Productivity Trends in New Zealand and Australian Manufacturing

Rolf Färe, Shawna Grosskopf and Dimitri Margaritis
Oregon State University and University of Waikato

1. Introduction

The purpose of this paper is to study relative trends in total factor productivity (TFP) between the Australian and New Zealand manufacturing sectors during the post - 1984 period. This is the period that marks the start of a comprehensive economic liberalisation programme in New Zealand. Prior to 1984, a long period of border protection had largely insulated the New Zealand economy from international competition and a wide range of market interventions had distorted price signals and prevented adaptation of business activity to changes in market conditions. The manufacturing sector was highly diversified but very inefficient. Tax incentives, subsidies and import controls provided domestic manufacturers with ample opportunity to control the home market with inflated prices. Such regulatory factors also inhibited the economy's ability to adapt in response to changing circumstances. For example, the economy maintained reliance on protected primary product industries in spite of a steady deterioration in New Zealand's terms of trade and difficulties in finding export markets.

The particular interest in TFP analysis is driven by recent scepticism, even disillusionment, regarding the New Zealand economy's ability to capture the benefits of its liberalised market model. New Zealand economist Paul Dalziel has vividly summarised the critics views in a recent (NZ Herald) newspaper article by observing that "if New Zealand had continued to grow as fast as Australia [which followed a more gradual and less comprehensive reform path] after 1984, our [New Zealand] GDP last year would have been nearly a third higher than it was". He estimates the output gap over the 1984-1998 period to amount to $215 billion or the equivalent of two years of the country's output. Naturally, such comparisons, however disturbing they may appear to be at first sight, deserve more careful examination. For example, the New Zealand economy grew very strongly in the 1992-1996 period. Since then it has been affected by the adverse effects of a major drought, the Asian crisis and undue monetary tightness in 1995-1997. New Zealand also boasts a much better unemployment record than Australia in the 1990s, in part a reflection of a less regulated labour market.

Labour market deregulation in New Zealand is now under attack because of evidence provided by labour productivity trends, particularly in the manufacturing sector. The critics are quick to point out that Australia's more regulated labour market has delivered a better productivity record. But labour productivity comparisons can be misleading as no account is taken of the amount of capital per worker used in production. It is helpful to remember that labour productivity, output per worker, is the product of output per unit of capital and capital per worker. It is possible, for example, that Australia's better labour productivity record reflects the country's higher unemployment rate. It costs more to employ workers in the more regulated labour markets and those excluded from jobs tend to be less productive. The Economist (October 31st, 1998) uses similar arguments comparing the productivity performance in Britain with that of France and Germany. A better measure of productivity is TFP, i.e., output divided by labour and capital. In fact, TFP is the engine that drives per capita output growth in the long-run. The problem with TFP is that its measurement is quite a complicated task and reported figures are often unreliable. This is a major goal of this study.

2. The Productivity Index

This section introduces the index used in this study to measure productivity. The index is defined in terms of output distance functions. These functions measure the ray distance between a given output vector and maximal potential output. This maximal output belongs to the boundary of the reference or frontier technology. We start by explaining how the frontier is constructed from data.

At each time period t=1, ..., T there are k=1, ..., K groups or observations that use $x^{k,t} = (x^t_{1k}, \ldots, x^t_{Nk}) \varepsilon R^N_+$ inputs to produce a single output $y^t_k \varepsilon R_+$ for each of the two country manufacturing sectors. From these observations an overall manufacturing production technology is constructed for each time period. Rather than specifying and estimating a specific production function we choose to construct the technologies non-parametrically using activity analysis. This technique is also known as Data Envelopment Analysis (DEA) (see Charnes et al. 1978).

For a given period t, the frontier technology is

(2.1) $$S^t_{CRS} = \{(x^t,y^t):$$

$$\sum_{k=1}^{K} z_k y_k^t \geq y^t,\ \sum_{k=1}^{K} z_k x_{nk}^t \leq x_n^t,\ n=1,\ldots,N,\ z_k \geq 0,$$

$$k=1,\ldots,K\}.$$

This formulation admits constant returns to scale (CRS) and free disposability of inputs and output. Output levels may be less than or equal to linear combinations of observed output, that is, output is freely disposable. Input levels may be greater or equal to linear combinations of observed input, that is, producers may freely dispose of inputs as well. The technology, and consequently the associated distance functions, are independent of measurement units and, although CRS is imposed in each period, each period is allowed to have a completely different CRS technology.

The intensity variables, z_k, k=1, ..., K, indicate at what intensity a particular activity (or observation) may be employed in production. They are only required to be non negative, thus they form the convex cone of the data. The convexity implies that convex combinations of observed inputs and outputs are hypothetically feasible. The technology being a cone is equivalent to constant returns to scale.

Two alternative scale properties are non-increasing returns to scale (NIRS) and variable returns to scale (VRS). These are modelled as in (2.1) by adding

(2.2) $$\sum_{k=1}^{K} z_k \leq 1 \qquad \text{(NIRS)}\ S^t_{NIRS}$$

(2.3) $$\sum_{k=1}^{K} z_k = 1 \qquad \text{(VRS)}\ S^t_{VRS}$$

respectively. These models are nested by inclusion in the sense that $S^t_{CRS} \supseteq S^t_{NIRS} \supseteq S^t_{VRS}$ (see Grosskopf 1986). Relative to any one of the three frontier technologies S_j^t, j=CRS, NIRS, VRS, one may define the corresponding output distance function for k′ as

(2.4) $$D_o^t(x^{k',t},y^{k',t}\mid j) = \min\{\theta : (x^{k',t},\frac{y^{k't}}{\theta})\varepsilon S_j^t\}$$

$$= [\max\{\theta : (x^{k',t},\theta y^{k',t})\varepsilon S_j^t\}]^{-1}$$

$$= [F_o^t(x^{k't},y^{k',t}\mid j)]^{-1}$$

(see Shephard, 1970 or Färe 1988 for details). In (2.4) F_o^t (•) denotes the Farrell (1957) output- oriented measure of technical efficiency. Thus (2.4) shows that the distance function and the Farrell technical efficiency measure are reciprocals. This fact is important, since we decompose our productivity index into two components: one measuring efficiency change and another measuring technical change. This index has become known as the Malmquist index. It was introduced as a theoretical index by Caves et al. (1982) who named it the (output-based) Malmquist productivity index after Sten Malmquist who had earlier shown how to construct quantity indexes as ratios of distance functions (see Malmquist 1953).

Following Färe et al. (1989) the Malmquist productivity change index (M) is defined as

(2.5) $$M_o(k',t,t+1) =$$

$$\left[\frac{D_o^t(x^{k',t+1},y^{k',t+1})}{D_o^t(x^{k',t},y^{k',t})}\ \frac{D_o^{t+1}(x^{k',t+1},y^{k',t+1})}{D_o^{t+1}(x^{k',t},y^{k',t})}\right]^{1/2}.$$

This index is the geometric mean of two Malmquist productivity indexes as defined by Caves et al. (1982) (CCD), namely

(2.6) $$M^t_{CCD} = \frac{D_o^t(x^{k',t+1},y^{k',t+1})}{D_o^t(x^{k',t},y^{k',t})}$$

and

(2.7) $$M^{t+1}_{CCD} = \frac{D_o^{t+1}(x^{k',t+1},y^{k',t+1})}{D_o^{t+1}(x^{k',t},y^{k',t})}.$$

An important feature of the Färe et al. (1989) version of the Malmquist index (2.5) is that it can be decomposed into two independent components, namely

(2.8) Efficiency Change = ECH =

$$\frac{D_o^{t+1}(x^{k',t+1},y^{k',t+1})}{D_o^t(x^{k',t},y^{k',t})}$$

and

(2.9) Technological Change = TCH =

$$\left[\frac{D_o^t(x^{k',t+1},y^{k',t+1})\ D_o^t(x^{k',t},y^{k',t})}{D_o^{t+1}(x^{k',t+1},y^{k',t+1})\ D_o^{t+1}(x^{k',t},y^{k',t})}\right]^{1/2}.$$

Thus (2.5) can be written as

$$(2.10) \qquad M_o(k',t,t+1) = MALM = ECH \cdot TCH$$

and for each group k'=1, ..., K, time paths of productivity, efficiency and technical change can be calculated.

The productivity index and its components are all constructed from distance functions. It is therefore sufficient to show one example,

$$(2.11) \qquad [D_o^t(x^{k',t+1}, y^{k',t+1} \mid CRS)]^{-1} = \max \theta$$

s.t.

$$\sum_{k=1}^{K} z_k y_k^t \geq \theta y_{k'}^{t+1},$$

$$\sum_{k=1}^{K} z_k x_{nk}^t \leq x_{nk'}^{t+1}, \quad n=1, \ldots, N,$$

$$z_k \geq 0, \; k=1,\ldots K.$$

This example shows how the reciprocal of the distance function is computed relative to the constant returns to scale technology. We note, moreover, that the observation k' is from period (t+1) while the technology is constructed from data at (t), that is, the linear programming problem is a mixed period problem. If we substitute the (k',t) observation with (k',t+1) (2.11) becomes the usual Farrell efficiency problem.

We calculate the Malmquist index and its components under the CRS technology. Fluctuations in productivity may be due to variation in capacity utilisation and differences in the structure of each sector which will be reflected in changes in the efficiency component. This follows from the fact that observations are compared to the best practice frontier.

Improvements in productivity yield Malmquist index values greater than unity. Deterioration in performance over time is associated with a Malmquist index less than unity. The same interpretation applies to the values taken by the components of the overall TFP index. Improvements in the efficiency component yield index values greater than one and are considered to be evidence of catching up (to the frontier). Values of the technical change component greater than one are considered to be evidence of technical progress. While the product of the efficiency and technical change components must, by definition, equal the Malmquist index, those components may be moving in opposite directions.

3. Data and TFP Results

We calculate productivity growth and its components for a sample of the manufacturing sectors of Australia and New Zealand during the period 1986 to 1996 (March years). The output (value-added) and capital (K) series are measured in constant 1992 New Zealand dollars (the Australian figures have been re-based and PPP adjusted). Labour (L) is measured as total hours worked.

The approach outlined in section 2 constructs a best practice frontier from the data. In particular, it constructs an aggregate frontier for the overall two country manufacturing sector and individual country sectors are compared to that frontier. In this context, ie, where we have one output for each sector, the output distance function is equivalent to a frontier production function.

The upper columns of Table 1 give a summary description of the average multi-factor productivity performance of each country's manufacturing sector over the period 1986 to 1996 (1986 is the base year with an index value equal to unity). Since the productivity index is based on discrete time, each sector will have an index for every pair of years. Recall that index values greater (less) than one denote improvements (deterioration) in the relevant performance.

Table 1
1986-1996 Averages

	DIST	TFP	ECH	TCH
NZ	0.9173	1.0133	0.9942	1.0187
AU	1.0000	1.0108	1.0000	1.0108

	YGR	LGR	KGR	Y/L	Y/K	K/L
NZ	0.76%	-0.35%	1.35%	0.353	0.30	1.18
AU	2.20%	0.37%	2.02%	0.386	0.44	0.89

The TFP figures of 1.0108 and 1.0133 in Table 1 indicate that the overall average productivity growth over the sample period was 1.08 percent for Australia and 1.33 percent for New Zealand. Australia is the frontier country and therefore all the TFP growth is due to technical change. On the other hand, New Zealand's average TFP growth was due to technical change (TCH of 1.87%) rather than improvements in efficiency (ECH of 0.9942 or -0.58%). One notable feature of our results is that the New Zealand manufacturing sector appears on the average to be more productive than the Australian sector. However, it is associated with a negative efficiency record. In fact, a visual inspection (not shown here) of the ECH index movement over time shows that the efficiency gains achieved during the sector's extensive restructuring of the late 1980s have been followed by a steady fall (aside from a temporary blip in 1993) in the index during the 1990s. Similar evidence is indicated by the distance function (DIST) value of 0.9173. The interpretation of this figure is that New Zealand manufacturers could have produced the same output using about 8 percent on average less inputs. This requirement has actually increased to about 15 percent less inputs toward the end of the sample period.

The following are indicative (non-parametric and parametric) tests of the statistical difference between the two country manufacturing TFP indices:

Mann-Whitney Confidence Interval and Test

TFPNZ	N = 10	Median =	1.1485
TFPAU	N = 10	Median =	1.0654

Point estimate for ETA1-ETA2 is 0.0749

95.5 Percent CI for ETA1-ETA2 is (0.0273,0.1156) W = 140.5

Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0082. The test is significant at 0.0081 (adjusted for ties)

Two Sample T-Test and Confidence Interval

Two sample T for TFPNZ vs TFPAU

	N	Mean	StDev	SE Mean
TFPNZ	10	1.1406	0.0541	0.017
TFPAU	10	1.0729	0.0312	0.0099

95% CI for mu TFPNZ - mu TFPAU: (0.025, 0.1100)

t-Test mu TFPNZ = mu TFPAU (vs not =): T= 3.43 P=0.0041 DF= 14

Table 1 also provides information on average output and input growth, output to labour, output to capital and capital to labour ratios over the sample period. The Australian manufacturing sector exhibits a better output growth rate than its New Zealand counterpart, higher rates of factor accumulation as well as better labour and capital productivity rates. But while Australian manufacturers make a much better relative use of capital, they cannot be investing very much of it. The New Zealand capital to labour ratio is much higher. This may be why the Australians fall behind New Zealand manufacturers in terms of multi-factor productivity. Differences in product and labour market regulation between the two countries may give a possible explanation for the above result.

Graph 1 depicts the evolution of the manufacturing output and TFP index for Australia and New Zealand over the sample period. A notable feature in this graph is the contrasting cyclical behaviour of the two TFP indices, pro-cyclical in the case of Australia and counter-cyclical in the case of New Zealand. The latter is consistent with what is referred to in the literature as the 'cleansing effect' of economic downturns and/or structural reforms. During these periods the least productive firms are forced out of business while more competitive firms are encouraged to adopt state-of-the-art technology (see Malley and Muscatelli, 1997).

Another pattern worth noting is the negative relationship between output growth in New Zealand and PPP, i.e., a real exchange depreciation is associated with a fall in manufacturing output growth. The following is a table of correlation coefficients between output (Y), PPP and TFP indices.

Correlations (Pearson)

	YGRNZ	YGRAU	PPP	TFPNZ
YGRAU	0.407			
PPP	-0.769	-0.269		
TFPNZ	-0.479	0.444	0.602	
TFPAU	0.457	0.902	-0.345	0.379

Further indicative evidence on the relationship between the (log) productivity (LFTP) and (log) PPP (LPPP) indices is given by the following regressions:

The regression equation for New Zealand is

LTFPNZ = - 0.0021 + 0.395 LPPP + 0.00861 T

Predictor	Coef	StDev	t	P
Const	-0.00209	0.03962	-0.05	0.959
LPPP	0.39490	0.1554	2.54	0.039
T	0.008607	0.003596	2.39	0.048

SEE=0.03264 R-Sq = 64.5% R-Sq(adj) = 54.3%
F = 6.35 P = 0.027 Durbin-Watson = 1.51

The regression equation for Australia is

LTFPAU = 0.0608 - 0.152 LPPP + 0.00763 T

Predictor	Coef	StDev	t	P
Const	0.06078	0.02046	2.97	0.021
LPPP	-0.15179	0.08023	-1.89	0.100
T	0.007631	0.001857	4.11	0.005

SEE=0.01685 R-Sq = 74.0% R-Sq(adj) = 66.5%
F = 9.94 P = 0.009 Durbin-Watson = 2.07

where T is a time trend and no attempt is made to infer a directional causal relationship between TFP and PPP. If anything, theory would normally predict that productivity drives the movement in the real exchange rate. Real exchange rate depreciation appears to be directly related to productivity in the New Zealand manufacturing. The same is true for Australia although the relationship is weaker in magnitude as well as in a statistical sense.

4. Concluding Remarks

Unlike previous studies, we offer evidence on relative TFP productivity trends in the Australian and New Zealand manufacturing sectors in total as well as in terms of the efficiency and technical change components of productivity growth. Our results indicate that New Zealand's TFP record in manufacturing has on average been slightly better than Australia's. The opposite is true when comparing labour productivity between the two sectors. A possible source of lower TFP performance in Australia is identified as relatively low capital intensity in the production process which may be linked to higher degrees of market regulation. The most notable feature of our results is that New Zealand's efficiency record is not at a level one would expect from an economy which has gone through a major process of micro-economic reforms. New Zealand manufacturers appear able to adopt state-of-the-art technology and shift the production frontier but they fall short on their ability to manage the diffusion of technology efficiently. Recent attempts by the New Zealand government to set research funding priorities in the area of technology diffusion should be regarded as an important and positive development. On the other hand, the strong political emphasis on lowering the currency value in the last few years is inappropriate and reminiscent of the old protectionist era mentality. The challenge for the New Zealand manufacturing sector is to deliver solidly on the long awaited achievement of productive efficiencies and further boost its overall productivity growth level.

References

Caves, D., L. Christensen, and W. E. Diewert (1982) "The Economic Theory of Index Numbers and the Measurement of Input, Output and Productivity," *Econometrica*, 50, pp. 1390-1414.

Charnes, A., W. W. Cooper, and E. Rhodes (1978) "Measuring the Efficiency of Decision Making Units," *European Journal of Operational Research*, 2, pp. 429-444.

Färe, R. (1988) *Fundamentals of Production Theory*, Springer-Verlag, Heidelberg.

Färe, R., S. Grosskopf, B. Lindgren, and P. Roos (1989) "Productivity Developments in Swedish Hospitals: A Malmquist Output Index Approach," in *Data Envelopment Analysis: Theory, Methodology and Applications*, A. Charnes, W. W. Cooper, A. Lewin, and L. Seiford (eds.), Quorum Books.

Färe, R., S. Grosskopf, M. Norris, and Z. Zhang (1994) "Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries," *The American Economic Review*, 84(1), pp. 66-83.

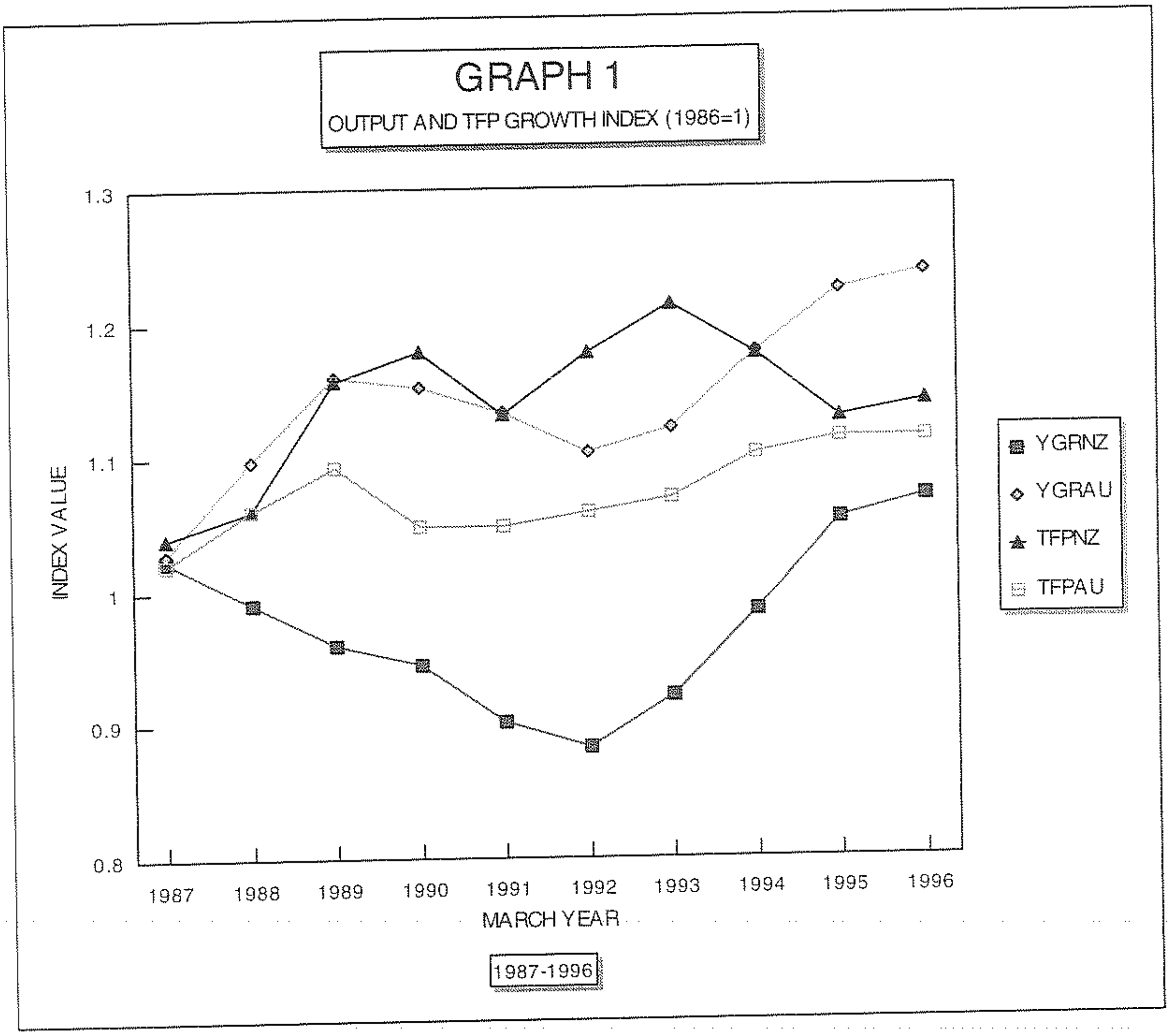
Farrell, M. J. (1957) "The Measurement of Productive Efficiency," *Journal of the Royal Statistical Society*, Series A, General, 120, Part 3, pp. 253-281.

Grosskopf, S. (1986) "The Role of the Reference Technology in Measuring Productive Efficiency," *The Economic Journal*, 96, pp. 499-513.

Malley, J. and V.A. Muscatelli (1997) "Business Cycles and Productivity Growth: Are Temporary Downturns Productive or Wasteful?" working paper, University of Glasgow.

Malmquist, S. (1953) "Index Numbers and Indifference Curves," *Trabajos de Estatistica*, 4(1), pp. 209-242.

Shephard, R.W. (1970) *Theory of Cost and Production Functions*, Princeton University Press, Princeton, NJ.


GRAPH 1
OUTPUT AND TFP GROWTH INDEX (1986=1)
INDEX VALUE
1.3
1.2
1.1
1
0.9
0.8
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
MARCH YEAR
YGRNZ
YGRAU
TFPNZ
TFPAU
1987-1996