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MEASURING PRODUCTIVITY CHANGE UNDER DIFFERENT LEVELS OF ASSISTANCE: THE AUSTRALIAN DAIRY INDUSTRY

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The effects of different levels of protection on productivity measures are frequently ignored in economic analysis. In this paper, a procedure is developed to net out the effects of non-marginal cost pricing on the traditional Tornqvist productivity measure. Total factor productivity in the dairy industry is estimated to have grown at a 1.5 per cent annual rate over the period 1967-68 to 1982-83. A state and regional analysis of the dairy industry showed that the Victorian industry had outperformed the New South Wales industry, a factor that was attributed to major policy differences between the two states.

The measurement and analysis of productivity change in agriculture has been an area of continuing interest for economists and policy makers both in Australia and elsewhere (see, for example, Schultz 1947; Griliches 1963; Saxon 1963; Young 1971; Lawrence and McKay 1980; Paul 1984). With the continuing decline in the terms of trade facing farmers, productivity growth is seen as the major means by which farm incomes can be maintained.

Productivity change is frequently a poorly understood concept. Accordingly, earlier work published by the Bureau of Agricultural Economics (BAE) (Paul 1984; Paul and Abey 1984) focused on clarifying a number of the definitional and conceptual problems associated with the measurement of total factor productivity change and with developing broad estimates for specific rural industries.

The objective of this paper is to extend this previous work in several ways. The first is to review current methods available for productivity estimation and investigate some developments that will allow unbiased productivity estimates to be calculated for protected industries. The second is to apply the appropriate techniques to the Australian dairy industry to obtain productivity growth estimates at a national, state and regional level. Traditional measures of productivity growth are based on the assumption that markets are competitive. Compared with other rural industries such as wheat, wool and beef, the dairy industry is both highly regulated and highly protected (Industries Assistance Commission 1983*a*).

The conventional approach to the measurement of total factor productivity involves the compilation of an index of total outputs and an index of all factor inputs. Total factor productivity is then computed as the ratio of the output index to the input index (see Christensen 1975). Here, attention is focused on the use of the total factor productivity measure in describing productivity change. However, some reference is also made to measures of partial productivity (defined as the change in output relative to the change in some subset of inputs) where they provide an insight into sources of total productivity change, for example, output per unit of capital employed.

The following section contains a brief background to the Australian dairy industry. This is followed by the methodology review and a description of data used in the study. Results are then outlined and conclusions are drawn.

Background to the Australian Dairy Industry

Over the 16 year period (1967–68 to 1982–83) considered, notable features of the Australian dairy industry have been the rapid structural adjustment which has occurred and the quite separate state market structures which have operated. Trends in the relative importance of dairying in each state are shown in Table 1. Victoria strengthened its position as the dominant dairying state during the period. The scope of structural adjustment in the industry can be observed from the number of dariy farmers leaving the industry. The number of dairy farms declined by almost 50 per cent between 1969 and 1983 (Table 2), although the rate of decline varied between states. The average land area operated increased markedly, due to farm amalgamations.

As mentioned above, the dairy industry is highly regulated. Milk produced in each state is sold either for manufacturing purposes (manufacturing milk) or for direct consumption (market milk). Exports consist mainly of manufactured milk products. The marketing and pricing policies adopted during the 16 year period under consideration have clearly violated the competitive assumptions required for traditional productivity measurement. The Commonwealth has regulated the manufacturing milk sector through various export pooling arrangements backed up by underwriting of prices. In effect, this has meant that lower export prices have been supported through industry levies, with an average (or equalised) return paid to dairy farmers.

State legislation controls the price of market milk. Overall, the prices for market milk have been similar across states, with little interstate trading. Different state systems have controlled access to the market milk sector (for details, see Lembit and Bhati 1987). One effect of these controls has been to maintain the price received for market milk at around double that for manufacturing milk for most of the period 1967–68 to 1982–83.

TABLE 1

Milk Production: By State[a]

State	1968–69 to 1970–71		1980–81 to 1982–83	
	Annual average	Proportion of total	Annual average	Proportion of total
	kL	%	kL	%
New South Wales	1306	18.0	873	16.3
Victoria	3935	54.3	3086	57.7
Queensland	807	11.2	549	10.3
South Australia	473	6.5	322	6.0
Western Australia	258	3.6	215	4.0
Tasmania	461	6.4	302	5.7
Australia	7240	100.0	5345	100.0

[a]Source: Australian Bureau of Statistics (1982, 1985).

TABLE 2

Number of Dairy Farms and Land Area: By State[a]

State	3-year average 1968-69 to 1970-71	3-year average 1980-81 to 1982-83	Annual rate of change between periods
	No.	No.	%
	Dairy farms[b]		
New South Wales	7878	3110	-7.7
Victoria	16 066	10 123	-4.0
Queensland	6872	2756	-7.8
South Australia	2061	1252	-4.5
Western Australia	1357	607	-7.1
Tasmania	2215	1164	-5.6
Australia	36 462	18 977	-5.6
	Land area: average per property		
	ha	ha	%
New South Wales	159.0	212.9	2.5
Victoria	102.5	116.7	1.0
Queensland	171.7	214.1	2.3
South Australia	135.8	221.3	4.2
Western Australia	276.2	297.4	0.5
Tasmania	125.5	190.7	2.9
Australia	136.1	163.4	1.5

[a] Sources: Australian Bureau of Statistics (1982, 1985); Bureau of Agricultural Economics.
[b] With 40 or more dairy cattle.

Accordingly, with this discriminatory pricing policy, the effective rate of protection for market milk has been much greater than that of manufacturing milk. The Industries Assistance Commission has estimated the effective rate of protection afforded the market milk sector at over 100 per cent, and over double that afforded the manufacturing milk sector for most of this period (Industries Assistance Commission 1980, 1983*a*, *b*, 1984).

The levels of access to the market milk sector for individual farms have also varied markedly between states, both in absolute terms and in rates of growth (Table 3). In New South Wales, Western Australia and Queens-

TABLE 3

Trends in the Proportion of Market Milk Sold: 1967-68 to 1982-83

State	3-year average 1967-68 to 1969-70	3-year average 1980-81 to 1982-83	Annual rate of growth 1967-68 to 1982-83
	%	%	%
New South Wales	33.9	64.9	9.8
Victoria	12.5	16.5	4.5
Queensland	24.0	50.2	10.7
South Australia	27.4	34.7	6.3
Western Australia	40.7	64.9	8.8
Tasmania	6.3	11.3	3.6
Australia	18.8	31.1	7.3

land, each farm had (on average) greater than 50 per cent market milk access for the 3 years 1980-81 to 1982-83, whereas in Victoria and Tasmania it was less than 20 per cent. In addition, the rate of growth in access to the market milk sector has been much slower in Victoria and Tasmania. This means that the dairy industry has received a much lower level of protection in Victoria and Tasmania than in the other states.

The need to account for these differences in rates of protection between states when measuring productivity growth is taken up in the following section.

Definition and Measurement of Productivity Change

The basic aim when estimating productivity growth in the rural sector is to apportion the growth in rural output over time to the change in conventional inputs such as labour, capital and land, and to a residual term, defined as productivity growth. There are two conceptually different ways of doing this, either, directly, by estimating a production function or, indirectly, by employing an index number procedure.

If the production function can be estimated econometrically, then both the magnitude and sources of productivity growth may be directly estimated. The recent development of multi-output, multi-input production functions has made this a more feasible option when continuous time series data at the farm level are available (Just, Zilbermann and Hochmann 1983). However, the use of this method in the case of Australian rural industries is limited by the lack of suitable panel data. Consequently, the index number approach is used in this study.

The index number approach implies an underlying production function and this affects the choice of index number used. Heterogeneous inputs and outputs need to be aggregated and various authors have used the principles of production theory for this purpose (see, for example, Kendrick 1973). A number of index formulas have been developed and applied (Solow 1957; Lydall 1968; Hoogvliet 1973). However, recently, the shortcomings in the Solow and related methods have been more fully recognised. These methods imply restrictive assumptions related to changes in relative factor prices and substitutability between inputs. An effort has been made to find indexes which are more flexible in functional form (Diewert 1976, 1978; Lau 1979; US Department of Agriculture 1980; Caves, Christensen and Diewert 1982).

Conceptually, the most widely accepted method of aggregation for use in productivity analysis is the Divisia index (Diewert 1976). However, the formula for the Divisia index is expressed in terms of instantaneous changes. For data obtainable only at yearly intervals, the most commonly used discrete approximation to the continuous formula is provided by the Tornqvist index (Tornqvist 1936). Consequently, the Tornqvist index is used here.

Underlying the conventional measurement of productivity via the Tornqvist procedure are the assumptions of perfectly competitive markets with constant returns to scale. For the Australian broadacre industries (sheep, beef and wheat), which involve a large number of producers with free entry and exit, it seems reasonable to assume that these competitive assumptions apply. Accordingly, a number of previous studies have used the Tornqvist method to investigate productivity change in various parts of these industries and for various time periods (Paul 1984; Lawrence and McKay 1980; Lawrence 1980; Beck, Moir, Fraser and Paul, 1985).

There have been no equivalent studies of productivity change in protected rural industries such as the dairy industry where the direct application of the Tornqvist index may lead to serious bias in the productivity estimates.

The model that gives the most insight into the difference between productivity measurement in competitive and regulated industries is provided by Denny, Fuss and Wavermann (1981). This model shows the mathematical relationship between shifts in the production function through time (that is, the effects of technological change) and changes in total factor productivity as measured by the Divisia index. In the case of a regulated industry, the model allows for separation of total factor productivity as measured by the Divisia index into three components. The first component is that resulting from technological change; the second is from non-constant returns to scale; the third could be regarded as a 'bias' brought into the measure through the use of prices that do not reflect marginal costs.

The mathematical exposition of the relationship between total factor productivity and the production function may be expressed as follows (Denny *et al.* 1981):

$$T\dot{F}P = \dot{A} + (\dot{y}^p - \dot{y}^c) + (E^{-1} - 1)\dot{X} \tag{1}$$

where $T\dot{F}P$ is the proportional growth rate in total factor productivity as measured by the Divisia index; $\dot{A}$ is the proportional growth rate in the production function; $\dot{y}^p$ is the proportional growth rate in outputs at market prices; $\dot{y}^c$ is the proportional growth rate in outputs at prices equal to marginal costs; E is the sum of the cost elasticities; and $\dot{X}$ is the proportional growth rate in inputs.

If marginal cost pricing occurs, $\dot{y}^p = \dot{y}^c$ and if there are constant returns to scale, $E = 1$. Thus, under these assumptions, $T\dot{F}P = \dot{A}$. That is, total factor productivity solely reflects technological change or production function shifts. However, given the discriminatory pricing policies which have applied in the Australian dairy industry, it is unrealistic to assume that all prices reflect marginal costs. This means that $\dot{y}^p \neq \dot{y}^c$ in equation (1). Under these circumstances, the term $(\dot{y}^p - \dot{y}^c)$ represents the contribution of non-marginal cost pricing to the conventional measure of total factor productivity,[1] the term $\dot{A}$ represents the effects of technological change on the productivity measure, and the term $(E^{-1} - 1)\dot{X}$ represents the effects of non-constant returns to scale.

In this study, the approximation to the continuous Divisia measure $T\dot{F}P$ [from equation (1)] is defined as ΔTFP. The index formulation used is the Tornqvist indirect quantity index which is derived from the Tornqvist direct price index. The formula for the Tornqvist direct price index is given by

$$\ln P_T(p^0, p^1, x^0, x^1) = \sum_{i=1}^{N} W_{Ti} \ln(p_i^1/p_i^0) \tag{2}$$

where p_i^1 is the price of output (input) x_i in time period 1

[1] Denny *et al.* (1981, p. 197) have shown that, in special cases, departure from marginal cost pricing may have no effect on total factor productivity. Hence, the magnitude of the term $(\dot{y}^p - \dot{y}^c)$ has no implications for the inefficiency of resource allocation resulting from non-marginal cost pricing policies.

and $$W_{Ti} = \tfrac{1}{2}\ [(p_i^1x_i^1/p^1x^1) + (p_i^0x_i^0/p^0x^0)]$$

where $p_i^1x_i^1$ is the value of the ith output (input) in time period 1 and p^1x^1 is the total value of all outputs (inputs) in time period 1.

From the Tornqvist direct price index [P_T from equation (2)] a corresponding quantity index is defined implicitly by using the weak factor reversal test. The relationship between P_T and the implicit quantity index Q is defined as

$$(3) \qquad P_T(p^0, p^1, x^0, x^1)\ Q(p^0, p^1, x^0, x^1) = p^1x^1/p^0x^0$$

The theoretical justification for the use of this index and a more detailed outline of its construction are presented in the Appendix.

By choosing the index to equal 100 in a particular year and accumulating the measure in accordance with equation (3), separate indexes can be derived for total outputs and total inputs. The index of total factor productivity is the ratio of the output index to the input index.

The analytical approach used to net out the effects of protection on productivity measures was to derive two separate Tornqvist indexes of total outputs, namely, Q_A, which is based on the actual output quantities and a proxy for marginal cost prices, and Q_B, which is based on actual output quantities and actual prices received. An index of total inputs (I) was constructed using actual input prices and quantities. Two Tornqvist indexes of total factor productivity, TFP_A and TFP_B, were derived: $TFP_A = 100(Q_A/I)$ and $TFP_B = 100(Q_B/I)$. Logarithmic trend lines were fitted by regressing these two indexes against time. This provided two measures of the average annual rate of productivity change, ΔTFP_A and ΔTFP_B.

In terms of equation (1), ΔTFP_A may be regarded as an approximation of $\dot{A} + (E^{-1} - 1)\dot{X}$, the contribution to productivity growth of technological change and non-constant returns to scale. $\Delta TFP_B - \Delta TFP_A$ therefore represents the non-marginal cost component of the conventional productivity measure, that is, $(\dot{y}^p - \dot{y}^c)$ in equation (1).

ΔTFP_B, which is based on actual prices received, is an appropriate productivity measure for competitive industries. However, ΔTFP_A is the preferred measure for a protected industry and forms the basis of the results presented for the dairy industry. The marginal cost proxy used to calculate ΔTFP_A was the price dairy farmers received for manufacturing milk. Total milk production was valued at this price. It was assumed that this price is a good approximation of the marginal revenue facing dairy farmers for the period under consideration. This point is discussed further in Knopke and Jervois (1985). The use of a proxy for marginal revenue is designed to preclude bias in the productivity estimate. In the absence of an adjustment for non-marginal cost pricing, the weights of the Tornqvist index [that is, W_{Ti} in equation (2)] may be biased by protection. The extent of any bias in the total productivity index depends critically on the rate of change in the quantity of the protected output relative to the rate of change in the quantities of other output items.

It should be noted that this formulation corrects for non-marginal cost pricing on the output side but assumes marginal cost pricing on the input side. This assumption may not hold in the dairy industry where barriers to entry (for example, market milk quotas) may increase the market value of fixed inputs such as land. A sensitivity analysis was undertaken using a range of land values in the states where effective rates of protection were highest. The use of lower land values did not significantly affect the results.

The Use of BAE Data in Measuring Productivity

The Tornqvist index formula requires time series data with a value and a quantity for each output or input component of the index. The data used in this study were obtained from surveys of the Australian dairy industry, conducted by the BAE. From the available data, annual time series were constructed for the period from 1967–68 to 1982–83.

The procedures used to calculate the values and quantities of individual inputs and outputs are described by Knopke and Jervois (1985) and are not discussed in detail here. One departure from the procedure adopted in most earlier studies was the use of real rather than nominal interest rates to value the service flows from capital inputs. Given that the use of nominal interest rates will overstate the opportunity cost component of service flows from durable capital inputs in inflationary periods, there is a strong case for expressing interest rates in real terms. The main difficulty with this procedure occurs when the real interest rate is negative. A log-based index number formulation such as the Tornqvist index cannot handle negative numbers. An alternative approach discussed by Paul and Abey (1984), and adopted here, is to use real interest rates with very small values substituted for negative real interest rates. Although this approach is not without conceptual problems of interpretation, it does minimise the overstatement of capital input costs associated with the use of nominal rates of interest. The real interest rate series used here was calculated by subtracting the annual rate of inflation (derived from the consumer price index) from the interest rate.[2]

Productivity indexes were constructed using estimates from the annual BAE Australian dairy industry survey. For the years 1967–68 to 1982–83 this survey included farms with at least 30 dairy cows (cows in milk or dry, and mated heifers) at 30 June and less than 20 per cent of revenue from milk vending and/or stud operations. Dairy industry data are available at a state level and at a regional level in Victoria and New South Wales. (Regional data are not available for other states.) Regional boundaries are those used for the BAE Australian dairy industry survey since 1976–77.

In the dairy survey, quantity data are not available for all variables (for example, amount of stock feed bought). In such cases, a proxy was obtained by dividing the value of the item by an appropriate BAE prices paid or prices received index. For the quantity proxy to reflect quantity changes only, price indexes should be independent of quality changes. The BAE prices paid indexes are calculated to discount quality changes; nevertheless, it is recognised that the data do not allow for all quality changes. In particular, this applies to the labour input, where increased managerial skills and improved education levels are likely to have contributed to productivity growth.

In addition to the total factor productivity index, other quantity indexes were calculated for separate categories of inputs and outputs.

The results presented below are based on survey data which are subject to sampling error. In addition, climatic variability can be expected to influence productivity in the short term. For these reasons, most emphasis should be placed on longer term trends where the effects of short-term fluctuations and sampling errors are likely to be minimised.

[2]The interest rates used were the 5-year debenture rates published by the Reserve Bank of Australia. These were used on the assumption that the alternative to investment in agriculture is investment in fixed securities.

Results and Discussion

Bias caused by non-marginal cost pricing

Estimates of ΔTFP_A and ΔTFP_B, which provide measures of productivity growth in the dairy industry at the national, state and regional levels over the years 1967–68 to 1982–83, are presented in Table 4. The non-marginal cost pricing component (that is, $\Delta TFP_B - \Delta TFP_A$) also appears in this table. This shows that the bias introduced to traditional productivity measures by non-marginal cost pricing would have been particularly serious in the market milk-oriented states of New South Wales, Queensland and Western Australia. In these states, the quantity of market milk supplied (average per farm) increased very rapidly over the period under consideration (Table 3). This is in sharp contrast to Victoria, Tasmania and South Australia, where the quantity of market milk supplied increased at a much slower rate.

Because ΔTFP_A can be considered the more accurate and consistent measure of total factor productivity across states and regions, it is the only measure that will be referred to in the following discussion.

Productivity growth at the national and state level

The growth rates of outputs, inputs and total productivity over the period 1967–68 to 1982–83 for the dairy industry at the state and national levels are summarised in Table 5 and plotted for individual years for the two major dairying states, New South Wales and Victoria, in Figure 1.

TABLE 4

Annual Productivity Growth in Dairying 1967–68 to 1982–83[a]

State or region	(ΔTFP_A) Dairy product valued at manufacturing milk prices	(ΔTFP_B) Dairy product valued at actual prices	(ΔTFP_B-ΔTFP_A) Non-marginal pricing component
	%	%	%
New South Wales	0.9	2.8**	1.9**
Victoria	1.5**	1.8**	0.3
Queensland	0.7	2.5**	1.8**
South Australia	2.6**	2.9**	0.3
Western Australia	2.7**	3.9**	1.2*
Tasmania	1.9**	2.2**	0.3
Australia	1.5**	2.2**	0.7
New South Wales			
Region 1	0.5	4.0**	3.5**
Region 2	1.6**	2.4**	0.8
Region 3	0.8	3.8**	3.0**
Victoria			
Region 1	1.4**	1.4**	0.0
Region 2	1.4**	1.8**	0.4
Region 3	1.7**	2.0**	0.3

[a]Based on logarithmic trend line fitted by regression of indexes against time.
*Significant at the 5 per cent level; **significant at the 1 per cent level.

TABLE 5

Annual Growth in Outputs, Inputs and Productivity in Dairying 1967-68 to 1982-83[a]

State or region	Total outputs	Total inputs	Total productivity
	%	%	%
New South Wales	3.7**	2.8**	0.9
Victoria	1.5**	0.0	1.5**
Queensland	2.7**	2.0**	0.7
South Australia	4.7**	2.1**	2.6**
Western Australia	3.8**	1.2*	2.6**
Tasmania	2.2**	0.3	1.9**
Australia	2.4**	0.9**	1.5**
New South Wales			
Region 1	2.6**	2.1**	0.5
Region 2	3.8**	2.2**	1.6**
Region 3	4.8**	4.0**	0.8
Victoria			
Region 1	0.8	-0.6	1.4**
Region 2	1.8**	0.4	1.4**
Region 3	1.8**	0.2	1.7**

[a]Based on logarithmic trend line fitted by regression of indexes against time.
*Significant at the 5 per cent level; **significant at the 1 per cent level.

Over the 16-year-period, total output from the dairy industry grew at an average rate of 2.4 per cent a year. Total inputs, however, grew by only 0.9 per cent, providing growth in total productivity of 1.5 per cent a year.

The highest rate of productivity growth was achieved in Western Australia (2.6 per cent a year) and the lowest in Queensland (0.7 per cent). For the two major dairying states, Victoria and New South Wales, the annual growth rates were 1.5 per cent and 0.9 per cent, respectively. Although there was rapid growth in outputs over the period 1967-68 to 1982-83 in New South Wales (3.7 per cent a year), the growth in inputs (2.8 per cent) was the highest of all states. This contrasted markedly with Victoria which had the lowest growth in outputs (1.5 per cent a year) but no growth in inputs. The net result was higher productivity growth in Victoria than in New South Wales. In all states, productivity gains were significantly less than the adverse movements in the terms of trade (Knopke and Jervois 1985).

In order to provide further insight into the apparent productivity difference between New South Wales and Victoria, a regional analysis was undertaken.

Productivity growth at the regional level

For the Australian dairy industry survey, each of the largest two milk producing states, Victoria and New South Wales, is divided into three regions. In New South Wales, region 1 consists mainly of farms in the northern coastal areas, region 3 consists of farms in the lower western areas around the Murray and Murrumbidgee Rivers, while the remaining

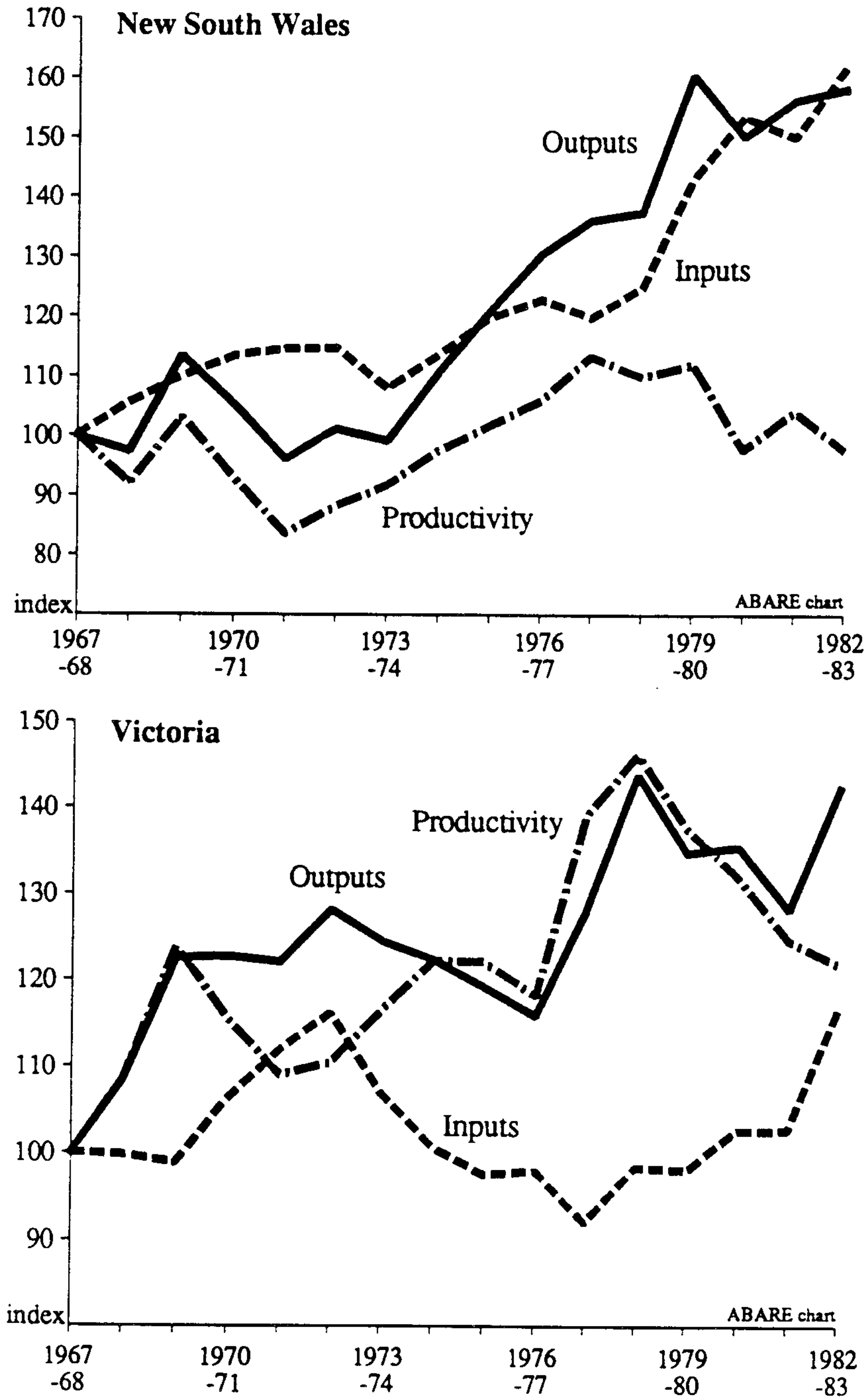

FIGURE 1 — Growth of Outputs, Inputs and Total Productivity in the Dairy Industry.

dairy districts are grouped in region 2. In Victoria, region 1 includes farms in the south-west of the state, region 2 the north-west, and region 3 the areas east of Melbourne.

The growth rates of outputs, inputs and total productivity over the period 1967-68 to 1982-83 for each of the regions are presented in Table 5.

Region 3 of New South Wales recorded the fastest output growth (4.8 per cent a year). However, a correspondingly high input growth (4 per cent a year) resulted in a low growth in total productivity. This contrasts markedly with region 1 of Victoria where, although the growth in outputs was low (0.8 per cent a year), the quantity of inputs used fell by 0.6 per cent a year, resulting in an average annual growth in total productivity of 1.4 per cent. Although productivity growth did not vary much between the regions in Victoria, the converse applied in New South Wales. Region 2 of New South Wales achieved an estimated productivity growth rate of 1.6 per cent a year, region 3, 0.8 per cent and region 1, 0.5 per cent.

The explanation for the relatively low productivity growth in New South Wales regions 1 and 3 would seem to lie with the transition that has taken place from manufacturing milk dependence to market milk dependence over the period 1967-68 to 1982-83. The transition resulted in high growth in land area operated, capital investment and purchased inputs (Table 6). For all these inputs, rates of growth were significantly higher in New South Wales than in Victoria.

This is also reflected in the partial productivity measures. In regions 1 and 3 of New South Wales, the rates of growth in outputs per unit of land and purchased inputs were both negative and the growth rates of outputs with respect to labour and capital were significantly lower than in region 2 of New South Wales. In Victoria, only in region 1 was the growth in partial productivity with respect to land negative.

TABLE 6

Annual Growth in Input Components in Dairying 1967-68 to 1982-83[a]

State or region	Land area operated	Capital[b]	Labour	Purchased inputs	Seed and fodder
	%	%	%	%	%
New South Wales	2.5	1.4	1.3	6.0	9.4
Victoria	1.0	0.1	0.2	0.7	-0.8
Queensland	2.3	2.1	1.7	4.3	5.6
South Australia	4.2	1.1	2.3	3.2	3.2
Western Australia	0.5	0.9	1.0	2.8	6.6
Tasmania	3.0	0.5	0.3	0.9	-1.8
Australia	1.5	0.8	0.7	2.5	3.3
New South Wales					
Region 1	4.5	2.3	1.2	5.2	6.3
Region 2	0.6	0.0	0.8	5.6	10.0
Region 3	5.8	2.5	3.1	6.2	13.2
Victoria					
Region 1	1.5	0.4	-0.3	0.1	-5.7
Region 2	-0.2	0.3	0.8	1.2	-1.8
Region 3	1.4	-0.1	0.1	0.7	2.2

[a]Based on logarithmic trend line fitted by regression of indexes against time.
[b]Excluding land and livestock.

The contrast between Victoria region 2 and New South Wales region 3 is particularly interesting because of their climatic similarity; dairy farming in both regions is separated only by the Murray River. However, the dairy industry in these two regions has been subject to quite different policies. These policy differences are described in detail by Lembit and Bhati (1987). In a comparative study of these two dairy regions they found that, for the years 1980–81 to 1982–83, the costs of production in New South Wales region 3 were significantly higher than in Victoria region 2. They attributed this largely to the effects that the different dairy policies were having on the seasonality of milk production in the two states. In New South Wales, a rigid quota system requires year-round milk production. Farmers are penalised through loss of quota if they cannot maintain milk output in winter months when production costs are higher. In contrast, the less-regulated Victorian industry is able to reap cost savings through more seasonal production patterns.

Higher input use in New South Wales has also been encouraged by higher average unit prices received by farmers. These higher prices are partly the result of a national policy which has virtually prohibited interstate trade in milk for human consumption.

Interstate policy differences also appear to have influenced productivity growth. In New South Wales region 3, the growth in outputs per farm was very high over the period 1967–68 to 1982–83 (4.8 per cent a year). This contrasts with Victoria region 2 where outputs increased at an annual average rate of 1.8 per cent. In New South Wales region 3, the growth in inputs was also high (4.0 per cent a year) compared with that in Victoria region 2 (0.4 per cent a year). Table 5 highlights the significant differences in the rates of growth in inputs between the two regions. The net result is that annual productivity growth in Victoria region 2 exceeded that in New South Wales region 3 by a considerable margin (about 0.6 per cent). It is clear that the high growth of output in New South Wales region 3 was achieved only at the cost of relatively high input growth, which can be explained partly by farmer response to dairy policy in that state.

Sources of productivity growth

The index number approach to measuring productivity does not allow for the explicit identification of sources of productivity growth. The measure used in this study, ΔTFP_A, includes the effects of technological change and non-constant returns to scale as well as the effect of any unmeasured inputs. These inputs include improvements in the quality of the labour and management input arising from better education and other unmeasured quality improvements in inputs over time arising from technological advances. Sources of improved technology in the dairy industry include better pastures, improved genetic quality of livestock, mechanisation and better disease control (Johnston and Girdlestone 1983).

The effect of farms leaving the industry on the measured rates of productivity growth (average per farm) over the period 1967–68 to 1982–83 cannot be measured. It is possible that the farms which left the industry (taken as a group) may have had lowered rates of productivity growth had they remained in the industry. Evidence on this point is inconclusive. Gargett (1983) found that farms leaving the industry between 1972 and 1975 were generally smaller and less profitable than the farms which remained. He did not, however, r [illegible] productivity growth. In the present study, it was found that the states with the largest annual rates of decline in dairy farm numbers between 1967-68 and 1982-83 were New South Wales (7.7 per cent) and Queensland (7.8 per cent). Significantly, productivity growth rates in these two states were lower than in Victoria, where farm numbers declined at a much slower annual rate (4.0 per cent).

It is likely that the differences in measured rates of productivity growth between states were due partly to the impact that different dairy policies in each state had on production strategies. Output per unit of labour input in New South Wales grew faster than in Victoria, as did production per cow. The latter, however, was achieved only through a large increase in purchased inputs (particularly seed and fodder) and is therefore unlikely to have contributed positively to overall productivity growth. The stocking rate (number of dairy cows per hectare) increased faster in Victoria than in New South Wales, whereas the quantity of seed and fodder purchased fell. This would indicate significant gains in pasture improvement in Victoria. A more detailed analysis of the sources of productivity growth would require a much closer investigation of the differences in cost structures between states and this has not been attempted here.

Concluding Remarks

The purpose of this paper was twofold: first, to discuss productivity measurement, particularly as it applies to protected industries and, second, to apply the appropriate techniques to provide estimates of productivity growth in the Australian dairy industry.

Traditional methods of deriving a productivity index were reviewed and a number of important issues related to the measurement of productivity growth in regulated industries were highlighted. The analysis showed that regulations can have a substantial effect on conventional measures of productivity growth which are based on the assumption of a competitive market. A procedure was developed which allows the effects of non-marginal costing to be netted out of the Tornqvist index formulation, thus facilitating better estimates of productivity growth in protected industries. While this adjustment was possible on the output side, accounting for bias in productivity measures on the input side is much more difficult.

The standard and modified Tornqvist index formulations were used to investigate productivity growth in the Australian dairy industry. The annual rate of productivity growth over the period 1967-68 to 1982-83 was estimated at 1.5 per cent a year, with output valued at manufacturing milk prices, and 2.2 per cent a year, with output valued at actual prices. Manufacturing milk prices were used since they were considered a means of removing a significant source of bias in the estimated rates of productivity growth, particularly in the market milk-oriented states. However, even at the higher estimated rates, gains in productivity were not enough to offset the declining terms of trade in dairying.

Although the New South Wales dairy industry had significantly higher rates of growth in outputs per farm over the period 1967-68 to 1982-83 than the Victorian industry, this was achieved only through higher rates of input use. The net result was that the Victorian industry was able to achieve higher productivity growth than the New South Wales industry. It is evident that regulation is having a substantial effect on the choice of production techniques within the dairy industry and that this is leading to input cost structures in the market milk-oriented states that are quite different from those in the manufacturing milk-oriented states. This indicates that differences in milk policies between states are having an adverse effect on the rates of productivity growth in the dairy industry.

APPENDIX

Technical Characteristics of the Tornqvist Index

The formula for the Tornqvist direct quantity index is given by

$$\text{(A1)} \qquad \ln Q_T(p^0, p^1, x^0, x^1) = \sum_{i=1}^{N} W_{Ti} \ln(x_i^1/x_i^0)$$

and the formula for the Tornqvist direct price index is given by

$$\text{(A2)} \qquad \ln P_T(p^0, p^1, x^0, x^1) = \sum_{i=1}^{N} W_{Ti} \ln(p_i^1/p_i^0)$$

where $W_{Ti} = \frac{1}{2}\,[(p_i^1 x_i^1/p^1x^1) + (p_i^0 x_i^0/p^0x^0)]$

and x_i^1 is the quantity of output (input) x_i in time period 1

p_i^1 is the price of output (input) p_i in time period 1

$p_i^1 x_i^1$ is the value of the ith output (input) in time period 1

p^1x^1 is the total value of all outputs (inputs) in time period 1

The Tornqvist index between adjacent periods is the antilog of the sum of log changes for components weighted by the arithmetic mean of their share in the total value for the two periods. More generally,

$$Q_T(p^0, p^k, x^0, x^k) = \text{antilog} \sum_{j=1}^{k} \ln Q_T(p^{j-1}, p^j, x^{j-1}, x^j) \quad k = 1, 2, \ldots, T$$

where the vector of N prices for period j is denoted by

$$p^j = (p_1^j, p_2^j, \ldots, p_N^j)$$

and the corresponding vector of quantities for period j is

$$x^j = (x_1^j, x_2^j, \ldots, x_N^j),\ j = 0, \ldots, T$$

The Tornqvist index is a superlative index, which means that it is exact for a particular flexible functional form. A flexible functional form provides a second order approximation to an arbitrary twice differentiable linearly homogeneous functional form. Diewert (1976, 1978) has shown that the translog unit cost function is exact for the Tornqvist price index, while the linearly homogeneous translog production function is exact for the Tornqvist quantity index.

The Tornqvist index is calculated using the chain principle rather than a fixed base. It can be shown to satisfy most of the standard Fisher tests, in particular, the commodity reversal test, the identity test, the commensurability test, the strong proportionality test and the time reversal test. It does not satisfy the factor reversal test and is only approximately consistent in aggregation. That is, an overall Tornqvist index of Tornqvist indexes of subaggregate groups is approximately equal to a Tornqvist index of all the basic components within these subaggregate groups (Diewert 1978). For the Tornqvist quantity index [Q_T from equation (A1)] and the Tornqvist price index [P_T from equation (A2)] a corresponding quantity or price index can be defined implicitly by using the weak factor reversal test. The relationship between P_T and the implicit quantity index Q is defined as

$$\text{(A3)} \qquad P_T(p^0, p^1, x^0, x^1)\ Q(p^0, p^1, x^0, x^1) = p^1x^1/p^0x^0$$

If P_T is a superlative price index, then Q, the corresponding implicit quantity index, is also superlative (Allen and Diewert 1982). Given the problems in aggregation, the direct quantity index (Q_T) may differ from the implicit quantity index (Q). Thus, which index number formula should be used, Q_T or Q? If there is less variation in the price ratios (p_i^1/p_i^0) than the quantity ratios (x_i^1/x_i^0), Allen and Diewert (1982) recommend the use of a superlative direct price index such as the Tornqvist index and a corresponding implicit quantity index.

In the case of the dairy industry, quantity data exhibited much more variability than price data; therefore, the direct price index (P_T) and the indirect quantity index (Q) were used in this study. Nevertheless, for most of the productivity estimates presented, there were no significant differences between the indirect and direct indexes. The exceptions were some of the regional estimates where the annual quantity data exhibited greater variability than at the state and national levels.

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