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Recent Trends in New Zealand Agricultural Productivity and its Measurement¹

by

Rod Forbes and Robin Johnson²

This paper updates the results of an earlier paper (Johnson 1996) exploring productivity trends 1972-92 prepared for the OECD. Tornqvist indexes are used to compensate for changes in the mix of outputs and inputs. Capital is charged at service prices. Present indications are that labour and capital inputs have not increased in the last ten years but total factor productivity has increased at the rate of around 4 per cent per year reflecting past investments and adaptation to new challenges. Comparisons are made with indexes based on static factor shares and suggestions are made on the construction of more ideal index numbers for measuring productivity change where the data is available.

Introduction

These estimates of Tornqvist productivity indexes were first prepared for a productivity conference at the University of New England in 1995 (Johnson 1996). That paper compared Tornqvist indexes with Laspeyre (base-weighted) type volume indexes, and discussed the reasons for using geometrically weighted factor shares as weights. The present paper updates the data series from 1992 to 1998 and checks out the earlier results and their implications. The necessary data for re-weighting national income data is only available back to 1972. While provisional nominal data is available for March 1999, the data in real terms has yet to be derived by Statistics NZ.

Tornqvist weighting can be used for a total input productivity index (TIP) or a total factor productivity index (TFP). The TIP index takes account of changes in the composition of intermediate inputs as well as labour and capital inputs. The TFP index simply expresses net real output as a function of labour and capital input. In national accounting terms, intermediate inputs are deducted from gross output to obtain factor or net output for an industry. Using national accounting conventions involves important assumptions about the marginal returns to intermediate inputs. With marginal revenue equal to marginal cost, any productivity gain is therefore attributed to labour and capital.

Tornqvist weighting is used to overcome biases caused by changes in the respective weights of the components of a given volume index. In the case of intermediate inputs, for example, the use of fertiliser may be changing systematically during the period of observation. Base year weights of different inputs would freeze the true weighting over a period of time. Similarly for the total fertiliser index of volume - a base year weight would freeze the mix of different fertilisers when farmers were changing their respective mixes. These biases can thus arise from any change of use in a productive input and are commonly found in fertilisers,

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² Ministry of Agriculture and Forestry, and Private Consultant respectively, Wellington, New Zealand.

weedkillers, sprays, and other inputs. The same reasoning applies to changes in the mix of outputs.

In the agricultural sector, statistics on a System of National Accounts (SNA) basis are available back to the 1950s. The accounts present nominal estimates of gross output, intermediate inputs and net income (equivalent to gross domestic product). For productivity analysis, these entities must be converted to volume terms. In the case of the agricultural sector, real inputs are deducted from real gross output to obtain real net output. Both gross output and intermediate inputs are deflated separately. Estimating these volume series may be by one implicit index or by the use of price indexes for each component of gross output and intermediate inputs. In turn these price series are derived by statisticians from surveys of the productive sectors. In doing so, the statisticians adopt various methods to weight the individual components of a price index. A base year weighting system introduces the same biases as for the input volume series. Theoretically, such price indexes should also be geometrically weighted as well. This would involve complete access to the data bases of the statisticians if it were to be carried out systematically.

The present paper sets out the methodology of estimation of Tornqvist indexes of agricultural productivity for New Zealand since 1972, and then examines the impact of different weighting systems on estimates of TIP and TFP. The use of service costs of capital are discussed and compared with factor shares based on the national accounts. Different methods of depreciating capital stocks are discussed and the results compared. The overall results are compared with other sectors of the economy for which comparable data is available.

A major political-economic paradigm shift occurred in 1984 with the election of a Labour Government. A mini-Budget in December 1984 cancelled government subsidy support to the agricultural sector and the NZ dollar was allowed to freely float from March 1985. For this study we chose a break point of March 1985, for a pre and post reform comparison of growth rates in the various indexes derived.

Methodology

The national income identity for nominal factor income is as follows:

$$(1) \quad FI = PQ - SM$$

FI = factor income (GDP)

PQ = value of gross output (P = price)

SM = value of intermediate inputs (S = price).

The underlying profit maximisation equation can be written:

$$(2) \quad \Pi = PQ - SM - WL - RK$$

WL = reward to labour (W = price)

RK = reward to capital (R = price)

In real terms, factor income (FI^*) is estimated by the double deflation method:

$$(3) \quad FI^* = PQ/P - SM/S$$

Since the aggregates are composed of the individual input (i) and output (j) categories, (3) can be written as:

$$(4) \quad FI^*_t = \sum_j P_{jt} Q_{jt} / P_{jt} - \sum_i S_{it} M_{it} / S_{it}$$

where $P_{jt} Q_{jt}$ = price and quantity of the j^{th} output category in year t ,
and $S_{it} M_{it}$ = price and quantity of the i^{th} input category in year t .

The factor income productivity index can be defined as:

$$(5) \quad FIP_t = FI^*_t / (W_o L_t + R_o K_t)$$

This can be rewritten to include base year prices for factor income:

$$(6) \quad FIP_t = (P_o Q_t - S_o M_t) / W_o L_t + R_o K_t$$

where P_o, S_o, W_o, R_o are the prices of the base year.

A total input productivity index may also be defined in the same way:

$$(7) \quad TIP_t = (P_o Q_t / W_o L_t + R_o K_t + S_o M_t)$$

To overcome the base year bias problem in the volume indexes and the price indexes, the Tornqvist discrete approximation to a Divisia Index is used here (Diewert (1976)). This defines the Index, Q_t , as the weighted change in the proportions of its base weighted value components:

$$(8) \quad Q_t = \sum_i (Q_{it} / Q_{io})^{1/2 (w_{it} + w_{io})}$$

This can be transformed by logarithms to the base e to give the estimation formula:

$$(9) \quad \ln Q_t = \sum_i 1/2 (w_{it} + w_{io}) (\ln Q_{it} - \ln Q_{io})$$

where w_{it} = the share of the i^{th} input (j^{th} output) in total nominal input (output) in the year t , and
 w_{io} = the share of the i^{th} input (j^{th} output) in total nominal input (output) in the base year.

By taking anti-logs, the base year takes on a value of one. The base year for this study is 1982/83 March year. The Tornqvist method estimates the rate of change in aggregate inputs or outputs from the geometrically weighted rate of change of the components of total input and total output. Average percentage growth rates can be estimated for seven indexes derived by this method - total output, total input, factor income, intermediate inputs, total factor input, total input productivity and total factor productivity.

In most studies of factor productivity, factor income is derived from the national accounting identities and then expressed as a ratio of factor income to the weighted average input of labour and capital (equation 6). In this study, the accounting identity for intermediate inputs is

not utilised and the Divisia weighted volume index is substituted. Thus we have an expression for factor income which is derived from two Divisia weighted aggregates (total output and total inputs) which is then compared with a Divisia weighted average of capital and labour inputs. Alternatively, the total input factor productivity ratio can be estimated by comparing Divisia weighted total output and the Divisia weighted average of labour, capital and intermediate inputs.

e.g.

Divisia factor income = Divisia total volume index - Divisia intermediate inputs

Divisia factor productivity = Divisia factor income/ Divisia combined factor inputs.

Since two indexes cannot be subtracted, the equivalent value series is derived for each series, subtracted, and then converted back to an index.

The weighting of capital and labour inputs should follow, in theory, the procedure devised by Tornqvist. That involves determining the nominal shares of factor income going to labour and capital (including depreciation). The SNA approach divides factor income into rewards to labour, consumption of capital, operating surplus plus a correction for subsidies and taxes. As there is no separate share for capital, the Tornqvist method cannot be directly used.

There are two methods that can be used to overcome the problem. One method is to accept the wage component as a "paid" reward and attribute the remainder of factor income to capital reward. This gives a nominal factor share that does not vary much from year to year. Another method is to estimate capital rewards first and make wage rewards the residual.

This latter procedure was followed in the previous paper (Johnson 1996). In that paper, the reward to capital was the sum of depreciation of capital and the service cost of capital. The total cost of capital (TC) is estimated as follows:

$$(10) \quad TC_t = A_t ((d_t/100) + ((1-e_t)(m_t/100)(n_t/m_t)))$$

where A_t = nominal asset value at beginning of year t ,

d_t = wastage or disappearance rate during year t ,

e_t = equity to asset ratio in year t ,

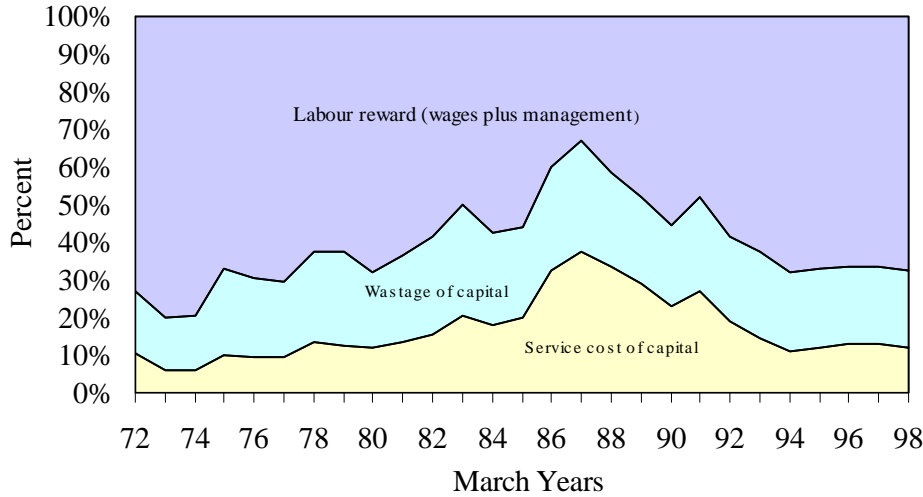
m_t = interest rate on new mortgages registered in year t ,

n_t = actual average interest rate paid on sheep and beef farms³ in year t .

In general, wastage rates are slightly higher than conventional depreciation rates, while the service cost of capital is lower than the full opportunity cost of capital including equity. The factor share of labour varies considerably by this method over a period of time. The resulting factor shares in nominal agricultural GDP, or net income are shown in Figure 1. The share to the service cost of capital mirrors the way monetary policy was pursued over time. The freeing up of the economy from 1984 led to historically high, new mortgage interest rates between 1986 (19.1%) and 1988 (18.9%). Rates fell steadily to 7.9% in 1994 and then rose to remain slightly above 10% between 1995 and 1998.

³ From the Meat and Wool Economic Services of NZ's annual sheep and beef farm survey.

Figure 1: Disposition of nominal agricultural GDP



Remember the objective is to determine appropriate weights in nominal terms for the application of the Tornqvist formula. By using service cost of capital as the weight for capital input volumes, the balance of net output must be considered the labour share made up from equity returns on capital and paid wages⁴. This recognises the special position of self-employed entrepreneurs (i.e. the farmers).

The definition of the capital stock variable requires further discussion. The previous study employed a device to estimate wastage of capital directly. This was possible because of the special attributes of the agricultural sector data where comparisons could be made of the "disappearance" of capital over a specified period of time. Philpott (1995, 1999a) provides another series of capital stocks derived from business depreciation rates. This results in a series not dissimilar to the wastage series. Alternatively, Philpott (1994, 1999a) provides estimates of capital stock based on a vintage model where "disappearance" is estimated for whole blocks of assets on a systematic basis. Philpott's gross capital stocks tend to be 50 per cent higher than his net capital stocks. The gross series is used in this study for measuring real assets employed. All capital stocks are derived from a perpetual inventory model in terms of the following identity:

$$(11) \quad K_t = (1 - f) K_{t-1} + E_{t-1}$$

where K_t = the stock of conventional capital at the beginning of period t in constant prices,
 K_{t-1} = the stock of capital at the beginning of period t-1,
 E_{t-1} = capital expenditure during period t-1 in constant prices, and
 f = the depreciation or obsolescence rate of capital chosen.

For discussion of the choice of starting dates see Philpott (1994), Industry Commission (1995), Diewert and Lawrence (1999), Philpott (1999b) and Johnson (1999).

⁴ The national income identity is $W+D+OS+IT-S$. Paid interest is deducted from operating surplus. Thus if capital shares are based on depreciation and debt servicing, the wage share is the balance of operating surplus adjusted for indirect taxes and subsidies and wages paid.

Results

The volume of real net output (real factor income) has increased steadily over the period from 1972 to 1998 with little growth in total labour employed and gross capital stock employed (Figure 2). The labour force has been in decline since 1982 and the capital stock employed has been in decline since 1987; the latter due to the slowdown of reinvestment. The average rates of growth on an annual basis are shown in Table 1.

Figure 2: Indices of real income, labour units and capital value

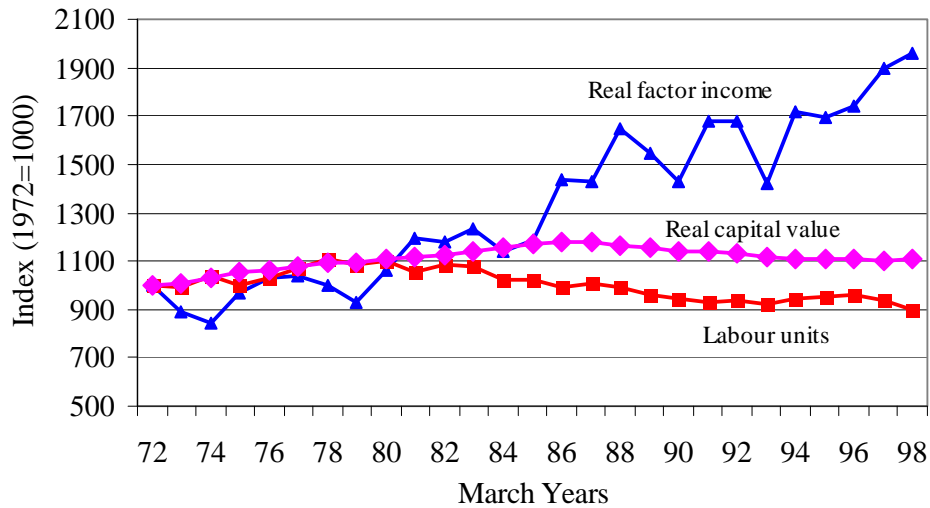


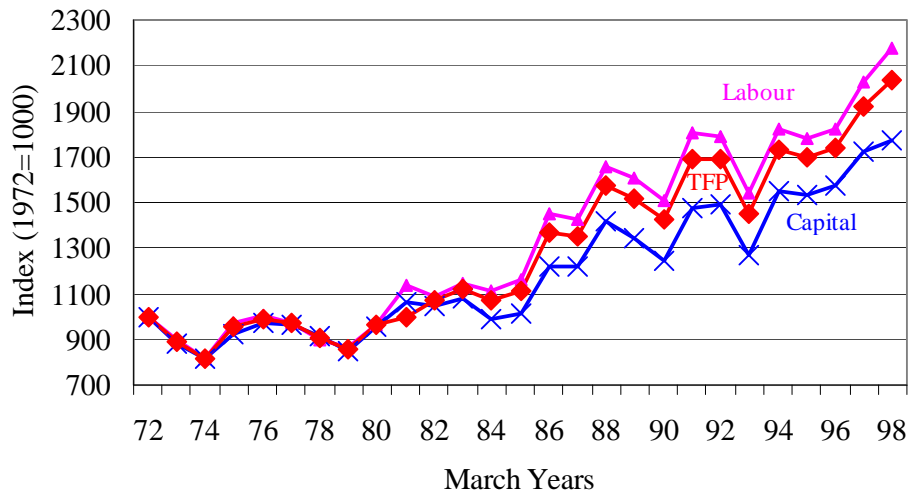
Table 1: Laspeyre method results

(trend % per annum)

Labour force	-0.3
Capital stocks	-0.1
Real value added	4.0
Labour productivity	4.3
Capital productivity	4.0
Total factor productivity	4.1

Figure 3 shows the trends in labour and capital productivity and the weighted mean of the two. Fluctuations in productivity are caused by changes in national income from agriculture rather than from the input series.

Figure 3: Agricultural productivity



The rates of change shown in Table 1 are derived from regression estimates of the rate of change over the whole period. Table 2 shows the goodness of fit statistics for the regressions for the variables entering into the total productivity and the factor productivity estimates. Where the Durbin-Watson test was poor, a first difference transformation was explored. The different specification does not change the growth rate estimates by a great margin.

Table 2: Goodness of Fit for Whole Period
1972-98

	Original data			First differences		
	b	R ²	DW	b	R ²	DW
Tornqvist						
output	1.6	.90	1.41	1.6	.91	2.01
all inputs	0.7	.02	1.54	-		
TIP	1.5	.86	1.27	1.6	.85	2.16
factor income	3.4	.88	1.86	-		
factor inputs	-0.2	.12	0.24	-0.6	.24	2.33
TFP	3.5	.87	1.52	-		
Laspeyre						
output	1.8	.92	1.15	1.9	.87	2.04
all inputs	0.9	.03	1.67	-		
TIP	1.7	.89	1.15	1.8	.86	2.06
factor income	4.0	.91	1.66	-		
factor inputs	-0.1	.05	0.21	-0.5	.23	2.37
TFP	4.1	.89	1.38	4.4	.90	1.99

Table 3 shows total input productivity (TIP) estimated by Laspeyre base-weighted method and by the Tornqvist geometric weighted method. The latter weights are derived from average value shares between the current year nominal factor shares and the base year factor shares. If an input or an output mix is changing in a systematic way the geometric method makes the appropriate adjustment. Figure 4 shows a comparison of the two weighting methods for gross

output of the agricultural sector, Figure 5 shows the comparison for total inputs employed, and Figure 6 shows the comparison for the total input productivity index.

Table 3: Total Input Productivity by Weighting Method and Periods
(growth rates)

	Tornqvist			Laspeyre		
	Output	Input	TIP	Output	Input	TIP
1972-84	1.1	0.5	0.6	1.0	0.3	0.7
1985-98	1.8	0.0	1.8	2.2	0.3	1.9
1972-98	1.6	0.7	1.5	1.8	0.9	1.7

Figure 4: Comparison of Agricultural Gross Output Indexes

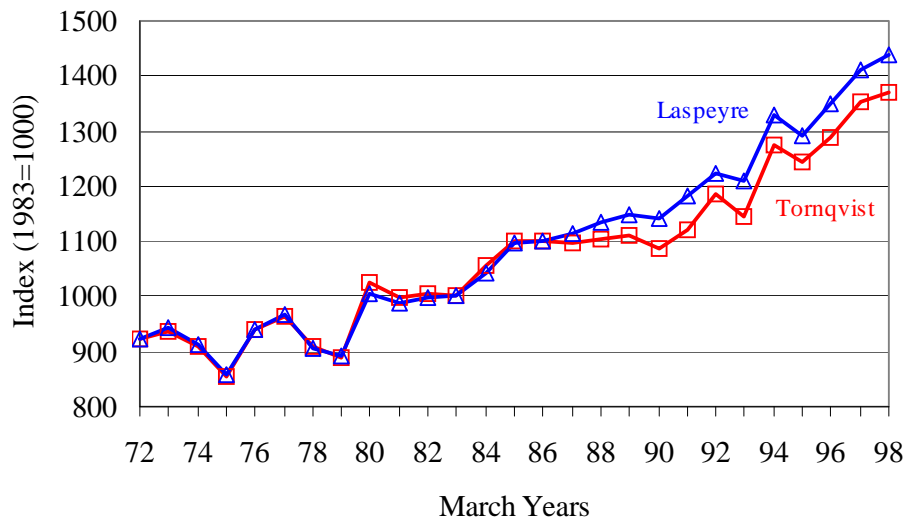
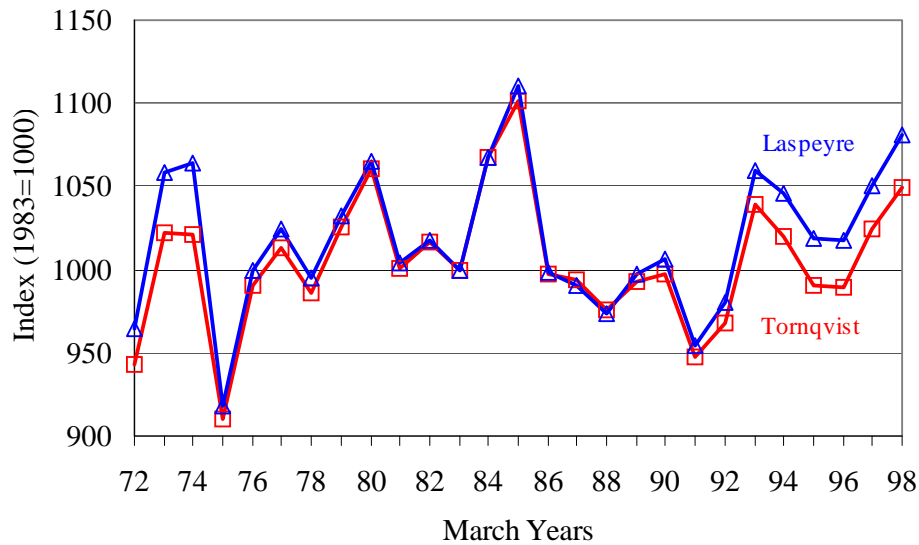
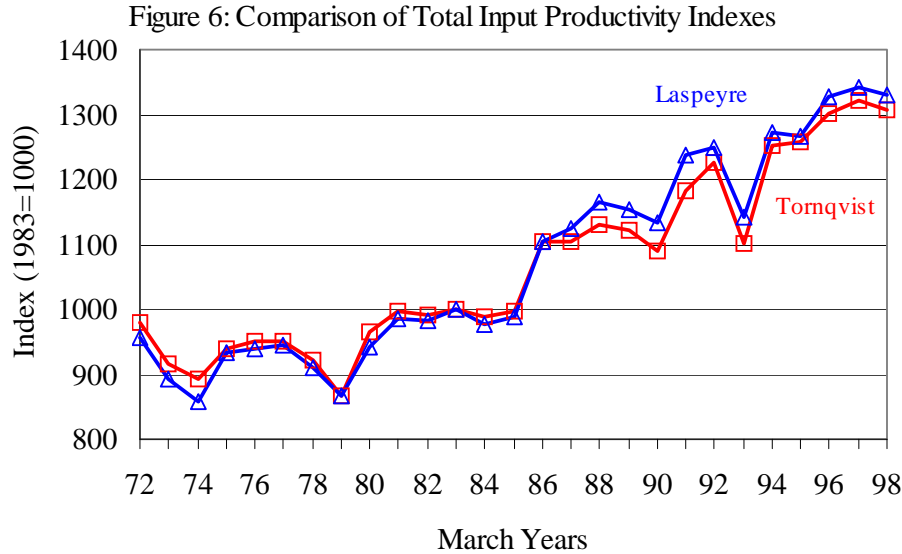


Figure 5: Comparison of Agricultural Total Input Indexes





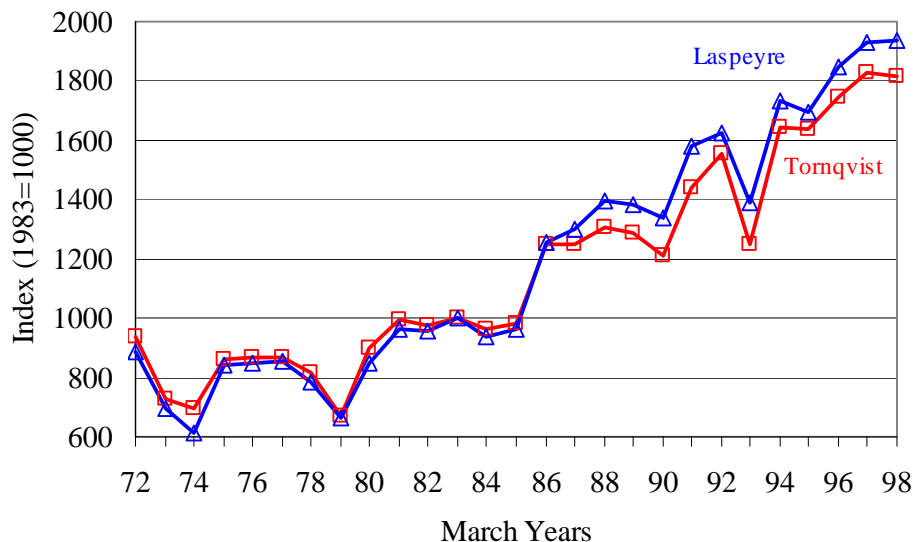
Total input productivity tends to be over-stated by base-weighted indexes particularly since 1985. Thus the better estimate of long run total productivity is 1.5% per year since 1972. Both methods suggest that the rate of growth has improved since 1985 compared with the earlier period 1972-84. Table 4 shows the same results for total factor productivity and Figure 7 shows a comparison of the two weighting methods for the total factor productivity (TFP) index.

Table 4: Total Factor Productivity by Periods
(growth rates)

	Tornqvist			Laspeyre		
	Income	Input	TFP	Income	Input	TFP
1972-84	2.6	0.8	1.8	3.1	0.9	2.2
1985-98	3.2	-0.8	4.0	3.7	-0.6	4.3
1972-98	3.4	-0.2	3.5	4.0	-0.1	4.1

Again Tornqvist indexes tend to lower the factor income increase and the factor input increase (slightly) with the resulting effect on the productivity growth rate. Thus the best estimate for factor productivity growth for the period since 1972 is more likely 3.5% per year rather than 4.1% per year as might have been indicated by the Laspeyre index.

Figure 7: Comparison of Total Factor Productivity Indexes



Comparative Results

Diewert and Lawrence (1999) estimate the rate of growth of factor productivity in agriculture for the period 1978 to 1998 as 3.87% per year. This lies between the above two estimates. For more careful comparison we need to look at the specification of their model.

"To form separate TFP indexes for the 20 industries we now take real production GDP as output, normalise it to equal 1 in 1978, and form a chained Fisher index of the three industry inputs - labour hours, plant and equipment stocks, and building and construction stocks - using labour costs and capital user costs as weights. We then take the ratio of the industry's total output to total input index to form the industry's TFP index. The industry TFP indexes use our preferred base case specification of production base GDP, the database's composite labour series, and our net capital estimates".

The chained Fisher index gives very similar results to the Tornqvist index - it being the geometric average of the Paasche and Laspeyres indexes. Production based GDP is the same as used above; the use of labour hours tends to increase the input of labour and decrease the resulting TFP; and the net capital stock grows more slowly than the gross capital stock used above. Thus the Diewert and Lawrence results are lower by reason of their labour definition but higher by reason of their capital definition. A summary of their sector estimates of industry TFP growth by their methodology is shown in Table 5.

Table 5: TFP's by Diewert and Lawrence (1978-98)

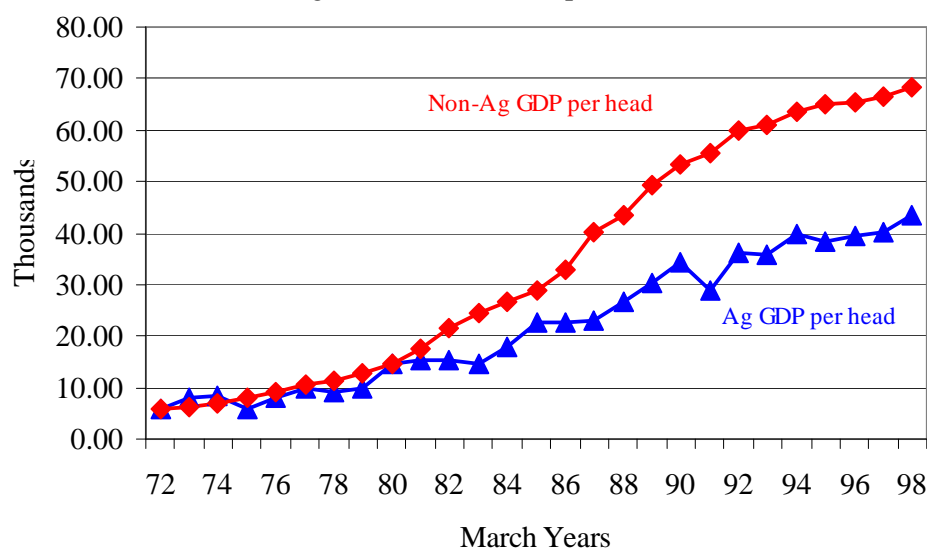
Agriculture	3.87	Fishing	0.25
Forestry	6.34	Mining	4.92
Energy	3.50	Construction	0.63
Trade, Rest'rants	-0.75	Transport	3.87
Communications	6.77	Finance services	-2.11
Community services	0.03	Textiles	0.68
Wood products	0.30	Food & beverages	0.68
Paper products	1.28	Chemicals	0.25
Non-metallic min	2.36	Basic metals	1.01
Machinery	0.03	Other manuf'ing	2.43

The particular reasons for the growth or lack of growth in each sector needs to be examined against the background of labour and capital input changes, the uptake of technology, and other factors which might bear on productivity increases. This data does give a uniform set of answers though as Diewert and Lawrence point out there are still definitional problems in some sectors (particularly the service sectors) which need to be resolved. For the record, the agriculture sector is third equal in the productivity comparisons over the period concerned.

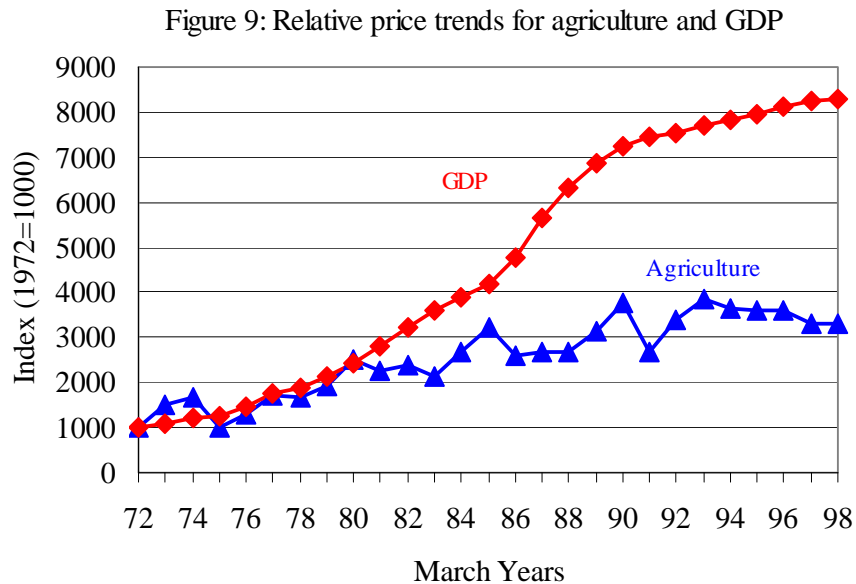
Reasons for Agriculture's high productivity and low income

Agricultural producers in New Zealand continue to complain of the low incomes they receive (compared with the past). Clearly, the high gains in productivity have not been translated into farm incomes. This can be seen from a comparison of nominal GDP per head earned in farming compared with the rest of the economy (Figure 8). Up to 1980, farm producers earned comparable incomes in GDP terms to the rest of the economy. Since that time, there has been a consistent deterioration in relative incomes. Two factors stand out, the economic reforms from 1984 and commodity terms of trade.

Figure 8: Nominal GDP per head



Prior to 1980, a regime of producer support and a fixed exchange rate appears to have kept relative prices stable between the farm sector and the rest of the economy. The main determinant of changes in farming incomes is the commodity terms of trade. Farmers are at the mercy of international commodity price trends, modified by changes in the exchange rate and the competitive structure in the value added chain between farm gate and FOB. Figure 9 shows the trends in the price indexes of GDP and agriculture from 1972 to 1998. From 1980, agricultural prices have lagged well behind average prices in New Zealand. Over much of the 1985 to 1998 period, the non-tradeable sector remained shielded from international price competitiveness, while the export sector experienced this from the start.



Structural adjustments within the farm sector have taken place in response to the reforms since 1984 and these reflect in the strong productivity growth that is evident from our analysis. Economic farm sizes have steadily increased along with the shedding of farm labour and an increasing reliance on off-farm income. At the same time, there has been an increase in subdivision into lifestyle blocks, with the number more than doubling over the last 10 years to about 98,000.

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