Towards Building A New Consensus About New Zealand's Productivity

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Abstract

There is a wide consensus that New Zealand's productivity has been poor despite the comprehensive market-oriented reforms of the 1980's. This consensus is based on estimates of New Zealand's productivity growth measured either in terms of GDP per capita or total factor productivity (TFP). TFP is typically computed using growth accounting (i.e., calibrating a Solow model with fixed capital share). We argue that identification of the nature of the trend and the method of estimation are important elements of any study of productivity growth. Although difficult, it is quite important to determine whether the trend is linear deterministic or stochastic. It is equally important to measure the trend and TFP growth when there is a structural change (the reform in 1984 and the following adjustment periods) because factor shares, which are coefficients in the production function, are unstable. New Zealand data are short and undoubtedly badly measured and estimates of the standard errors of factor shares are quite large. Thus, even when we account for structural change, TFP estimate, which depends on the estimate of factor shares, is an unreliable measure of New Zealand's productivity. There is evidence, both time series and panel data that productivity has improved in the 1990's and by more than we thought. There is also significant evidence of increasing returns to scales (spillovers), which when ignored understates the estimate of the share of capital. Also, there is evidence of improving convergence of productivity between New Zealand and Australia during the 1990's. The conclusion has policy implications. We need to re-think and scrutinise the current consensus regarding current estimates before we engage in planning programmes to lift productivity.

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Prescott (2002) shows that average growth rate of GDP per working-age person in the United States in the twentieth century is 2 percent. New Zealand's average growth rate of real GDP per working-age person (15-65 years) for the period 1993-2001 is 2 percent. That is the post- reform period. The Economist issue of January 4, 2003(p.76) reported that New Zealand's average growth rate over the period 1998-2002 is 2 percent and slightly better than the US.

1. Introduction

In 1984, a comprehensive reform process began in New Zealand. It involved making new laws, new policies and the building of market-oriented institutions. The reform process was sequential and it took time. Most of the new laws and policies were in place by 1990. In 1991, the government passed the Employment Contracts Act, which aimed at establishing labour market's flexibility. The period 1984-1991 included a sequence of changes and economy-wide adjustment processes that economies in transition typically experience. At the end, a severely constrained economy was transformed into one with considerable flexibility.

Despite all these reforms and the fact that the average growth rate of real GDP per working-age population is 2 percent for the post-reform period 1993-2001, there is a very wide consensus that New Zealand's productivity is really poor.[2] This paper questions this consensus.

It is often reported that New Zealand's productivity is about 1 percent, that New Zealand's productivity is poor compared to Australia's, and that the reform process did not result in real gains. The consensus is largely based on an average growth rate of real GDP per working-age population and on TFP growth, which are indeed about 1 percent for the period 1970-2001. Typically, TFP growth is the growth rate of the so-called Solow residuals obtained using growth accounting by calibrating a Solow model with a fixed capital share.

This paper argues that the current consensus might be affected by a few factors. First is whether or not there is a structural break. Second, what is the nature of the trend, and how is it estimated? Third is whether or not the production function exhibits increasing returns to scale. Fourth, TFP is an unreliable measure of productivity in New Zealand because the estimates of factor shares have wide confidence intervals. Not accounting for these factors understates New Zealand's productivity.

All the studies that reached negative conclusions about New Zealand's productivity neglected structural changes in the data and used samples that incorporated observations from regimes prior to 1984. Diewert and Lawrence (1999)

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[2] The OECD (2000) reports that New Zealand's productivity has been poor and among the lowest in the OECD countries. New Zealand's GDP per capita trend growth and TFP growth are significantly lower than average OECD area during the period 1990-1998. There are many other studies that reach a similar conclusion. For example, Prescott (2002) uses a sample from 1970-2000 and linear trend, and many papers in the book, *The New Politics: A Third Way for New Zealand* (1999), use samples from the 1950s. Scarpetta et al (2000) report New Zealand's GDP per capita growth rate during the period 1980-1990 is 1.7 percent and it declined to 0.7 percent during the period 1990-1998. It then increased to 3.4 percent in 1999. Trend growth of GDP per capita is 1.2 percent and 0.8 percent during the periods 1980-1990 and 1990-1998 respectively. TFP growth was reported to be 0.5, 0.6 and 1 percent in the samples from 1970-1998, 1980-1990 and 1990-1998 respectively. They estimate trends using the HP filter.

mentioned significant breaks in New Zealand data, but used deterministic trend.[3] The only other paper that discusses structural breaks is Engelbrecht and McLellan (2001).[4]

Barro and Sal-i-Martin (1995) and Hansen (2001) discuss the effect of structural breaks in the data on productivity estimates. There are two important issues. Structural break in the data causes a change in the mean and the slope of the trend or both.[5] A trend line drawn through data from 1970-2001 will have a different slope from a trend line drawn from 1990-2001 because trends are sensitive to starting and endpoints. In the case of New Zealand, the starting points matter because the economy has undergone significant changes and structure adjustment from 1984 to the early or mid 1990's.

The nature of the trend also matters and the ways to estimate trends are different. Linear trends are estimated differently from stochastic trends as will be shown later in this paper. Also, when the production function exhibits increasing returns to scale (spillovers) the estimate share of capital is understated. This paper shows that current estimates of GDP per capita trend growth and TFP growth may be highly uncertain, particularly for TFP, because – even when we account for structural break – the standard errors of the estimates of factor shares are quite high. There is evidence of increasing returns to scale and convergence to Australia's productivity in the 1990's, but the convergence is in the variance not in the mean, as it should be measured, Friedman (1992).

In the next section, we will show how the trend of GDP per capita is different in the 1990's from the1970's and 1980's and we will search for a plausible breakpoint in the data. In section 3, we examine typical indicators of factor productivity. Section 4 reports estimates of TFP growth. We use both time series and panel data to estimate factor shares. We also test for increasing returns to scale and discuss its impact on TFP growth. Section 5 includes a summary, conclusions, policy implications and a discussion of future research.

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[3] "OECD Productivity Manual: A guide to the Measurement of Industry-Level and Aggregate Productivity Growth," (2001) is a large document. It does not mention structural break at all. Gregory (1999) studies the period before and after the reforms, which is not exactly accounting for structural break. The year 1984 is not the breakpoint in my opinion.

[4] Mawson (2002) found that measurements of GDP growth are sensitive to sample period.

[5] Structural change might be an argument for the Lucas critique, which says that econometric models, in general, that are used to explain and forecast the future are not useful as far as telling us anything about the future because the parameters or the coefficients of these models are assumed to be constant, i.e., don't change when policy regimes change. The fact is that the coefficients are themselves functions of the policy regime and they change when the regime changes. It could be argued that the technology parameter and the shares are functions of policy, among other things. The Lucas critique does not apply for "structural" parameters like taste for example. It applies to "behavioural" parameters. However, the capital share may not be a structural parameter. In other words, changes in policy can affect the capital – labour ratio. Lucas (2000, p. 166) himself ignored the Lucas critique for convenience. Prescott (2001) discusses these issues. Prescott suggests that changes that increase or decrease the tax one factor imposes upon the other affect factor shares. In other ways, workers in an industry may as the result of changes in labour laws, get a claim to some of the return on physical capital.

2. Measurement issues and the neglect of regime shifts

Prescott (2002) shows that New Zealand's GDP per capita, relative to a growth rate of 2 percent per annum, has fallen 30 percent below its rate in 1970.[6] According to his definition of depression, the New Zealand economy is depressed. In other words, we were better off thirty years ago than we are today. Is this really true? The answer is probably, no.

Prescott's figure is reproduced below along with two other measures. Prescott chooses a 2 percent benchmark because the productivity leader, the U.S. average productivity trend over the twentieth century is 2 percent per annum. Prescott measures GDP per capita as GDP (1995=100) per working-age population, where working-age population (15-65). Prescott GDP data are from the International Financial Statistics, and his population data are from the World Bank.[7]

We plot Prescott's detrended index in figure 1.[8]

Figure 1: Prescott's New Zealand GDP per working-age population
Index 1970=100

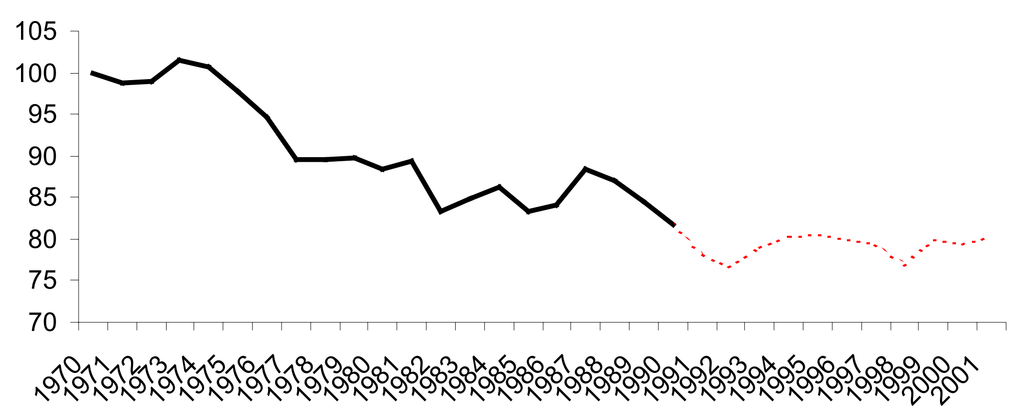

Figure 1, in general, leaves no doubt that New Zealand's GDP per capita fell significantly over the sample. But there is a neglected observation. It is intriguing that the slope of GDP per working-age population, which represents the deviation from trend, becomes flat at the end of the sample in figure1. Roughly, the slope flattens in the early 1990's, but it is hard to tell exactly when just by visually inspecting the data. This segment(s) is plotted in a dotted line(s) to distinguish it from the rest of the sample. It seems that the flat portion has a slope approximately equal to zero, on average. Keep in mind that we plot the deviations from 2 percent.

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[6] Prescott revised the estimate to 20 percent, instead of 30, recently.

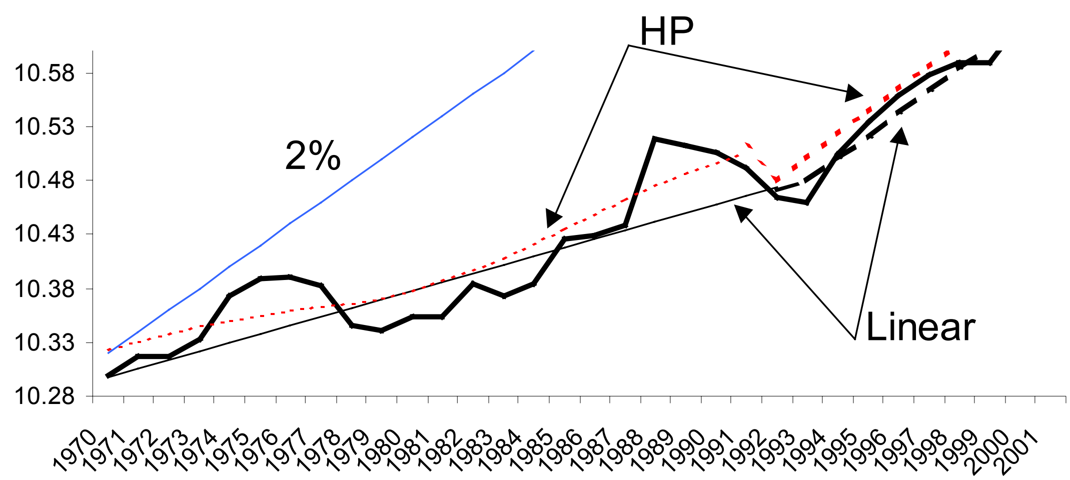
[7] I thank Ed Prescott for sharing his data with me.

[8] There is a huge difference between the two measures of working-age population, 15 years and over (15+) and (15-65 years). In New Zealand, people older than 64 have been entering the labour force in large numbers in the last 10 years.

In figure 2a, the data shown in figure 1 are plotted in a different way to shed more light on the trend. The break in the data corresponding to the flat segment in figure 1 occurred sometime in the mid 1990's, but we don't know when exactly. What really matters is that the data of the 1990's have different trends than the data of the 1970's and 1980's. To illustrate the point, we arbitrarily break the data of GDP per capita in 1992. We plot real GDP per working-age population (15-65) years.

The trends over the two sub-samples, 1970-1980's and 1990's, are estimated separately. Prescott's 2 percent trend line is the benchmark. The solid thin line denotes a 2 percent trend growth. Actual GDP per capita is drawn as a solid thick line. At this point we also don't know what type the trend is: deterministic or stochastic. We compute two trends. One is a linear deterministic trend, which is a solid very thin line. This is derived from an OLS regression on a constant term and a linear trend. The other, a dotted thin line, is derived from passing GDP per capita through an HP filter with a smoothing parameter equal to 100, which is typically used in annual data. In figure 2a, real GDP per working-age population (15-65) grew at 0.84 percent during the period 1970-1992 and at 2 percent during the period 1993-2001.[9] The changes in the slopes of the lines are plotted in thicker dotted and dashed lines.

Figure 2a: Real GDP per working-age population (15-65) linear and HP trends



[9] The HP filter is only chosen to illustrate the point. It is commonly used in the literature even though it is highly criticised. OECD uses it and a variant of it. As the smoothing parameter increases, the HP trend approaches a linear trend. Also note that in figure 2, the HP trend seems different from the linear deterministic trend over the 1970's and 1980's, but the two trends are indistinguishable during the 1990's. Differences between filters and the fact that different filters imply different models are beyond the scope of this particular section. I acknowledge the fact that filters have problems of their own. I also acknowledge the fact that de-trending is a rather more serious matter than just passing the data through various filters.

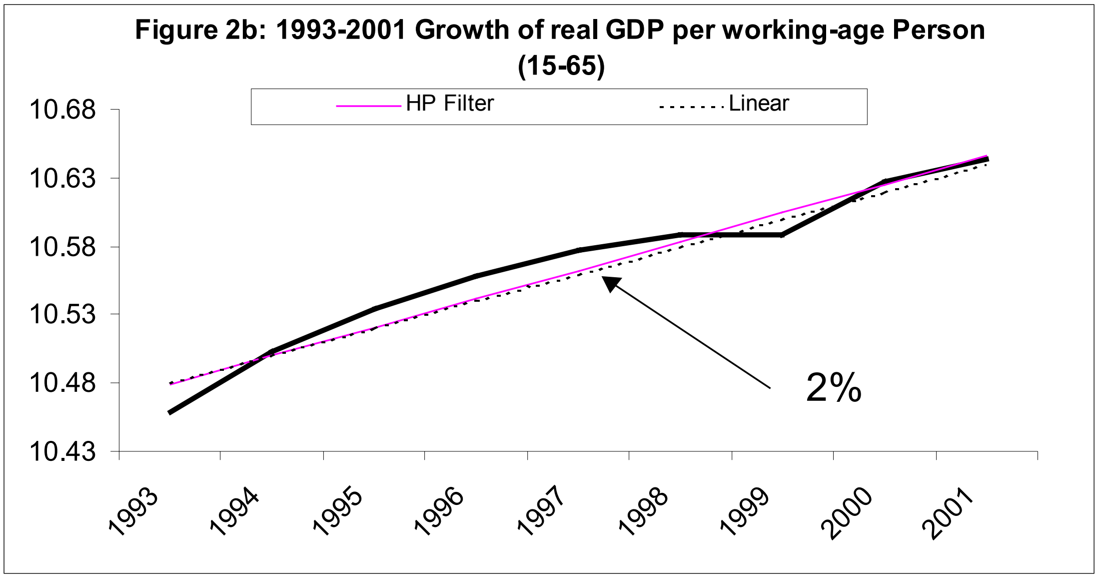


Figure 2b magnifies the period 1993-2001. Real GDP per working-age person (15-65 years) is the solid line, which remained above 2 percent for almost the whole sample period, except for a brief period during the Asian crisis in 1998. Two issues remain unclear. First, what is the exact breakpoint and does it really matter if it is, for example, 1990 or 1993? Second, what is the nature of trend, linear or stochastic, and does it really matter?

Is the slope of the trend line sensitive to starting date?

The answer is yes. It is difficult to detect structural breaks in time series data. The trend is sensitive to endpoints. Prescott plots the deviation of GDP per capita from 2 percent, which has flattened out in the1990's, not in 1984. Ex-post, we know that the reforms started in 1984, but they were sequential and stretched out until 1991, when the Employment Contracts Act was passed. The economy also underwent an adjustment process that lasted a few years. We are not sure of the precise length of this adjustment period.[10] But, 1984 could not possibly be the breakpoint.

Diewert and Lawrence (1999) tested for structural break around the time of the reforms, but acknowledged that the reforms have been ongoing. They suggested several breakpoints. They arbitrarily decided (maybe by visual inspection of data) to cut the data in four places: 1972-1982, 1982-1984, 1984-1993 and 1993-1998. They used linear spline method for testing changes in the growth rates. They ran regressions of the log of GDP per capita on time trend (starting at zero in the first year) and introducing an additional trend (spline), which starts from a value of one the year after the change is thought to have taken place. They found the break in 1982 and 1984 to be significant and possibly also in 1993. However, the trend they used in the test is a linear deterministic trend. The remaining question is whether it makes a significant difference if the trend is not deterministic and whether the breakpoint is 1991 and not 1993?

[10] In the IMF Country Report (2002), Kochhar et al. use a sample from 1988. They call the period the "post-reform". While it is correct that this sample represents the post-reform period it includes the adjustment period. The authors do not account for structural breaks.

Stochastic versus deterministic trend

Is the trend stochastic or deterministic? Tests for unit root like the ADF test, the Philips-Perron test and tests like Elliot (1999) and Perron (1997) are commonly used to test for unit root. These tests do not reject the hypothesis that there is a unit root in GDP per capita measured as real GDP per working-age population (15-65 years) for the period 1970-2001 so the trend is most probably stochastic. But these tests have problems of their own such as lack of power to distinguish the types of trend and they are sensitive to sample size, the number of lags, and whether the data have structural breaks or not. For this reason, Perron (1997) procedure is used to test for unit root with an endogenous unknown breakpoint.[11] Also, this test could not reject the null hypothesis that GDP per capita has a unit root, i.e., the trend is probably stochastic.

To test for the nature of the trend and the breakpoint we will estimate a deterministic and a stochastic trend using methods appropriate for each type and over different sub-samples. We will then report a vector of estimates over different sub-samples.[12] Table 1 reports estimates of the trend (linear deterministic and stochastic) for five sub-samples. There are five columns in table 1. The first column lists the sub-samples over which the trend is estimated. The sub-samples represent four breakpoints. These are: 1970-1990 / 1991-2001; 1970-1991 / 1992-2001; 1970-1992 / 1993-2001; 1970-1993 / 1994-2001 and 1970-1994 / 1995-2001 respectively. One could not make the sub-sample shorter, e.g., 1996-2001, because it would be difficult to estimate the trends. A shorter sample makes the estimates imprecise. The second and third columns list the OLS estimates of the slope of the linear trend with the corresponding P values. However, the second column is for log real GDP per working-age population (15 +), and the third column is for log real GDP per working-age population (15-65 years).

The linear trends are estimated by regressing log GDP per working-age population for the whole sample from 1970-2001 on two dummies and two linear trends, D1 and D2 and trends T1 and T2 respectively. The dummies represent two intercepts for the two sub-samples. The trends take a value of 1-N and zero otherwise for each sub-sample. For example, T1 takes a value of 1, 2, 3 and up to N from 1970 to 1990 and then zero from 1991-2001. T2 takes a value of 0 from 1970 to 1990 and then 1, 2, 3 to N from 1991-2001.

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[11] Perron (1997) is a test for unit root with endogenous time break. This test is coded in RATS (Alan Taylor). Several models were estimated: Innovation outlier with a change in the intercept model; innovation outlier with a change in the intercept and in the slope model; and additive outlier with a change in the slope only, where both segments of the trend function are joined at the time break. Three methods are used to choose the optimal break date.

[12] It is not possible to visually identify the nature of the trend in GDP per capita. A linear deterministic trend and a stochastic trend would be indistinguishable. Trend is said to be stochastic because it is variable rather than constant. If GDP has a stochastic trend then its mean and its variance are functions of time. If trend is deterministic then it can be removed from GDP by simply taking out linear deterministic trend. The de-trended GDP series is called "trend-stationary" whose forecast error variance is finite and converges to a constant as time goes by. If trend is identified as being stochastic then its removal, which is usually accomplished by differencing the data, renders GDP stationary. The de-trended GDP is called "difference-stationary" in this case. The forecast error variance of a variable that has a stochastic trend is infinite and does not converge to a constant as time goes by. If the variable GDP has a unit root then its trend is stochastic.

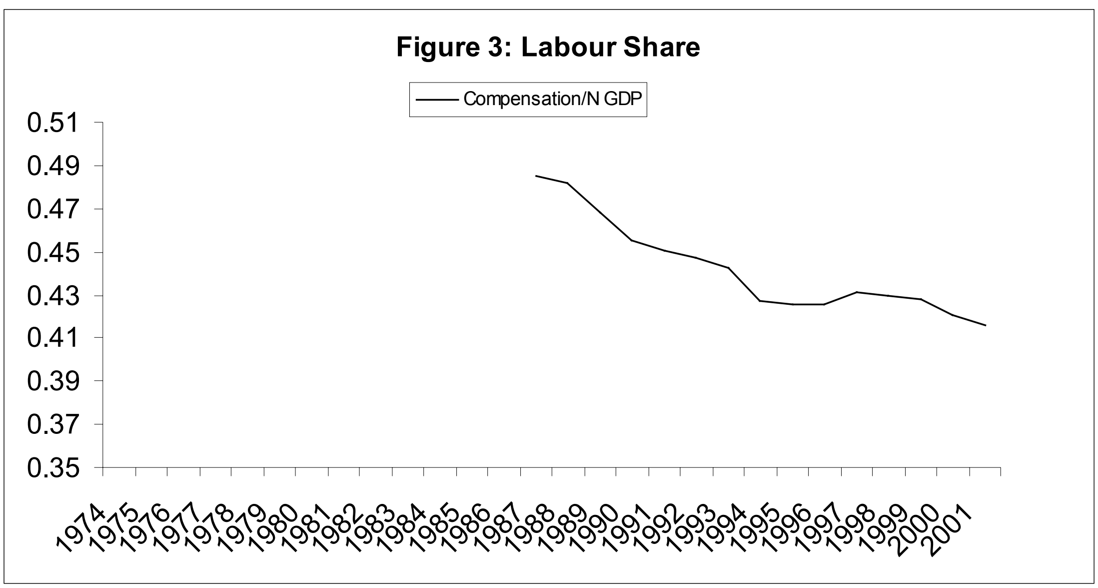
The second set of regressions reported in columns four and five are OLS regressions of the *first difference* of the log of real GDP per working-age population on constant terms, which are the estimates of the mean and in this case the estimates of the trend growth. The regression assumes that GDP per capita is I (1) and the trend is stochastic, Schmidt and Phillips (1992).

There are three results in table 1. First, no matter where we break the sample in the 1990's, GDP per capita trend growth is much higher in the 1990's than in the 1970's and 1980's. Trend growth over the 1990's varies between a minimum of 1.17 percent and a maximum of 2.3 percent depending on when we break the sample. Second, GDP per capita measured as log real GDP per working-age population (15-65 years) grows faster than GDP per capita measured as log real GDP per working-age population (15+). Third, there is a reasonable indication that the break occurred in 1992/1993, where the slope is approximately 2 percent, which coincides with the flat segment in Prescott's figure 1.

This evidence casts sufficient doubt on the claims that New Zealand's GDP per capita trend growth is poor. These estimates presented above are significantly higher than what has been reported in the literature.

3. Typical indicators of factors productivity

In the absence of any econometric estimate of the input shares, economists typically examine the ratio of compensations to employee to nominal GDP from the national income account as a measure of the share of labour. Figure 3 plots the data, which are available from 1987.[13]

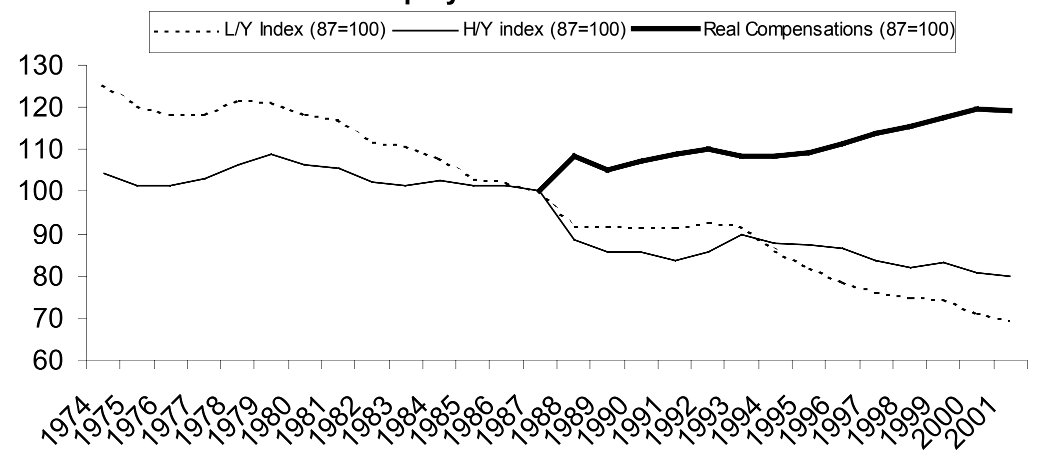


[13] The data do not include self-paid employees. Therefore, it understates the increases in labour productivity.

Figure 3 shows that the share of labour seems to have been falling over time. It was about 0.5 in the mid 1980's then started to drop. It could be anywhere between 0.45 and 0.40.

But what causes the share of labour to drop? Figure 4 plots real compensation (real hourly wages) and the ratios of employment to real GDP and hours to real GDP. The data are converted into indices so one can compare. The question is whether the fall in the share of labour over time is explained by labour being relatively more expensive than other factors like capital, or that real output increased by more than hours or by more than employment?

Figure 4: Real Compensations, Hours/GDP and Employment /GDP Indexes



During the 1990's, compensations rose only slightly while both (labour – output) L/Y and (hours work – output) H/Y trended downward, which seem to suggest a slight increase in labour productivity. Neither visual inspection of the data nor any statistical test can help us explain whether real wages cause the share of labour to fall, or whether the fall of the share of labour causes higher wages. A rise in wages relative to the rental price of capital implies firms use less labour and more capital in production. Equivalently, one might argue that a decline in the share of labour L/Y and/or H/Y might be indicative of a rise in labour productivity, which implies an increase in the reward of labour, i.e., real wages. The data plotted in figures 3 and 4 support both scenarios and the nature of causality is probably irrelevant.

There is other evidence that might support the increase in productivity. Table 2 reports the labour cost index published by Statistics New Zealand (2002). The index is designed to measure changes in labour cost for a fixed level of labour input. The index is a price index, which is controlled for changes in "quality" among other things like price changes and pay changes. In principle, only changes in salary and wage rates for the same quantity and quality of work are reflected in the index. Changes in quality that are considered by Statistics New Zealand include: changes in the number of years of service (experience); changes in qualifications; changes in the performances; changes in the amount of work completed or hours; changes in allowances or penal rates; and changes in persons doing the same job. Loosely speaking, one can interpret *some* of these changes in quality as *approximately* "productivity"; thus the difference between the adjusted and the unadjusted index for quality. The data are available from September 1998. On average, the quality differential is 2 percent per annum during the 1990's. Some of this differential is due to quality changes.

Let us now examine the data that economists typically use to measure the share of capital, which is the ratio of gross operating surplus – nominal GDP ratio. Data are shown in figure 5. The ratio seems to trend up, reaching nearly 0.45 in 2001. So what makes the share of capital rise? Do firms substitute more capital for labour in production if capital is relatively cheaper than labour, or do firms pay less rental capital when capital productivity falls? The real interest rate might be used as *a proxy* for the user cost of capital or the rental price of capital. The evidence suggests that the real interest rate drifted downward since the second quarter of 1988. Also, Plantier and Scrimgeour (2002) show that the neutral real interest rate fell since 1988.

Figure 5: Gross operating surplus / nominal GDP

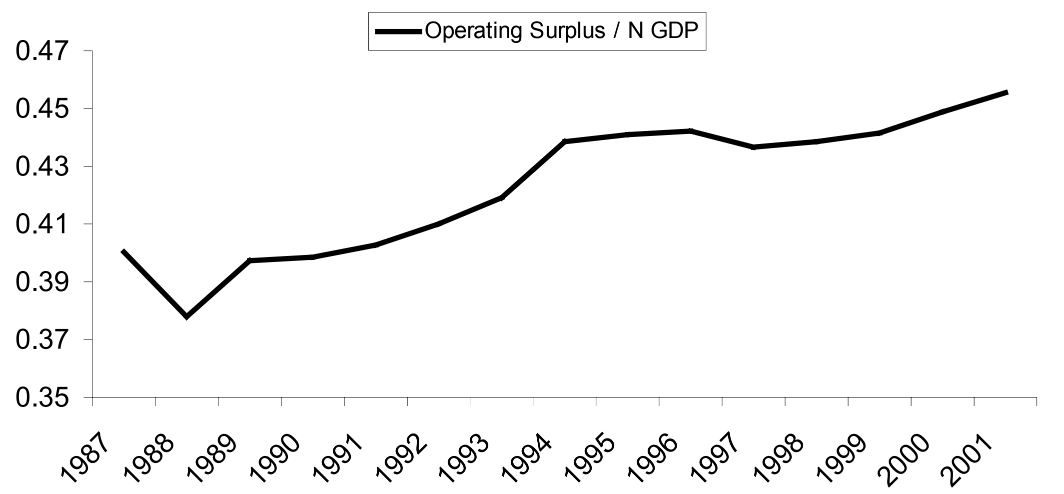


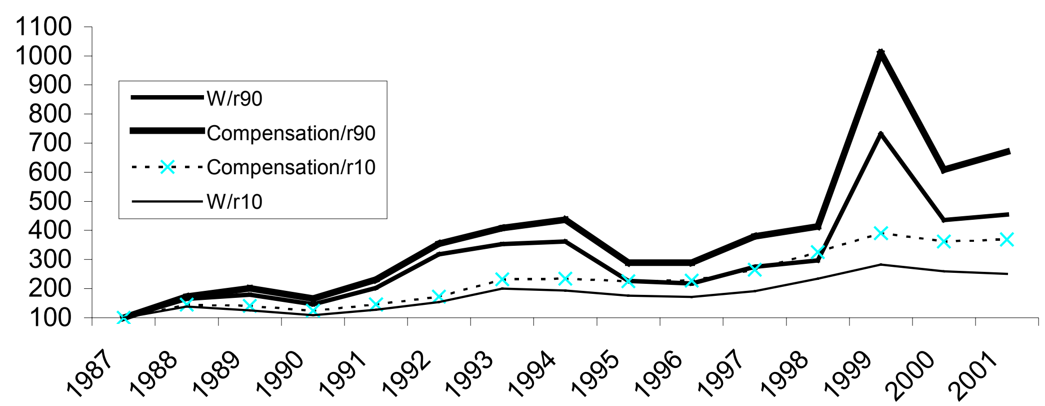
Figure 6 plots the ratios of the real wage – real 90 day interest rate, real wage – real 10 year interest rate, compensations to employees – real 90 day interest rate and compensations to employees – real 10 year real interest rate as proxies for the relative price of labour. Note that the relative price w/r has been trending upwards.[14] This plot implies that real wage increased by more than the interest rate. Thus, firms should substitute capital for labour, the share of capital rises and the share of labour falls.

Consider this alternative scenario: capital deepening implies firms accumulated more capital, the share of capital increased during the 1990's, and the returns to capital measured by the real interest rate (not the cost of capital) has fallen. Again, we need to know the direction of causality. Diewert and Lawrence (1999) suggest that the decline in the marginal productivity of capital is due to capital intensity and that diminishing marginal returns set in more rapidly.[15] The IMF Country Report (2002)

[14] Real interest rate is the nominal interest rate minus expected inflation measured by the Reserve Bank of New Zealand survey of inflation expectations that measure one year a head expected inflation. The real wage is average hourly wages divided by the CPI index.
[15] This is consistent with faster convergence.

argues that New Zealand experienced lower capital deepening than Australia during the period 1988-1999.

Figure 6: Relative Prices Index (1987=100)



4. What about TFP?

In this section we will compute TFP for New Zealand and show that it is an unreliable measure of New Zealand's productivity. Studies that include 1970's and 1980's in the sample could have underestimated TFP growth because, regardless of the model, factor shares may not be regime or policy-invariant. In other words, they are unstable over time.[16] The evidence will also suggest that TFP is not a reliable measure for New Zealand's productivity because – even when we account for structural break – the estimates of the standard errors of factor shares are quite large, which affect the measured TFP. Also, the estimates of factor shares that we are reporting in this section, particularly the share of capital, are inconsistent with the indicators presented in the previous section, i.e., operating surplus / GDP ratio.

Many researchers studied growth performance in New Zealand. Diewert and Lawrence (1999) rightly point out the fact that the New Zealand's economy passed through different regimes from 1970 to-date. Conway and Hunt (1998) also discuss a shift in TFP.

Two ways to compute TFP are presented. First, we estimate a Solow model and use the residuals. Second, we estimate a production function and use the estimated shares to compute TFP. We resort to *estimation* rather than *calibration* because the maintained hypothesis is that the shares have changed over time and the change in the shares alters the estimates of TFP. Particularly, we estimate the Solow model using time series for the period 1986-2001. Because the sample is too short, the estimates of the shares over two sub-samples are not reliable. We try two remedies. First, we provide a recursive estimate of the share and its standard error. Second, we estimate

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[16] Some researchers might argue that the coefficients can remain stable, but the distributions of shocks change over time. In this case, the Lucas critique is not the issue. It is hard to have a definite answer on this claim.

the Cobb-Douglas production function using *panel* data that consists of seven industries or sectors over the period 1985-2000.

The Solow model

The model is fully described in any textbook. The steady-state equation is give by:

$$\ln\frac{Y_t}{L_t} = \ln A_0 + gt + \frac{\theta}{1-\theta}\ln(S/Y)_t - \frac{\theta}{1-\theta}\ln(n+g+\delta) \quad (1)$$

Output Y_t is measured by real GDP, labour L_t is measured by working-age population (15-65 years), S_t is savings, which is typically substituted for by gross investment, population growth is a constant given by n, g is growth rate of technology, which is also constant, and δ is the depreciation rate. A is the level or the stock of technology, which is exogenous.[17]

The equation implies that saving and population growth (adjusted for depreciation and technological progress growth) have similar impact on GDP per capita with the opposite signs. Essentially, the model says real income is higher in countries with higher saving rates and lower in countries with high population. $\ln A_0$ is a constant plus a random error, which reflects exogenous technology, resource endowment, institutions etc. Equation (1) is typically estimated using OLS in the following log form:

$$\ln(Y/AL)_t = b_0 + b_1 t + b_2\ln(I/Y)_t + b_3\ln(n)_t + \xi_t \quad (2)$$

Where, $b_2 = \frac{\theta}{1-\theta}$, and $b_3 = \frac{\theta}{1-\theta}$ where the b's are elasticities. Gross investment is used to proxy savings. The residuals are the so-called Solow residuals. The coefficient b_0 includes all constant terms.

Solow predicts that the *elasticities* of saving and population with respect to output, b_2 and b_3 have the same magnitudes but opposite signs. The implied share of capital,

[17] The model is a simple general equilibrium model that combines a neoclassical production function with the assumption of a constant saving rate. The production function is Cobb-Douglas with constant returns to scale. The assumption is that both technology and population grow at constant rates g and n respectively and that the number of effective units of labour is A_tL_t, which grows at a rate $n+g$. The Solow model assumes a fraction of output, $s = S/Y$ is saved and invested I/Y. In the closed economy, saving is equal to investment. The capital per effective unit of labour is $k = K/AL$ and y is the level of output per effective unit of labour Y/AL. The capital-labour ratio evolves according to $\dot{k}_t = sy_t - (n+g-\delta)k_t$ or $\dot{k}_t = s(k_t)^\theta - (n+g-\delta)k_t$, where the depreciation rate is a constant equal δ. The above dynamic equation implies that capital, k_t, grows and converges to a steady-state number say k^*, which is given by $sk^{*\theta} = (n+g-\delta)k^*$ or $k^* = [s/(n+g-\delta)]^{1/1-\beta}$. Clearly, θ is an important coefficient for the evolution of capital and for determination of its value in the steady state. It will also influence the calculation of TFP.

θ, can be computed if we estimate b_2 as $b_2 = \dfrac{\theta}{1-\theta}$.[18] Solow suggested that the elasticities above have a value of 0.5 based on the assumption that the share of capital in GDP is approximately 0.30, which is approximately what the New Zealand Treasury and the Reserve Bank of New Zealand assume. Before we test that investment-output ratio (as a proxy for savings-output or capital-output ratios) has a unit root over the period 1970-2001, I plot the main variables in the Solow model in figures 7, 8 and 9. The data are annual.

There are a few estimation problems with equation (2). First, the data might be integrated, in which case OLS is inappropriate for inference. Second, saving or investment is not exogenous, in which case OLS suffers a single-equation bias. Third, savings (investments) might be measured with error leading to biased estimates of the elasticities. Fourth, the capital share is not regime-and policy-independent; it changes over time. There might be some temporal aggregation problems too.

We used different tests to test for unit root, starting with the commonly used tests, the ADF, the Phillips-Perron and then the newer ones, Elliott's (1999) and Perron (1997). These tests could not reject the null hypothesis that GDP per working-age population (15-65 years) and log population growth have unit roots, but the Elliot's test rejected it for the investment-GDP ratio. Note that the investment-output ratio is rather constant.

Given all these problems, two methods are used. First, we estimate the Solow model using the FM-OLS (Fully Modified OLS) of Phillips and Hansen (1990). This method is appropriate to deal with integrated data, serial correlation in the residuals, and the endogeneity of the regressors.[19]

The results are reported in table 3. There are two panels in table 3. In the first panel, GDP per capita is measured as log real GDP per working-age population (15+). In the second panel, GDP per capita is measured as log real GDP per working-age population (15-65 years). Log investments-GDP ratio and log population growth are the typical explanatory variables in the Solow model. Investment is a proxy for savings.[20]

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[18] The factor shares are equal to the marginal products of capital and labour under the assumption of perfect competitions.

[19] The general format is given by this regression:

$$y_t = b'x_t + \sum_{i=-p}^{p} \delta_i \Delta x_{t+i} + v_t \ .$$

The vector x includes the log of investment – GDP ratio, log population growth, a constant term and trend. In this method we used one lag and one lead because the sample is small and we wanted to avoid overfitting. To modify the statistics and to conduct inference, we used the Newey – West method. In general, let: $v_t = \phi(L)\varepsilon_t$ and $E(\varepsilon_t'\varepsilon_t) = \sigma^2$. Define λ as a modifier and it is estimated as follows,

$$\lambda^2 = c_0 + 2\sum_{i=1}^{k}(1-\frac{i}{k+1})c_i \text{ , where } c_i = T^{-1}\sum_{t=i+1}^{T} v_t v_{t-i} \ .$$

[20] This is a strong assumption for an open economy like New Zealand.

Figure 7: ln Real GDP per working age population

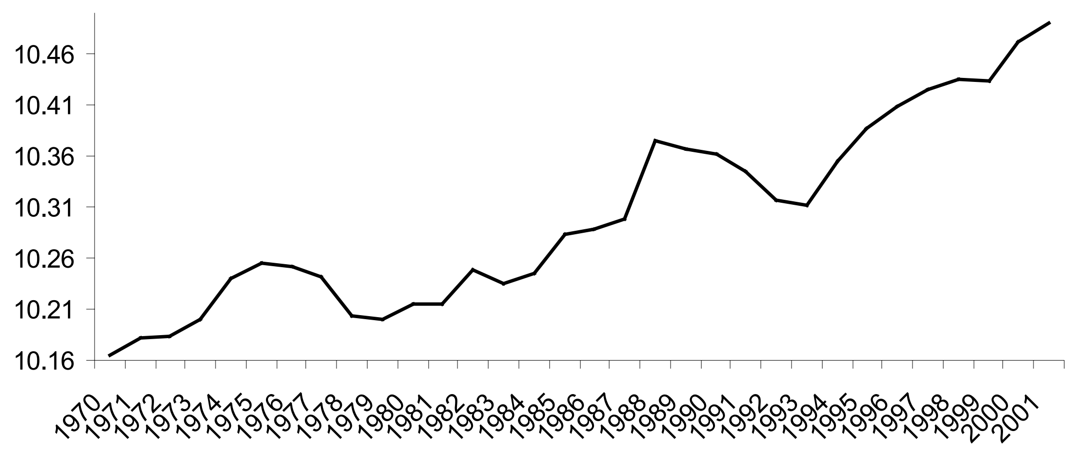


Figure 8: ln Real total investment / GDP ratio

Figure 9: Population Growth

The elasticity of investment-GDP ratio with respect to output-per capita for the full sample from 1970-2001 is 0.43, which is not significantly different from 0.5, the value that the Solow model predicts. The implied share of capital, θ, is 0.30. The elasticity of population growth with respect to GDP per capita is significantly different from -0.5. It is -0.12, has the correct sign and is only marginally significantly different from zero. This is consistent with empirical findings in the literature. Population growth does not seem to be highly correlated with output growth. Similar estimates are obtained when we measure GDP per capita using working-age population (15-65 years). These results are shown in the lower panel of table 3.

Then, we re-estimate the model over two sub-samples, 1970-1992 and 1993-2001. Note how the magnitude of the elasticity changes significantly in the second sub-sample. The estimated capital shares are approximately 0.08 and 0.10 in the two regressions described above respectively. However, the estimates are also statistically insignificant (the standard error is approximately 0.45). It is difficult to use FM-OLS to estimate the Solow model over sub-samples, where there are fewer observations.

The second method of estimation aims at resolving the small sample problem and maintain the interest in a time-varying coefficient estimates. We allow for recursive estimates of the coefficients and use all available observations from 1970's to 2001.[21] TFP in this model are assumed to be a random walk with a drift.

$$\ln(Y/L)_t = b_0 + b_{2t}\ln(I/Y)_t + b_{3t}\ln(n)_t + \xi_t \quad (3)$$

$$b_{2t} = b_{2t-1} \quad (4)$$

$$b_{3t} = b_{3t-1} \quad (5)$$

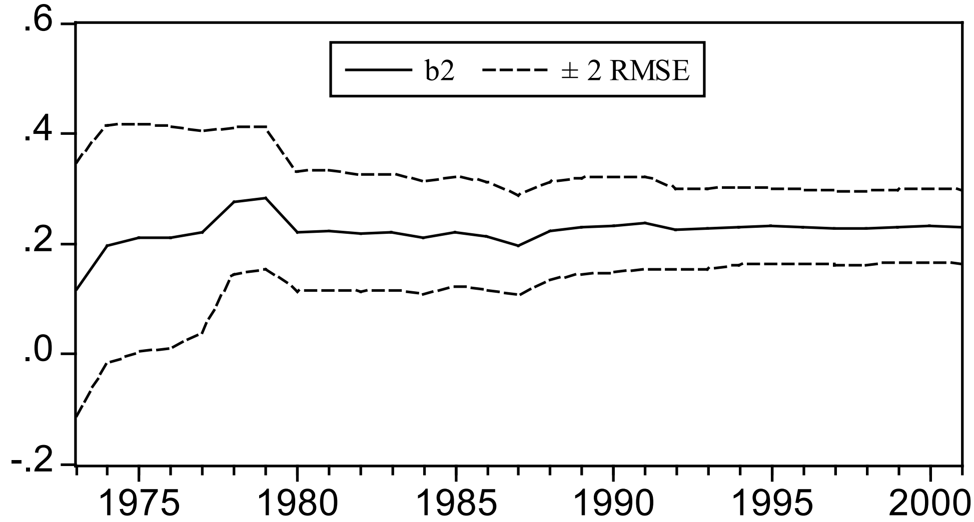
$$\zeta_t = \alpha + \rho\zeta_{t-1} + v_t \quad (6)$$

The model is estimated using the maximum likelihood method. The results are reported in table 4 and the estimated coefficient b_{2t} is plotted in figure 10.

The estimate of the standard error suggests that the elasticity was anywhere between 0.4 and –0.1 and somewhere between 0.3 and 0.1 over the 1980's and 1990's respectively. Thus, the share of capital θ is somewhere between 0.2 and 0.1 (recall that $b_2 = \theta/1-\theta$). If the Solow model is the correct model and if the assumption of constant returns to scale holds, the share of labour is larger than what the New Zealand Treasury and the Reserve Bank of New Zealand use, i.e., larger than 0.65. This is again inconsistent with the ratio of compensations to employee / GDP ratio presented earlier.

[21] A state-space model could not be estimated. The sample is small and too many coefficients needed to be estimated. The Maximum Likelihood convergence was difficult.

Figure 10: State Estimate of b2



Panel estimation

Another way to estimate factor shares is to estimate a Cobb-Douglas production function using panel data. The panel might help us overcome the small sample problem that is affecting the standard errors in the second sub-sample, 1993-2001. Real GDP and employment are from Statistics New Zealand. Capital stock is from Johnson (2001), which is based on the Perpetual Inventory method. The data cover seven sectors (N=7), agriculture, fishery, forestry, food processing, manufacturing, energy (water, electricity and gas) and building and construction. The sample is from 1962-2000 (T=39). We stack the data in the same order mentioned above. The variables real GDP, capital stock and labour are in log. The model is a fixed effect model.

The general model is give by a log – linear Cobb-Douglas production function:

$$Y_{it} = X'_{it}\gamma + \varepsilon_{it} \qquad (7)$$

The X_{it} vector contains capital stock and employment (K_{it}, L_{it}).

The first component η_i is constant over time, but varies across sectors. The second component u_{it} is an idiosyncratic term that varies across time and across sectors. The model has a few potential problems. First, OLS estimates of γ will be biased and inconsistent if X_{it} is not strictly exogenous. The decision to install capital or to hire labour is endogenous to the firm, i.e., single-equation bias. However, the aggregate capital stock of the industry or the country might be exogenous to the firm. Second, if the $\text{cov}(\eta_i, X_{it}) \neq 0$, OLS estimator of γ is also biased. Third, the errors might be heteroscedastic. Fourth, the time series are most probably integrated of order (1), which may cause inference problems. Fifth, the errors may be correlated across sectors.

Unfortunately, we cannot provide remedies for all of these problems. The existence of unit roots in the data is a problem. We use the standard and common unit root tests (e.g., the ADF, the Phillips-Perron, Elliott (1999) and Perron (1997) unit root test with endogenous break). The ADF test for unit roots still cannot reject the unit root hypothesis in the time series. However, the unit root problem is resolvable in *fixed effects* models because the model requires de-meaning the data and that is asymptotically equivalent to first differencing. In the fixed effect model, the error term is decomposed into two parts:

$$\varepsilon_{it} = \eta_i + u_{it} \qquad (8)$$

And the group mean is subtracted from each variable in equation (7). This new data are also tested for unit roots using the same tests mentioned earlier and it seems that the hypothesis of unit roots can be rejected. Cointegration is even more problematic when the time series is short and the cross section is small. We don't attempt to test this proposition.

For heteroscedasticity and autocorrelation, we use the Newey-West procedure to estimate a consistent variance-covariance matrix. To deal with the endogeneity problem, we use instruments and the method of estimation is the Generalised Method of Moments (GMM). The optimal instrument has to be highly correlated with the regressors, but uncorrelated with the errors. The instrument has to be relevant too. It is hard to find optimal instruments. In this paper we use three lags of the regressors as instruments.

The estimates of capital and labour shares over three periods, 1962-2000, and the two sub-samples, 1962-1992 and 1993-2000, are reported in table 5. The estimate of the share of capital is 0.71 for the whole sample from 1962-2000 and highly significant. This estimate is higher than the time series estimate reported earlier. It is also higher than the time series estimates reported by Diewert and Lawrence (1999) and much higher than the ratio of operating surplus to GDP plotted in figure 5. As a matter of fact, it is twice as large as the share of capital used in the Reserve Bank and the New Zealand Treasury models. The estimated standard error is 0.057. The estimated 95 percent confidence interval is [0.60-0.83].

In the sub-sample from 1962-1992, the share of capital is estimated to be 0.60 with a standard error of 0.084, and a 95 percent confidence interval [0.43-0.76]. These are quite large intervals and the estimates are not very precise. The post-reform period, 1993-2000 provides a much smaller estimate of the share of capital, 0.29 with a standard deviation of 0.11 and a 95 percent confidence interval [0.07-0.52]. These results are consistent with the time series results. They indicate that the share of capital must have fallen in the late 1990's. The results, however, are inconsistent with the path of the operating surplus – GDP ratio. They suggest that the share of capital has changed over time and that the estimates are unreliable. The share of capital and the share of labour sum to unity in the full sample and in the second sub-sample, but the hypothesis of constant returns to scale is rejected in the first sub-sample from 1962-1992.

The share of labour is estimated to be 0.39 in the whole sample, with a standard error of 0.15 and a 95 percent confidence interval [0.10-0.69]. The estimate of the labour share during the period 1962-1992 is 0.82, with a larger standard error, 0.19 and a 95 percent confidence interval [0.44-1.19]. The estimate of the labour share falls only slightly, to 0.67 during the period 1993-2000 with a 95 percent confidence interval [-0.03 –1.38]. This estimate is pretty close to what the Reserve Bank of New Zealand and the New Zealand Treasury use, 0.65. Also, the fact that the share of labour falls over time seems consistent with the ratio of total compensations to GDP plotted in figure 3.

The uncertainty around the estimates of the factor shares will eventually translate into uncertainty about TFP. Given a few values of the time series estimates, a distribution of TFP growth can be computed. Table 6 has four panels, two on each side. The panels are identically designed. Panels on the LHS are for real GDP per working-age population (15+) denoted $\dot{y}$. Panels on the RHS of table 6 are for real GDP per working-age population (15-65 years) denoted $\hat{\dot{y}}$. The upper panels are reserved for linear deterministic trend and the lower panels are for stochastic trends.

Each panel has six columns. The first column lists the samples. The first is the full sample from 1970-2001 followed by the first sub-sample from 1970-1992 and the second sub-sample from 1993-2001. The second column reports the trend of GDP per capita, followed by the estimated capital shares θ. Columns three, four and five include the trend growth rates of investment, real GDP and TFP. TFP is computed as $\dot{y} - \theta(\dot{I} - \dot{Y})$. I choose different values for the share of capital to check the sensitivity of the results. The results suggest that TFP could vary between 0.80 and 1.96. These estimates of TFP reflect the uncertainty about the estimates of the trend and factor shares. TFP is an unreliable measure of New Zealand's productivity.

TFP and spillovers

TFP is also unreliable if the production exhibits increasing returns to scale while it is assumed not. Suppose that the production process for the *ith* firm is given by the Cobb-Douglas function, Barro (1999, p 125).

$$Y_{it} = A K_{it}^{\alpha} K_t^{\beta} L_{it}^{\gamma} \,, \qquad (9)$$

where $0 < \alpha < 1$, $0 < \gamma < 1$ and $\alpha + \gamma$ may sum to one. The production function is an "increasing returns to scale" or "evidence of spillovers" if $\beta \geq 0$.

Romer (1986) is a learning-by-doing model, where efficiency of production rises with cumulated experience. Knowledge spills over immediately from one firm to another and raises firm i's productivity. In the Romer model, each firm behaves competitively and takes the economy-wide input prices as given. Physical capital by industry or firm and aggregate capital are used to measure K_{it} and K_t respectively.

Using growth accounting, typically, researchers assume aggregate Cobb-Douglas production functions to compute TFP growth, where $\beta = 0$. Thus, the share of capital is understated if $\beta > 0$.

In this paper we test one case of spillovers only. We test if $\beta = 0$ using data for sectoral capital stock, so K_{it} is the sectoral physical capital stock, L_{it} is sectoral employment and K_t is the aggregate capital stock.[22] The same estimation methodology that we used to estimate the panel data earlier is used to estimate the log-linear version of equation (9). There is a significant spillover from the sectoral level to the aggregate economy-wide capital stock. Thus, ignoring that and assuming β is zero while in fact β is positive implies understating the share of capital. Aggregating equation (9) under certain assumption, TFP is given by Barro (1999, p. 126):

$$TFP = \dot{y}_t - (\alpha + \beta)\dot{K}_t - \gamma \dot{L}_t \qquad (10)$$

Table 7 reports the estimates for spillovers. In the full sample from 1962-2000, β is 0.75. It remains 0.75 in the sample from 1962-1992, but it becomes insignificant in the sample from 1993-2000. The production function is a constant return to scale in the private inputs. The hypothesis that $\alpha + \gamma = 1$ could not be rejected. The share of capita is 0.15 in the sub-sample from 1962-1992, and it increases to 0.30 in the second sub-sample. Thus, the contribution of capital is approximately 0.50. This is the only empirical result that is consistent with the path of operating surplus – GDP ratio. However, the standard error is still large and the 95 percent confidence interval is [0.06-0.53].

Convergence

Finally, we compare New Zealand's performance with that of Australia. The literature on convergence is large and we don't intend to discuss it here. However, we believe that convergence in the means of GDP per capita is misleading. Milton Friedman (1992) explains why. Friedman reminds us of the Hotelling (1933) review of "The triumph of mediocrity in business." Instead of the mean, the correct test for convergence is in the coefficient of variation. We compute the means and the standard deviations of real GDP per working-age population for both countries over two sub-samples, 1970-1992 and 1993-2001. New Zealand's productivity was low, 0.7 percent, while Australia's was 2.91 percent. During the period 1970 to 1992, the standard deviations for New Zealand and Australia's GDP per working-age population growth rates are 2.51 and 1.97 respectively.[23]Average productivity is

[22] Griliches (1979), K_{it} represents firm i's specific knowledge capital, and K_t is the sum of K_{it}, which is the aggregate level of knowledge in an industry. Therefore, the spillovers represent the diffusion of knowledge across firms. Many have suggested that researchers in firms across industries share knowledge via, for example, seminars, joint research and workshops. In Lucas (1988), K_{it} represents the firm's employment of human capital and K_t is the average level of human capital in an industry or in a country. Romer, on the other hand, assumes that K_{it} is firm i's capital and K_t is the aggregate economy-wide physical capital.

[23] Working-age population is 15-65 years.

clearly lower in New Zealand than in Australia. We test the hypothesis that the variances are equal against the alternative hypothesis that New Zealand's variance is larger. The $F_{23,23}$ value is 1.62 and less than the 5 percent critical value, which is approximately 2.01, thus the hypothesis that variances are equal cannot be rejected.

During the period 1993 to 2001, New Zealand's productivity averaged 2 percent. Australia's productivity averaged 3.87 percent. The standard deviations declined to 1.65 and 0.86 for New Zealand and Australia respectively. But the variance for New Zealand is slightly statistically larger than its Australian counterpart. The $F_{8,8}$ statistic is 3.68, which is only marginally less than the 5 percent critical value of 3.44.

The coefficient of variation defined as the standard variation divided by the mean suggests that New Zealand and Australia had different productivity growth rates during the period 1970-1992, 3.39 and 0.67 for New Zealand and Australia respectively. However, New Zealand's productivity seems to be converging to Australia's productivity during the period 1993-2001 with a coefficient of variation 0.86 for New Zealand and 0.22 for Australia. If we use a sample from 1970-1993 and 1994-2001 the statistics imply even more convergence in the variance. Statistics are reported in table 8. The evidence on convergence is consistent with the fall of the capital share, higher productivity in the 1990's and Statistics New Zealand's quality index.

5. Summary, conclusions and future research

Productivity is an unobservable variable that we measure or estimate with errors. These errors are large in the case of New Zealand. TFP can also be misleading because the estimates of factor shares either from the Solow model or from production functions are unreliable. The estimated standard errors of factor shares in New Zealand are quite large.

The primary objectives of this paper were: first, account for structural break in the data that represent regime and policy change, which we believed to have been ignored by researchers when they computed New Zealand's productivity performance. Second, although it is difficult, researchers should attempt to identify the nature of the trend on real GDP per capita. Stochastic trend requires a different method of estimation. Third, we tested for increasing returns to scale because TFP would be understated if researchers assume constant returns to scale while the production function exhibits increasing returns to scale.

This paper showed that productivity based on the growth rate of real GDP per working-age population might be, at least, one percentage point higher than any other estimate if one accounts for structural change and estimates the trend properly. We argued that the choice of the sample is crucial for answering the question regarding New Zealand's productivity because the data have a structural break. Neglecting such a structural change understates productivity by as much as 1 percent. Our estimate suggests that log real GDP per working-age population (15-65 years) trend growth is 0.8 percent per annum over the period 1970-2001. OECD reported that trend growth rate is 0.7 percent from 1990-1998. However, accounting for a structural change and transitional period in 1984-1992, yields an estimate of trend growth greater than 2 percent depending on the nature of the trend and on the way it is estimated. It is argued that the reforms started in 1984, but because they were sequential they stretched out until 1991 when the Employment Contracts Act was passed and the adjustment was near complete. Thus, we argue that the period 1992/1993-2001 is significantly different from 1970-1991 and researchers should not include the period prior to 1990 in the sample. The recent *Economist* of January 4, 2003 (p. 76) reported that New Zealand's GDP per capita average growth during the period 1998-2002 is 2 percent.

TFP growth is an unreliable measure of productivity because it could be anywhere between 0.80 to 2 percent depending on the magnitude of the share of capital and, of course, the sample size. Capital share is not regime-or policy-invariant. A change in the tax system or labour market might induce changes. For example, workers in an industry may, as the result of changes in labour law, get a claim to some of the return on physical capital. Growth accounting, which basically calibrates the Solow model to a particular fixed capital share of 0.35, yields misleading estimates of TFP growth. Our estimates of factor shares had very large standard errors and this uncertainty translated into uncertainty about TFP.

TFP estimates can be misleading. It is quite possible to have a low TFP coupled with a good economic performance if investments are sufficiently large. Also, measured productivity can be low or even be negative meanwhile technological progress is significant, capital and labour contributing to higher GDP per capita.

Young's (1992) tale of two cities compares Hong Kong's with Singapore's growth experiences. The main determinant of growth in Hong Kong has been technological progress. In Singapore, the main determinant has been accumulation of factor inputs, i.e., capital deepening. Investment rates have been high and increasing, but technical progress or TFP growth has been close to zero. Hsieh (2002) shows results of two different ways to compute TFP, primal and dual approaches. He reports a negative primal TFP (e.g., - 0.22 percent) and a positive dual TFP (e.g., 2.16) for Singapore over the period 1969-1990.[24]

Singapore relied on factor accumulation, high investments, tax incentives to foreign investments and more government policy intervention including targeting specific industries. Hong Kong is quite the opposite, with fewer regulations, and relies on the innovations that stem from an entrepreneurial and educated workforce. Singapore started to grow after Hong Kong, but it has now surpassed it. Both policies work.

A general policy recommendation that we draw from the finding of this paper is that New Zealand needs more capitalism, not less. It means that increasing private sector investments is important. Fiscal policy should not scare capital and labour away from New Zealand by over-taxing them. Alesina et al (2002) find very recent evidence of

[24] The dual approach for computing the Solow residuals = $s_k r + s_L w$ where s_k and s_L are factor shares and r and w are factor prices while the primal approach is $\dot{y}_t - \theta(\dot{I}_t - \dot{Y}_t)$, where $\dot{y}_t$ is GDP per capita growth rate, θ is the share of capital, $\dot{I}_t$ is growth rate of investments and $\dot{Y}_t$ is real output growth.

crowding out, taxes adversely affecting profits and government employment creates wage pressure in the private sector.

We conclude that the growth of real GDP per working-age population (15-64) is a more appropriate measure of New Zealand's productivity than TFP. However, when measuring productivity the researcher must take into account the structural break and the nature and the estimation method of trend. New Zealand's productivity is healthier than what has been reported. In addition, there seems to be a significant convergence to Australia's productivity in the variance. We hope that researchers and policymakers take this issue more seriously and build a new consensus regarding New Zealand's productivity.

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Table 1: GDP per capita Trend Growth Estimates

Sub Samples	Linear Trend (OLS)	Linear Trend (OLS)	Stochastic Trend OLS	Stochastic Trend OLS
	Log Y/L	Log $Y/\hat{L}$	Log Y/L	Log $Y/\hat{L}$
1970-1990	0.82 (0.0010)	0.87 (0.0010)	0.97 (0.0736)	1.03 (0.0624)
1991-2001	1.73 (0.0027)	1.83 (0.0028)	1.17 (0.1103)	1.25 (0.0917)
1970-1991	0.83 (0.00009)	0.88 (0.0009)	0.86 (0.1033)	0.91 (0.0875)
1992-2001	1.96 (0.0030)	2.00 (0.0030)	1.44 (0.0618)	1.52 (0.0507)
1970-1992	0.80 (0.0008)	0.84 (0.0009)	0.69 (0.1079)	0.75 (0.1395)
1993-2001	1.97 (0.0037)	2.02 (0.0037)	1.92 (0.0176)	1.99 (0.0149)
1970-1993	0.75 (0.0008)	0.80 (0.0008)	0.63 (0.3000)	0.69 (0.1533)
1994-2001	1.72 (0.0044)	1.85 (0.0045)	2.22 (0.0089)	2.30 (0.0074)
1970-1994	0.75 (0.0001)	0.81 (0.0001)	0.79 (0.1030)	0.85 (0.0849)
1995-2001	1.58 (0.0043)	1.71 (0.0043)	1.91 (0.0363)	2.00 (0.0303)

- Y is real GDP.
- L is working-age population (15 years+).
- $\hat{L}$ is working-age population (15-65 years).
- Linear trend is estimated by regressing log real GDP per working-age population on two dummies representing the two sub-samples with zero-one vales, and two trends.
- Stochastic trend is estimated by first differencing real GDP per working-age population and estimate the constant.
- P values are in parentheses.
- All data are from the Reserve Bank of New Zealand.

Table 2: Labour Cost Index
Salary and Ordinary Time Wage Rates (1998=1000)

Quarter	Adjusted Index	Annual %	Unadjusted Index	Annual %	Difference%
Sep-98	1000		1000		
Dec-98	1003		1006		
Mar-99	1007		1015		
Jun-99	1010		1024		
Sep-99	1015	1.5	1033	3.3	1.8
Dec-99	1018	1.5	1040	3.4	1.9
Mar-00	1022	1.4	1049	3.3	1.9
Jun-00	1027	1.7	1060	3.5	1.8
Sep-00	1030	1.5	1068	3.4	1.9
Dec-00	1034	1.6	1077	3.6	2.0
Mar-01	1040	1.8	1089	3.8	2.0
Jun-01	1045	1.8	1099	3.7	1.9
Sep-01	1051	2.0	1115	4.4	2.4
Dec-01	1057	2.2	1126	4.5	2.3
Average		1.5		3.7	2.2

- Source: Chris Pike, Statistics New Zealand (1996). The papers is updated in (2002).

Table 3: Estimate of the Solow model

$$\ln(Y/L)_t = b_0 + b_1 t + b_2 \ln(I/Y)_t + b_3 \ln n_t + \xi_t ;$$

$$b_2 = \frac{\theta}{1-\theta}$$

Dependent variable: y is log real GDP per working-age population 15+					
Period	b_2	Modified t	b_3	Modified t	Implied share θ
1970-2001	0.43 **A**	8.68* (0.0001)	-0.12	-2.42* (0.0155)	0.30
1970-1992	0.43	7.15* (0.0001)			0.30
1993-2001	0.08	0.1927 (0.8472)			0.074

Dependent variable: y is log real GDP per working-age population (15-65)					
Period	b_2^*	Modified t	b_3^*	Modified t	Implied share θ
1974-2001	0.41 **B**	7.55* (0.0001)	-0.08	-1.43 (0.1508)	0.29
1974-1992	0.44	7.40* (0.0001)			0.30
1993-2001	0.10	0.2260 (0.8211)			0.09

- Total investment is used to proxy savings.
- A: The elasticity is not significantly different from what Solow predicted 0.5. The modified $F_{1,18}$ statistic is 1.46 with a P value 0f 0.2423
- B: The elasticity is not significantly different from what Solow predicted 0.5. The modified $F_{1,18}$ statistic is 2.51 with a P value 0f 0.1262.
- The method of estimation is FMOLS.
- The sample is 1970 – 2001.
- Asterisk means significant at the 5% level.

Table 4: Maximum likelihood estimates of recursive coefficients

$$\ln(Y/L)_t = b_0 + b_{2t}\ln(I/Y)_t + b_{3t}\ln(n)_t + \xi_t \quad (3)$$

$$b_{2t} = b_{2t-1} \quad (4)$$

$$b_{3t} = b_{3t-1} \quad (5)$$

$$\zeta_t = \alpha + \rho\zeta_{t-1} + v_t \quad (6)$$

Coefficient	Final Estimate	P Value
b_0	-7.8	0.0001
b_2	0.20	0.0001
b_3	-0.01	0.1232
α	0.18	0.0001
ρ	0.95	0.0001
Log Likelihood	45.99	
Akaike Information Criteria	-2.77	
Schwarz Information Criteria	-2.73	

Table 5: Panel data estimates of the Cobb-Douglas production function
Fixed effect model

$$\ln Y_{it} = \alpha \ln K_{it} + \gamma \ln L_{it} + \varepsilon_{it}$$

$$\varepsilon_{it} = \eta_i + u_{it}$$

	1962-2000			1962-1992			1993-2000		
	Estimate	t (P-value)	95% CI	Estimate	t (P-value)	95% CI	Estimate	t (P-value)	95% CI
α	0.71	12.40 (0.000)	[0.60-0.80]	0.60	7.16 (0.000)	[0.43-0.76]	0.29	2.60 (0.009)	[0.07-0.52]
γ	0.39	2.67 (0.008)	[0.1-0.69]	0.82	4.31 (0.000)	[0.44-1.19]	0.67	1.88 (0.016)	[-0.03-1.38]
σ	0.22			0.21				0.20	
R^2	0.61			0.58				0.16	
NOB	252			196				56	
J stat	6.64 (0.15630)			17.425 (0.0016)				7.547 (0.1096)	

- Method of estimation is GMM.
- Instruments are: a constant term and 3 lags of the capital stock and 3 lags of employment.
- The correlation between capital stock and employment with their corresponding lagged values are all high and the instruments pass the Shea partial R^2 and (F) test for instrument's adequacy.
- The J test is distributed $\chi^2(4)$.
- The P values are in parentheses.
- The statistics are Heteroscedasticity and autocorrelation-consistent using the Newey-West method.
- The Kernel=Bartlett and the bandwidth is 2.

Table 6: Estimate of TFP

Linear Deterministic Trend OLS Method					
	$\dot{y}$	θ	$\dot{I}$	$\dot{Y}$	*TFP*
70-01	0.92	0.30	2.35	2.27	0.89
70-92	0.79	0.30	1.76	2.15	0.97
93-01	1.97	0.08	5.45	3.20	1.79
Sensitivity analysis using different values of θ					
93-01	1.97	0.05	5.45	3.20	1.85
		0.10			1.74
		0.20			1.52
		0.30			1.29
Stochastic trend OLS method					
	$\dot{y}$	θ	$\dot{I}$	$\dot{Y}$	*TFP*
70-01	1.03	0.30	2.11	2.35	0.90
70-92	0.69	0.30	1.70	2.15	0.82
93-01	1.92	0.08	5.75	3.20	1.71
Sensitivity analysis using different values of θ					
93-01	2.22	0.05	5.75	3.20	1.79
		0.10			1.66
		0.20			1.41
		0.30			1.15

Linear Deterministic Trend OLS Method					
	$\hat{\dot{y}}$	θ	$\dot{I}$	$\dot{Y}$	*TFP*
70-01	0.99	0.29	2.35	2.27	0.96
70-92	0.84	0.30	1.76	2.15	0.95
93-01	2.08	0.10	5.45	3.20	1.85
Sensitivity analysis using different values of θ					
93-01	2.08	0.05	5.45	3.20	1.96
		0.10			-
		0.20			1.63
		0.30			1.40
Stochastic trend OLS method					
	$\hat{\dot{y}}$	θ	$\dot{I}$	$\dot{Y}$	*TFP*
70-01	1.11	0.29	2.11	2.35	0.99
70-92	0.74	0.30	1.70	2.15	0.87
93-01	1.99	0.10	5.75	3.20	1.73
Sensitivity analysis using different values of θ					
93-01	1.99	0.05	5.75	3.20	1.86
		0.10			-
		0.20			1.48
		0.30			1.22

$\dot{y}$ is the trend growth rate of GDP per working-age population (15+).

$\hat{\dot{y}}$ is the trend growth rate of GDP per working-age population (15-65).

θ is the share capital as estimated in table 2.

$\dot{I}$ is the trend growth rate of real total investments.

$\dot{Y}$ is the trend growth rate of real GDP.

Table 7: Increasing Returns to Scale

$\ln Y_{it} = \alpha \ln K_{it} + \gamma \ln L_{it} + \beta \ln K_t + \varepsilon_{it}$, $\varepsilon_{it} = \eta_i + u_{it}$

	1962-2000			1962-1992			1993-2000		
	Estimate	t (P-value)	95% Interval	Estimate	t (P-value)	95% Interval	Estimate	t (P-value)	95% Interval
α	0.19	2.45 (0.014)	[0.04-0.34]	0.15	1.59 (0.111)	[-0.03-0.34]	0.29	2.54 (0.011)	[0.06-0.52]
γ	0.59	5.20 (0.000)	[0.37-0.82]	0.64	4.82 (0.000)	[0.38-0.90]	0.79	2.41 (0.016)	[0.14-1.44]
β	0.75	9.31 (0.000)	[0.59-0.91]	0.75	7.54 (0.000)	[0.55-0.94]	0.23	0.37 (0.713)	[-1-1.4]
σ	0.17			0.17				0.20	
R^2	0.76			0.74				0.12	
NOB	252			196				56	
J stat	7.179 (0.30463)			4.684 (0.58497)				8.364 (0.21266)	
$H0: \alpha + \gamma = 1$				$\chi_1^2 = 2.00$			$\chi_1^2 = 0.07$		
$\chi_1^2 = 2.72$				(0.1574)			(0.7950)		
(0.0991)									

- Method of estimation is GMM
- Instruments are constant and 3 lags of capital stock and employment.
- The correlation between capital stock and employment with their corresponding lagged values are all high and the instruments Pass the Shea partial R^2 and (F) test for instrument's adequacy.
- The J test is distributed $\chi^2(4)$.
- The P values are in parentheses.
- The statistics are Heteroscedasticity and autocorrelation-consistent using the Newey-West method.
- The Kernel=Bartlett and the bandwidth is 2.

Table 8
The mean, standard deviation and the coefficient of variation of GDP per working-age population (15-65)

		Mean	STD	Coefficient of Variation
1970-1992	New Zealand	0.74	2.51	3.39
	Australia	2.91	1.97	0.67
1993-2001	New Zealand	1.99	1.65	0.82
	Australia	3.87	0.86	0.22

- The $F_{23,23}$ statistic tests the null hypothesis that the variance of New Zealand's GDP per working-age population growth rate is equal to that of Australia during the period 1970-1992 against the alternative hypothesis that the variance of New Zealand's GDP per working-age population is larger than that of Australia. The value of $F_{23,23}$ is 1.62 is less than the 5 percent critical value, which is approximately 2.0. Therefore, the hypothesis cannot be rejected. The two variances are statistically equal. The $F_{8,8}$ statistic to test the same hypothesis over the sample 1993-2001 is 3.68, which is marginally greater than the 5 percent critical value of 3.44.
- STD is the standard deviation
- CV is the coefficient of variation = standard deviation/mean.

Data Appendix

Time	Y (Million)	Working-age population 15+ (000)	Working-age population 15-65 (000)	Gross Investment (Million)
Mar-70	48845	1880	1643.34	8837.73
Mar-71	50653	1918	1673.9	9568.77
Mar-72	51942	1962	1717.49	10158.18
Mar-73	54244	2016	1765.59	11941.45
Mar-74	58136	2075	1817.77	13305.72
Mar-75	60479	2129	1861.44	14234.19
Mar-76	61497	2172	1890.7	13614.96
Mar-77	61586	2197	1908.32	12536.5
Mar-78	59888	2217	1925.25	11117.57
Mar-79	60011	2230	1938.58	10544.4
Mar-80	61543	2254	1962.91	9993.73
Mar-81	62204	2276	1983.1	9885.08
Mar-82	65261	2312	2018.05	11700.19
Mar-83	65679	2358	2055.45	12258
Mar-84	67478	2396	2087.11	13055
Mar-85	70807	2420	2101.16	13788
Mar-86	71353	2430	2111.34	14744
Mar-87	72853	2454	2131.93	13898
Mar-88	79265	2474	2141.53	15612
Mar-89	79159	2489	2152.08	15312
Mar-90	79604	2519	2179.01	16187
Mar-91	79590	2557	2210.89	15613
Mar-92	78540	2597	2241.49	12851
Mar-93	79406	2640	2277.76	13147
Mar-94	84527	2689	2320.08	15506
Mar-95	89000	2743	2367.91	17948
Mar-96	92680	2797	2409.17	19890
Mar-97	95515	2834	2435.44	21241
Mar-98	97327	2859	2452.57	21086
Mar-99	97762	2876	2463.63	20276
Mar-00	102267	2895	2478.4	21587
Mar-01	104932	2919	2502.98	21563

Time	Net capital stock/Nominal GDP	Productive capital/Real GDP	Real 90-day rate
1972	2.4	3.0	#N/A
1973	2.3	3.0	#N/A
1974	2.3	3.0	#N/A
1975	2.7	3.0	#N/A
1976	3.0	3.1	#N/A
1977	3.1	3.2	#N/A
1978	3.2	3.4	#N/A
1979	3.3	3.5	#N/A
1980	3.3	3.4	#N/A
1981	3.3	3.4	#N/A
1982	3.3	3.3	#N/A
1983	3.2	3.4	#N/A
1984	3.1	3.4	#N/A
1985	3.2	3.3	#N/A
1986	3.2	3.4	#N/A
1987	3.0	3.4	15.1
1988	2.9	3.4	9.8
1989	2.9	3.5	8.7
1990	2.9	3.6	10.9
1991	2.9	3.7	8.0
1992	3.0	3.8	5.1
1993	3.0	3.8	4.6
1994	2.9	3.6	4.4
1995	2.9	3.5	7.2
1996	2.9	3.4	7.6
1997	2.8	3.4	6.1
1998	2.8	3.4	5.8
1999	2.8	3.5	2.4
2000	2.8	3.4	4.1
2001	2.8	3.4	3.9

Source of the data is the Reserve Bank of New Zealand. Real GDP production chain-volume series is seasonally adjusted in 1995/1996 prices, Y. Investments are real gross investments in 1995/1996 prices and seasonally adjusted.

Industry data
Source: Johnson (2001). Output is real GDP in millions of dollars, employment is 000 of people and the capital stock is in millions of dollars.

1. Agriculture

Years	Output	Employment	Capital Stock
62	894	135.6	14848
63	1031	136.9	15076
64	1222	138.9	15346
65	1334	140.1	15594
66	1446	142.1	15849
67	1495	142.3	16153
68	1547	140.6	16427
69	1590	138.7	16586
70	1571	132.1	16754
71	1602	134.6	16790
72	1650	132.1	16858
73	1467	131.4	16996
74	1392	136.7	17397
75	1599	131.6	17746
76	1706	136.2	17917
77	1712	140.9	18122
78	1644	146.5	18372
79	1537	142.9	18479
80	1747	145.2	18637
81	1965	138.8	18838
82	1944	143.4	19011
83	2041	142.7	19281
84	1882	135.1	19514
85	1960	135.3	19691
86	2372	131	19924
87	2363	132.8	19843
88	2723	131.5	19592
89	2551	127.3	19313
90	2353	124.7	19112
91	2772	123.2	19070
92	2774	124.1	18982
93	2347	121.7	18944
94	2835	124.7	18972
95	2797	125.9	19059
96	2877	126.7	19096
97	3187	123.9	19134
98	3191.1	118.9	19154
99	3022.4	116.1	19151
0	3244.6	126.5	19164

2.Fishing

Time	Output	Employment	Capital Stock
62	27	2.4	75
63	30	2.5	76.8
64	31	2.7	79.8
65	33	2.9	83.6
66	34	2.9	81.9
67	38	2.9	93.1
68	39	2.9	100.4
69	45	2.9	109.9
70	42	3.1	120.9
71	44	3.2	134
72	47	3.2	148.9
73	43	3.3	167.8
74	42	3.3	176.6
75	43	3.4	188.4
76	42	3.5	198.2
77	45	3.7	205
78	59	3.8	216
79	61	4	240.5
80	70	4.1	251
81	81	4.2	279.3
82	85	4.3	283.1
83	89	4.4	285.8
84	98	4.6	293.3
85	104	4.7	308.3
86	119	4.8	323
87	137	5.5	342
88	124	5.4	362
89	162	4.8	409
90	155	4.8	430
91	162	4.4	479
92	161	4.2	512
93	171	3.6	528
94	155	2.8	562
95	157	3.9	591
96	164	4.1	602
97	159.3	3.7	674
98	157	3.3	703
99	160.5	4	753
0	154.1	3.9	832

3.Forestry

Time	Output	Employment	Capital stock
62	166	4.8	584
63	154	5.1	588
64	156	5.4	591
65	163	5.7	589
66	160	6.1	589
67	162	6.3	588
68	164	6.5	597
69	186	6.8	605
70	210	7.2	611
71	221	7	623
72	214	7	636
73	224	7.6	661
74	239	7	690
75	240	7.3	719
76	242	7.8	749
77	280	8.2	783
78	268	8.8	801
79	278	9.5	824
80	306	9.9	843
81	342	9.9	853
82	351	10	866
83	349	10	878
84	358	11.5	870
85	371	11.6	865
86	383	10.8	860
87	375	9.4	850
88	334	5.8	835
89	408	6.1	817
90	447	6.4	805
91	504	5.7	800
92	519	6.7	818
93	528	7.3	847
94	546	8.1	859
95	574	9.8	904
96	580	9.1	975
97	565	9	1037
98	586.3	7.9	1097
99	572.3	8.8	1158
0	640.9	7.6	1230

4.Food Processing

Time	Output	Employment	Capital Stock
62	1583	136.1	4702
63	1545	138.6	5033
64	1606	143.7	5495
65	1640	147.3	5727
66	1879	152.8	6001
67	2057	158.9	6434
68	2064	153.8	6822
69	2010	159.4	7067
70	2185	167.2	7397
71	2279	173.9	7827
72	2237	174.0	8166
73	2360	177.8	8452
74	2636	182.3	8903
75	2664	184.9	9369
76	3795	182.9	9963
77	3758	188.2	10365
78	3569	181.0	10775
79	3615	183.7	10995
80	3768	192.0	11242
81	3830	184.1	11542
82	3987	184.2	11913
83	4070	179.5	12268
84	4190	176.8	12640
85	4509	182.0	12987
86	4315	176.6	13501
87	4581	168.8	13963
88	4411	160.8	14391
89	4271	150.2	14837
90	4118	139.7	15186
91	4029	140.6	16054
92	4051	136.6	16292
93	4151	136.9	16547
94	4384	151.6	16818
95	4601	161.0	17434
96	4706	160.6	17937
97	4769.2	150.0	18368
98	4781	149.9	18651
99	4562.9	150.8	19131
0	4654.2	148.1	19333

5.Manufacturing

Time	Real GDP	Employment	Capital Stock
62	1902	89.8	2782
63	2225	94.2	3045
64	2464	102.2	3271
65	2403	109.4	3436
66	2654	117	3797
67	2723	116.5	4174
68	2641	110.1	4460
69	2851	114.3	4691
70	3172	122.6	4932
71	3258	125	5361
72	3518	126.6	5601
73	3732	130.6	6026
74	4164	140.6	6333
75	4475	143.4	6663
76	3333	143.6	7055
77	3573	146.9	7677
78	3304	141.6	8395
79	3197	142.4	8990
80	3253	145.2	9341
81	3066	139.5	9582
82	3497	143.3	9767
83	3611	136.8	10398
84	3617	137.2	11805
85	4104	144.3	13179
86	4108	141.2	14242
87	4009	135.1	15372
88	3852	124.2	16204
89	3835	106.7	16879
90	3966	108	17356
91	3663	103.1	17682
92	3573	93.3	18286
93	3791	92.3	18666
94	4116	99.6	18990
95	4349	115.4	19401
96	4405	125.1	20039
97	4698.2	128.7	20612
98	4592.9	120.4	21164
99	4459.7	121	21339
0	4587.8	114.8	21370

6.Energy (Water, Electricity and Gas)

Time	Output	Employment	Capital Stock
62	229	11.5	7239
63	267	12	7611
64	286	12.3	7945
65	309	12.4	8297
66	349	12.6	8716
67	372	13.1	9238
68	385	13.4	9891
69	403	13.6	10476
70	426	13.9	11006
71	455	14.1	11489
72	512	14.7	11914
73	582	15	12314
74	616	15.3	12837
75	644	15.9	13236
76	719	16.5	13790
77	767	16.4	14428
78	775	15.9	14962
79	830	16.6	15497
80	908	15.1	15990
81	933	15.8	16306
82	955	16	16538
83	961	16	16814
84	1062	16.1	17115
85	1074	16.1	17421
86	1111	16.5	17658
87	1133	16.5	17853
88	1161	16.8	18069
89	1134	14.1	18265
90	1175	12	18451
91	1219	13.8	18664
92	1207	12.5	19033
93	1163	10.6	19242
94	1230	10.4	19310
95	1274	10.5	19337
96	1321	13.1	19377
97	1222.8	12.7	19496
98	1221.1	9.9	19876
99	1263	9.5	20418
0	1220	8.3	20414

7.Constructions

Time	Output	Employment	Capital Stock
62	1409	89.5	1779
63	1341	89	1989
64	1450	91.8	2148
65	1653	94.9	2312
66	1728	99.2	2445
67	1802	102.3	2559
68	1733	98.4	2695
69	1678	96	2801
70	1811	97.5	2862
71	1864	98.3	2914
72	1772	99.4	2952
73	1997	103.5	3004
74	2089	110.4	3024
75	2245	116.6	3100
76	2370	118.9	3141
77	2052	115.6	3157
78	2050	110.5	3166
79	1881	103.1	3161
80	1725	93.9	3103
81	1706	91.7	3095
82	1840	90.8	3108
83	1899	92.6	3167
84	2062	96	3146
85	2169	101.6	3116
86	2230	101.6	3089
87	2144	98.6	3083
88	2070	94.4	3060
89	1989	93	3037
90	2065	91.3	2995
91	1750	83.8	2908
92	1482	71.3	2902
93	1428	75.3	2844
94	1556	78.8	2771
95	1745	91.2	2828
96	1960	99.6	2886
97	2195.9	107.4	3029
98	2272.8	108.2	3149
99	2132.9	101.9	3264
0	2440.4	107	3508