulture	Pears	Spinach (fresh, processing)						
Floriculture	Pecans							
Greenhouse nursery	Plums	Sweet Potatoes						
	Prunes	Tomatoes fresh, processing)						
Sugar beet	Strawberries							
Sugar cane	Tangelos	Watermelon						
Mushrooms	Tangerines	Other vegetables						
Other crops not included elsewhere	Walnuts							
	Other fruit and nuts							

Appendix C Impacts of Various 'Ex Ante' Rates on Capital Services

This appendix derives the impact of 'ex ante' rates on the estimation of capital services, from a theoretical perspective. The results can be used to illustrate the debate between Ball *et al.* (1997b) and Andersen *et al.* (2011) on which 'ex ante' rates to choose: actual rates or fixed rates.

As derived in section III of the paper, Equations (8) and (11) define productive capital stocks and rental prices of each capital asset. If there are M types of capital assets, one can use a Fisher index to aggregate individual capital assets for total capital services, such that

$$TK_{t-1,t}^{F} == \left(TK_{t-1,t}^{L} TK_{t-1,t}^{P}\right)^{1/2} = \left(\frac{\sum_{K=1}^{M} c_{K,t} K_{K,t}}{\sum_{K=1}^{M} c_{K,t} K_{K,t-1}} \frac{\sum_{K=1}^{M} c_{K,t-1} K_{K,t}}{\sum_{K=1}^{M} c_{K,t-1} K_{K,t-1}} \right)^{1/2} \quad \text{(C1)}$$

where 'ex ante' rates are proportional to rental rates, as in Equation (8), if $F_{K,t}$ is stable. Hence, 'ex ante' rates can be extracted from the summation process and cancelled out, since they appear in both denominators and numerators.

$$TK_{t-1,t}^{F} == \left(TK_{t-1,t}^{L} TK_{t-1,t}^{P}\right)^{1/2} = \left(\frac{\sum_{K=1}^{M} \frac{W_{K,t} K_{K,t}}{1-F_{K,t}}}{\sum_{K=1}^{M} \frac{W_{K,t} K_{K,t-1}}{1-F_{K,t}}} \frac{\sum_{K=1}^{M} \frac{W_{K,t-1} K_{K,t}}{1-F_{K,t}}}{\sum_{K=1}^{M} \frac{W_{K,t-1} K_{K,t-1}}{1-F_{K,t}}} \right)^{1/2} \quad \text{(C2)}$$

Equation (C2) suggests that the impact of 'ex ante' rates on the aggregate capital services depends on the relationship between 'ex ante' rates and the decay process of individual assets (rather than on the 'ex ante' rates themselves) (Andersen et al. 2011). Specifically, if F_K (the present value of the stream of capacity depreciation on one unit of capital asset K) is sensitive to 'ex ante' rates, fixed rates would be preferred. This is consistent with Andersen *et al.*'s (2011, p 723) argument that "assets with relatively longer (shorter) service lives are given relatively more weight in the indexing procedure when interest rates are increasing (decreasing)." However, if F_K is not sensitive to 'ex ante' rates, actual rates would be preferred since they are more likely to reflect the expectations of investors when choosing between different assets.

In our case, F_K (derived from Equation (8)) is only affected by the average 'ex ante' rates over the service life of each capital asset. For example, the minimum average service life for transportation vehicles is 15 years. Thus, actual rates are preferred to fixed rates and only differences in the mean of actual rates and the fixed rate will cause divergence between the results.

Similar results can also be obtained when rental prices are assumed to take the form of $c = (r + \delta_K)P_K$, as in OECD (2001). The only difference is that, in that case, we need to assume that $\delta_K = r * \overline{\delta_K}(r)$. This assumption has been justified by Diewert (2005) who argued that the depreciation of a capital asset contains a significant proportion of economic 'obsolescence' which is sensitive to actual rates of return.