Why Does Australia Grow Faster Than New Zealand?

by

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at

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Dedication

To my friends and family.

Abstract

We analyse the divergence in productivity between Australia and New Zealand, with a special emphasis on quantifying the industry-level contributors to the divergence and on whether the countries have comparable growth processes. The Convergence Hypothesis is tested between industries and across countries. We find that two industries satisfy our definition of Conditional Convergence (Agriculture, Forestry and Fishing and Cultural and Recreational Services). Cointegration tests reveal more stochastic trends governing Australian productivity than in New Zealand. Decompositions of the divergence to the industry-level suggest large contributions from differences in labour growth across the two countries, and significant contributions from cross-country structural differences. Most of the industries add to the divergence, with particularly large contributions from differences across the Mining and Wholesale Trade industries. The evidence suggests that the growth processes of the two economies are fundamentally different, thereby questioning the relevance of comparisons between them.

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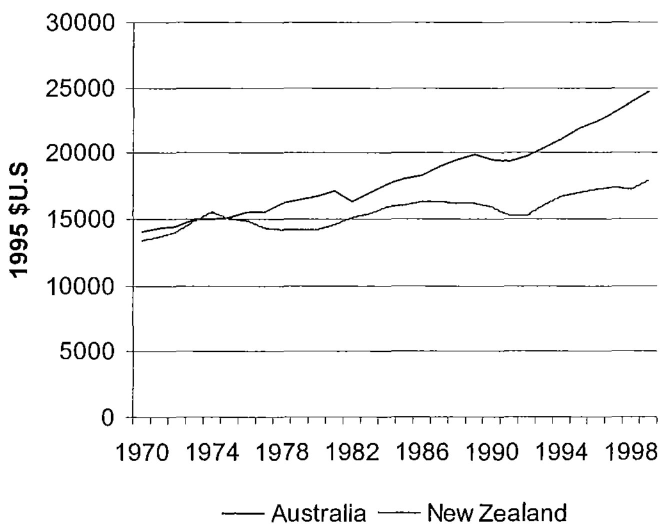
Chapter 1

Introduction

Edward Prescott (2002) describes New Zealand as "depressed relative to their 1970 trend-corrected level," and Greasley and Oxley (2000) characterise New Zealand's per capita income growth over the period from 1870-1993 as idiosyncratic, and diverging below the growth rates of its traditional trading partners. Similarly, Australia's growth in output per capita was below that of the OECD average in the period from 1950 to 1990 (Parham (2002)). Australia, however, has no doubts about its recent growth performance, with the OECD (2000) referring to its progress over the nine years to the middle of 2000 as "remarkable"; Australia's GDP per capita ranking – for OECD countries – improved from fifteenth in 1990 to seventh in 2001 (Parham (2002)).

Figure 1.1: Real GDP per capita: New Zealand and Australia



Source: OECD Statistical Compendium 1 #2001

Australia and New Zealand share similar colonial ties with Britain, and close economic and social relations historically. It is thus not surprising that comparisons between key macro-economic variables of the countries are often drawn (Greasely and Oxley (1999); Dalziel (1999); and IMF (2002), for example). These bilateral comparisons are often further motivated by highlighting the extent of economic reform that has taken place in both countries,[1] and the obvious contrasts in their economic performance since those reforms (as illustrated in Figure 1.1). Similarly, this thesis compares Australian and New Zealand labour productivity (henceforth productivity) performances over the 1990s. We, however, quantify the industry-sources of productivity growth, and seriously question whether the two economies are indeed comparable at the aggregate or industry level. We proceed as follows.

In Chapter 2, we review the literature pertaining to New Zealand's recent growth performance. From the literature it is apparent that New Zealand's growth performance has improved following the reforms of the 1980s and early 1990s, but not when compared with Australia. New Zealand's relatively poor productivity performance is largely attributed to a shift to labour intensive production techniques following the reforms (Philpott (1996); Malony (1998); and IMF (2002)).

In Chapter 3, we call upon the growth theory literature to offer possible reasons why Australian and New Zealand productivity growth might differ. We find that the neoclassical theory predicts convergence in productivity between countries with similar 'fundamentals'. The New Growth Theory (NGT), on the other hand, acknowledges that the processes driving growth (i.e. the fundamentals) in each country may differ. In Chapters 4 and 5, we discuss our data and define convergence. The convergence hypothesis is then tested across the Australian and New Zealand aggregates in Chapter 6. We find no evidence of long-run convergence, thereby not refuting either the neoclassical growth model, or a form of NGT model.

Cointegration tests, however, allow us to test whether any of the industries which comprise the aggregates of Australia and New Zealand can be considered representative of those aggregates, as asserted by standard neoclassical growth theory. In Chapter 7, we utilise these tests and find no evidence of 'the representative industry' in either country, thus motivating a disaggregate analysis of the aggregate divergence. We also find significant evidence of more stochastic trends driving productivity in Australia than we find in New Zealand, thereby highlighting differences in the growth processes of the two economies.

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[1] See Evans et al (1996) and Silverstone et al (1996) for summary of New Zealand's reforms, and Industry Commission (1998) for an exhaustive compendium of the Australian reform process.

Similarly, the industry-level convergence tests conducted in Chapter 8 reveal a myriad of growth outcomes across the industries, with some industries defined as convergent, some as divergent, and others as both convergent and divergent over the sample period. We, therefore, cannot make any general conclusions regarding the nature of growth processes in either country, or indeed whether the growth processes across industries are comparable. In order to gauge how, and by how much, each industry influences aggregate productivity growth in both countries, we then call upon some common productivity decompositions used in the productivity literature in Chapter 9.

We find that the conventional decompositions make assumptions in aggregation which can produce misleading results when decomposing growth. We further note that, unless certain conditions are met, aggregate and disaggregate productivity should be considered distinct concepts, which require separate analysis. Given the inadequacies of the conventional decompositions we then propose two, more flexible, decompositions of aggregate productivity growth in Chapter 10.

In Chapter 11, we use one of these decompositions to allocate each country's productivity growth into its industry-level contributors. We find evidence of some differences in the sources of aggregate growth across the two countries. In Chapter 12, we then posit an index of relative productivity divergence and find that most of Australia's industries out-perform their New Zealand counterparts, with differences across the Mining and Wholesale Trade industries being particularly large contributors to the aggregate divergence. We further find that labour differences across the two countries account for the majority of the aggregate divergence, thus indicating that Australian and New Zealand production processes differ over our sample period. An alternative decomposition, which controls for structural differences across the two countries, is then proposed in Chapter 13. The results from this decomposition suggest that there are non-trivial differences in the structure of the two economies, thus further questioning their comparability. Chapter 14 concludes with a synthesis of our findings.

Chapter 2

A Review of New Zealand's Recent Performance

This chapter reviews the literature pertaining to New Zealand's recent economic performance. The literature suggests an improvement in Total Factor Productivity following the reforms, and suggests an improvement in Total Factor Productivity Growth when compared with Australia and the United States. The cross-country output per worker comparisons surveyed, however, suggest that New Zealand's output per capita is diverging from that of Australia. Cross-country productivity differentials are found to account for the majority of growth differences between Australia and New Zealand. New Zealand's poor productivity performance is attributed to shift to labour intensive production techniques following the Employment Contracts Act, 1991.

2.1. The Scope of the Review

The New Zealand economy underwent extensive structural reform during the 1980s and early 1990s.[2] The performance of the economy following those reforms has been the subject of much research.[3] The literature can be classed into three broad areas: Total Factor Productivity (TFP) evaluations; cross-country comparisons, most notably with Australia; and productivity evaluations. This review provides a brief account of the research which has taken place in these areas since 1994.

2.2. TFP evaluations

Diewert and Lawrence (1999) is perhaps the most detailed description of New Zealand's TFP performance. Diewert and Lawrence go to great lengths in describing and justifying their preferred estimates of TFP at the aggregate and disaggregate (including 20 industries) levels, and the data from which they were derived. As an addition to standard sensitivity analyses, these TFP estimates are compared and contrasted with estimates formed in previous studies, some of which are discussed in this review. Diewert and Lawrence find some evidence supporting an increase in TFP

[2] See Evans et al (1996) and Silverstone et al (1996) for summary of the reforms.
[3] For a recent discussion and survey see Galt (2000).

growth in the early 1990s when comparing with TFP growth in the previous decade (see Table 2.1).

Diewert and Lawrence (1999) note that the Cobb-Douglas functional form is not flexible enough to model adequately trends in the New Zealand economy. They thus prefer an index number approach to that used by Chapple (1994); Philpott (1995); and Janssen (1996).

Fare et al (1996) use a Malmquist index methodology to decompose TFP into changes in efficiency (shifts in the production possibility frontier), and technical changes (shifts of the production possibility frontier) for 20 industries from 1972-1994. Though Diewert and Lawrence do not have any problems with Fare et al's methodology, they question how the authors constructed their industry-level production possibility frontiers; Fare et at assume that the value of outputs for each industry can be produced by every other industry, which, clearly, is not a valid assumption. The Fare et al estimates imply the largest increase in TFP of the studies surveyed by Diewert and Lawrence.

Overall the literature on New Zealand's post-reform TFP performance suggests an increase in trend TFP growth in the early 1990s. There is no clear evidence about the extent of this increase, however.

2.3. Comparisons

Greasely and Oxley (1999) and Dalziel (1999) compare Australian and New Zealand real GDP per capita over 1870-1994 and 1977-1998, respectively. Greasley and Oxley (1999) note divergence of New Zealand's real GDP per capita from that of Australia around 1950, suggesting small size, insular economic policies, and a less favourable resource endowment as distinguishing New Zealand's economic development from Australia's. Using data beginning much later than Greasely and Oxley, Dalziel (1999) notes divergence around 1984, and suggests that the extent to which New Zealand engaged in structural reform may have hindered its growth performance. OECD (1998, 2000) and IMF (2000, 2002) further discuss the possible reasons for the aggregate divergence between New Zealand and other OECD countries, a central theme of these surveys being different TFP outcomes.

Diewert and Lawrence (1999) compare "ABS Equivalent" estimates of New Zealand's aggregate TFP with aggregate TFP estimated by the Australian Bureau of Statistics (ABS). They highlight the critical role played by industry coverage when comparing TFP estimates; the 'ABS Equivalent' estimate of New Zealand's TFP is 8 percent higher than an estimate of New Zealand's TFP for the full market sector in 1998.[4] When 'ABS equivalent' estimates of TFP for New Zealand and Australia are compared, growth of New Zealand's TFP over the period 1978-1998 is found to be higher than Australia's (see Table 2.1).

Table 2.1: Trend TFP Growth Rates (percent per annum)[a]

%	1978-84	1984-93	1993-98	1978-98
'ABS Equivalent' NZ	1.12	1.35	2.38	1.56
ABS Estimates Australia	0.68	0.77	2.27	1.05

a Adapted from Diewert and Lawrence (1999), Table 1.

Similarly, IMF (2002) use a Cobb-Douglas methodology to investigate the divergence in ABS-defined market sector GDP per capita between Australia and New Zealand. They find that almost all of the divergence is accounted for by a difference in productivity between the two countries. In contrast to Diewert and Lawrence (1999), the IMF's estimates of TFP imply higher growth in Australia's market sector TFP over the 1990s.[5]

An important difference between IMF (2002) and other studies is the special emphasis that is placed on relative sectorial performance: Relative levels of productivity, capital intensity, and TFP are compared across each industry in the Australian and New Zealand market sectors. The IMF attribute the aggregate divergence in TFP to lacklustre performances in Manufacturing and Construction in the New Zealand market sector, and to inefficient resource allocation following the reforms.

Conway and Hunt (1998) use "cyclically adjusted" quarterly data from the fourth quarter of 1985 to the second quarter of 1997 to compare New Zealand's

[4] The ABS only uses industries which comprise the 'market sector' when estimating productivity. The market sector is discussed further in Chapter 4.
[5] Note that Diewert and Lawrence (1999) (Table 4.11) shows higher growth in 'ABS Equivalent' TFP for New Zealand in the period 1990-1996, and IMF(2001) finds the opposite result for the period 1988-1999.

aggregate TFP growth with that of the United States. The authors find some evidence in favour of an increase in New Zealand's TFP growth relative the United States around 1992, thereby not precluding TFP convergence between the two economies.

The literature comparing New Zealand's economic performance with Australia suggests divergence in real GDP per capita (Greasley and Oxley (1999) and Dalziel (1999)). The point at which this divergence occurs, however, is not clear. There is mixed evidence that New Zealand's TFP has diverged from Australia's (Diewert and Lawrence (1999) and IMF(2002)), and some evidence suggesting a TFP 'catch-up' with the United States (Conway and Hunt (1998)). Sectorial analysis and industry coverage variations suggest important factors are masked by aggregate comparisons (IMF (2002) and Diewert and Lawrence (1999)).

2.4. Productivity

Maloney (1998) is an extensive study into the impact that the Employment Contracts Act (ECA) ,1991, had on the labour market in New Zealand. Maloney concludes that the effects of the ECA on both union density and output can account for a slow-down in productivity following its inception. Diewert and Lawrence (1999), however, argue that the use of a Cobb-Douglas production function methodology in the Maloney study may well lead to a different conclusion from that yielded by a more flexible functional form.

Philpott (1996) also notes a slow-down in productivity following the ECA. He suggests that employment growth, and the subsequent downward pressure wage rates, may have led to greater accent on labour intensive production. He supports this by noting falling productivity in the relatively labour intensive service-oriented non-tradables sector since the ECA, but suggests further analysis using disaggregated data.

Philpott also argues that the slow-down in productivity over this period may be associated with a reduction in capital per worker brought about by a fall in the relative price of labour following the ECA. He thus suggests that the ECA may have encouraged low-skill labour intensive activity rather than that displaying high-skill and capital intensity. On this conjecture, he suggests further research.

IMF (2002) supports the broad conclusions of Philpott (1996). A disaggregate approach is taken to understanding New Zealand's poor real GDP per capita performance relative to that of Australia. The authors note that New Zealand's relatively poor productivity performance over the 1988-1999 period may be due to a shift to relatively labour intensive production techniques. It is found that three quarters of the productivity difference between the two countries over the sample period is due to different capital intensities,[6] thereby providing empirical support for one of Philpott's conjectures. Given the decade of annual data, little analysis is made of the dynamics of labour and productivity at the industry-level, however, so Philpott's other conjecture, that labour moved into labour intensive industries following the reforms in New Zealand, is not examined.

New Zealand's productivity performance following the ECA has not been impressive (Maloney (1998), Philpott (1996) and IMF (2002)). Possible reasons for this lacklustre performance are falling real wages, declining capital-labour ratios, and a shift to labour intensive production techniques (Philpott (1996) and IMF (2002)).

2.5. Summary

The literature reviewed here suggests an improvement in New Zealand's TFP performance since the reforms of the 1980s and early 1990s. There is inconclusive evidence that New Zealand's TFP performance relative to other countries has improved, however. New Zealand's real GDP per capita growth performance also seems to have improved following the reforms, but not when compared to other OECD countries, particularly Australia. Productivity differences explain almost all of the cross-country variation in real GDP per capita across New Zealand and Australia. A disaggregate approach is preferred by some researchers, and New Zealand's poor productivity performance is largely attributed to a shift to labour intensive production techniques following the ECA.

This thesis adds to the literature on New Zealand's post-reform growth performance by further analysing New Zealand's aggregate productivity performance through comparisons with Australia, with a special emphasis on whether or not the two economies are indeed comparable.

[6] The other one quarter is attributed to TFP.

We begin our analysis by reviewing the reasons why cross-country differences in productivity growth might exist.

Chapter 3

Why Might Productivity Growth Differ?

In this chapter, we briefly review the growth theory literature for possible reasons why Australian and New Zealand productivity outcomes have differed over recent years. We find that the neoclassical growth theory suggests a disportionate improvement in the fundamental drivers of growth common to both countries, which favoured Australia. In this case, productivity growth differentials across the two countries will be transitory in nature as the countries converge to different steady-state levels of productivity in the long-run. The New Growth Theory, on the other hand, suggests that the fundamental drivers of growth across Australia and New Zealand are likely to differ, which does not necessarily imply convergence in productivity levels or productivity growth in the long-run.

3.1. Theoretical Issues

Before we begin analysing Australian and New Zealand productivity, it will be informative to briefly review the reasons for differing time paths of productivity provided by the growth theory literature. The literature can be classed into two broad areas: 'Neoclassical', stemming from Solow (1956, 1970) and Swan (1956), and the 'New Growth Theory'(NGT) motivated by Romer (1986); Lucas (1988); Baumol (1990); and Rebello (1991).[7] The issue of convergence is an ongoing point of contention between the neoclassical and the new growth theorists, which has undergone much empirical scrutiny over the last two decades (see, for example, Baumol (1986); Barro (1991); Barro and Sala-i-Martin (1992); and Mankiw et al. (1992)).

Specifically, conventional neoclassical growth theory predicts convergence towards a balanced growth path, where the growth rate of productivity is determined by the rate of technological progress. When the convergence hypothesis is applied across countries, it implies that those countries with similar characteristics will converge to similar balanced growth paths. Standard neoclassical theory thus implies

[7] Barro and Sala-i-Martin (1998) outline both the theory and implications of various models of economic growth.

that if the New Zealand and Australian economies have similar 'fundamentals', such as savings rates; population growth rates; depreciation rates; and production functions over the sample period, they will converge to similar steady-state levels of productivity, whose growth path is in turn governed by the evolution of a single exogenous technology.

With different levels of the long-run fundamentals, on the other hand, the neoclassical model predicts only conditional convergence (Barro and Sala-i-Martin (1992) and Mankiw et al (1992)), where steady-state levels of productivity can differ across countries. In this case, neoclassical theory predicts that Australia and New Zealand will converge to different steady-state levels of productivity, and subsequently grow at a single rate.

Regardless of the nature of the relative levels of the long-run fundamentals of growth across countries, standard neoclassical theory predicts a positive relationship between productivity growth and the distance between steady-state levels of productivity and initial levels of productivity (Mankiw (1995)).

Romer (2001) shows that the issue of convergence in productivity is more complicated than this, however. In particular, changes in the underlying fundamentals of long-run growth have implications for the transition path to steady-state levels of productivity. If, for example, a country's fundamentals change whilst in transition to a steady-state, the steady-state level of productivity changes along with the transition path to that new steady-state. This has the implication that countries can have relatively high growth because they are below their steady-state levels of productivity, or because of improvements in their fundamentals.

According to standard neoclassical growth theory, therefore, there are many reasons why Australia's growth has been higher than New Zealand's since the late 1980s. Given the historical similarities in output per worker that have been documented (Dalziel (1999) and Greasely and Oxley (2000)), and the extensive reforms undertaken by both countries, however, the neoclassical growth model would suggest that there has been a disproportionate shift in the fundamental drivers of growth between the two countries which favourably influenced the steady-state level of productivity in Australia. If this is the case, we would expect to see Australia and

New Zealand converging to different steady-state levels of productivity at different rates.

Convergence in productivity, however, is not necessarily implied by the endogenous growth models of the new growth theorists such as Romer et al. These models stress the importance of the production of resources, such as knowledge (via Research and Development (R&D) and educational systems (Romer (1990) and Lucas (1988)), and the role played by institutions (i.e. the regulatory and legal environment). Analogous to the neoclassical growth theory, growth in these models is governed by technology, which, unlike the neoclassical theory, is a function of the production process. With growth made endogenous, increasing returns are typical amongst NGT models. A steady-state level of productivity, and hence cross-country convergence, therefore, is generally not a prediction of these models.[8]

Essentially, the NGT models expand the neoclassical set of long-run growth fundamentals, to allow a multitude of different factors to impinge on the growth process. Moreover, these types of models acknowledge that the fundamentals drivers of the growth process, such as production functions and the quality of inputs, are likely to be different across countries. In contrast to the neoclassical growth theory, therefore, NGT would not predict a tendency for the Australian and New Zealand productivity to grow at the same rate in the long-run because the fundamentals of growth may differ across the two countries. In this case, New Zealand's relatively poor productivity performance over the previous decade may be the result of a disproportionate shift in the processes governing growth in each country which led to relatively high growth in Australia, with no tendency for the growth rates to equilibrate in the long-run.

3.2. Summary and Implications

It is apparent that the neoclassical and NGT have very different, and important, implications for the nature and persistence of Australia's relatively high growth. On the one hand, the neoclassical theory would suggest a disproportionate improvement in the fundamentals of growth common to both countries, which favoured Australia.

[8] Of course in models with well-defined steady states, similarities in all aspects pertaining to the growth process across two countries would imply convergence in productivity between those countries.

Australia's subsequent high growth would then be transitory in nature as each country converges to its new steady-state level of productivity, where growth is governed by a single process across both countries. The NGT, on the other hand, would suggest that the improvement in Australia's steady-state level of productivity relative to that of New Zealand, may, if the fundamentals of growth in each economy are different, lead to permanent discrepancies in both productivity levels and productivity growth.

Using time-series tests of the convergence hypothesis, we will be able to gauge the persistence of the disparity between the productivity growth of the Australian and New Zealand market sectors. Before defining convergence, however, we first construct comparable measures of output and labour for both countries. This is the topic of our next chapter.

Chapter 4

Data

This chapter defines and constructs the output and labour data we use for the remainder of this thesis. We also discuss the concerns we have surrounding the accuracy of our data.

4.1. Period and Frequency

Our productivity concept is output per labour hour worked. We use quarterly data for output and labour ranging from 89:Q1 to 01:Q3, where Q1 is the quarter ending March. The data are obtained from Statistics New Zealand (SNZ), the Australian Bureau of Statistics (ABS), and Diewert and Lawrence (1999).

4.2. Industry Classifications

We classify the industries in accordance with the Australian and New Zealand Standard Industrial Classification (ANZSIC), 1996 (see Table 4.1).[9] Not all of the ANZSIC-classified industries are included in our characterisation of production, however: We exclude Property and Business Services; Education, Health, Personal and Other Services (henceforth referred to Other Services); and Government Administration and Defence. Thus, our industries are those which comprise the 'market sector'.

Table 4.1: ANZSIC-Industries (*i*)

1. Agriculture, Forestry & Fishing
2. Mining
3. Manufacturing
4. Electricity, Gas & Water
5. Construction
6. Wholesale Trade
7. Retail Trade
8. Accommodation, Cafes & Restaurants
9. Transport, Storage & Communication
10. Finance & Insurance Services
11. Cultural & Recreational Services

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[9] See www.abs.gov.au for details of this classification.

The market sector, as defined by the ABS, is a special industry grouping comprising of those industries whose value-added and factor inputs can be "meaningfully measured". The market sector, therefore, excludes the Government Administration and Defence; Education; Health and Community Services; and Property and Business Services industries, where real output estimates are based on input data, and the Ownership of Dwellings industry, where there are no labour inputs.

4.3. Output

The Australian and New Zealand industry-level output data are seasonally adjusted and chain-linked. The Australian industries are constructed using data from ABS Cat: 5206- Table 26, and the New Zealand industries are constructed using data from INFOS: Table 8522-2.02 and Table 8555-2.2N and data from the 1995/96 input-output tables for the New Zealand economy.[10]

Our concept of industry output is gross value-added (GVA) measured in basic prices.[11] Industry-level GVA is published by both the ABS and SNZ. The New Zealand data, however, are expressed in terms of producers' prices, which include taxes and subsidies and bank service charges, unlike the Australian data. Taxes, subsidies, and bank service charges must, therefore, be removed from the New Zealand data to facilitate cross-country comparisons of output.

We can think of SNZ's definition of industry i's GVA as:

$$x_i = y_i + t_i - s_i + b_i \tag{4.1}$$

where y is GVA in basic prices as published by the ABS, t is taxes, s is subsidies, and b is bank service charges.

Quarterly industry-level estimates of t, s and b are not available for New Zealand. We must, therefore, utilise the 1995/96 input-output tables for New Zealand. Using these tables, we derive the proportion of 'ABS-comparable' GVA in SNZ's estimates of industry-level GVA for the year ending 1996, i.e:

[10] Available from www.stats.govt.nz.
[11] Gross value-added measured at basic prices is the sum of the compensation of employees, the gross operating surplus, and the consumption of fixed capital.

$$\frac{y_i}{x_i} = 1 - \frac{t_i - s_i + b_i}{x_i} \tag{4.2}$$

where each industry's bank service charges are proxied by their intermediate consumption of services from the Finance and Insurance Services industry (the proportions are displayed in Table 4.2). We then assume that the relations hold over time and apply them to SNZ's quarterly GVA estimates. The resulting data are proxy measures for GVA measured in basic prices excluding bank services, which are comparable to the ABS GVA data.

Table 4.2: Proportion of ABS-Comparable GVA in SNZ's Published GVA

Industry	Proportion
Agriculture, Forestry & Fishing	0.950
Mining	0.981
Manufacturing	0.979
Electricity, Gas & Water	0.990
Construction	0.982
Wholesale Trade	0.953
Retail Trade	0.961
Accommodation, Cafes & Restaurants	0.954
Transport, Storage & Communication	0.993
Finance & Insurance Services	0.820
Cultural & Recreational Services	1.009

The Australian and New Zealand GVA series are measured in the average prices of the year ending 2000 and 1996, respectively. We re-base the Australian data to 1996 by multiplying each industry's real GVA observation by its corresponding 1996/2000 price deflator (i.e. that particular industry's ratio of 1996 current-value GVA to 1996 chain-linked GVA, which is referenced to 2000), using data from ABS Cat: 5204- Table 54.

4.3.1. Cultural and Recreational Services

Statistics New Zealand does not publish quarterly estimates of GVA for the Cultural and Recreational Services industry. Hence we must extrapolate our quarterly data from an aggregate which features this industry, i.e. Education, Health, Cultural and Other Services.

To do this we first calculate the proportion of the Cultural and Recreational Services industry in the Education, Health, Cultural and Other Services industry using annual data (INFOS: Table 8522-2.6N) from 1989 to 2001. We then estimate the annual compound growth rate of this proportion (p) as the estimated coefficient on the time trend (r) in the following regression:

$$\ln(p_t) = c + rt + e_t \tag{4.3}$$

where e_t is an independently and identically distributed white-noise process. This growth rate (r) is then divided by four to represent quarterly growth in the proportion.

Our quarterly real GVA in the Cultural and Recreational Services industry is then a proportion of the quarterly Education, Health, Cultural and Other Services industry, where the proportion grows at a constant rate over the sample period. i.e. the quarterly proportion (x_t) of Cultural and Recreational Services in Education, Health, Cultural and Other Services in period t is:

$$x_t = (1 + \frac{r}{4})^t x_0 \tag{4.4}$$

where x_0 is the proportion from the year ended 1989.

If y_t is real GVA in the Education, Health, Cultural and Other Services industry in period t, then real GVA in the Cultural and Recreational Services industry (z_t) in period t is:

$$z_t = y_t (1 + \frac{r}{4})^t x_0 \tag{4.5}$$

We apply this transformation to obtain our quarterly Cultural and Recreational Services output data.

4.3.2. Comparing Output

To make output comparisons across countries, all output data must be expressed in comparable units. Market exchange rates reflect the relative prices of tradable goods only, thus they are not accurate reflections of the comparative value of currencies in the production of all goods and services. Purchasing Power Parity (PPP) is another way of converting output data into comparable units.[12]

An aggregate PPP is not suitable for converting industry-level output into a common currency, however, because it is an average relative price taken over all industries, rather than a relative price specific to a particular industry.[13] Moreover, since we have removed some industries from our analysis, the use of an aggregate PPP would erroneously reflect the relative prices of our excluded industries.

We thus convert the Australian GVA data into 1995/96 New Zealand dollars by applying industry-level relative prices from IMF (2002), which are reproduced in Table 4.3. Note: These relative price levels are adjusted for cross-country differences in distribution margins and net indirect taxes.

Table 4.3: New Zealand/Australia Relative Prices 1995/96

ANZSIC Industry	PPP
Agriculture, Fishing & Forestry	1.14
Mining	1.06
Manufacturing	1.06
Electricity, Gas, & Water	0.85
Construction	1.05
Wholesale Trade	1.01
Retail Trade	1.02
Accommodation, Cafes & Restaurants	0.84
Transport, Storage & Communication[14]	1.00
Finance and Insurance	1.03
Cultural and Recreational Services	1.06

4.4. Labour

Quarterly hours worked data for New Zealand and Australia are computed using the Quarterly Employment Survey (QES) (INFOS: Table 5504-02), and the Labour Force Survey (LFS) (ABS Cat 6291.0.40.001- Table 26). The data relate to a reference week in the middle month of the quarter for both countries so that data from the week

[12] PPPs are price relatives, which measure the relative price of the same bundle of goods and services in different countries. The OECD calculates aggregate PPPs on a tri-annual basis (see www.oecd.org for a discussion of PPPs, and PPPs for Australia and New Zealand).

[13]See www.eco.rug.nl/GGDC/icop/html for a detailed discussion of industry-level price comparisons.

[14] IMF (2002) includes Communications as a separate industry. Our Transport, Storage and Communication relative price is the weighted average of the Transport and Storage and the Communication relative prices, where the 1995/96 Transport and Storage and the 1995/96 Communication industries' share of value-added in the Transport, Storage, and Communication (combined) industry were used as the weights.

surveyed are assumed to be representative of the weekly hours worked for the entire quarter.[15] The Australian data are indexed by the middle month in the quarter, i.e. February, May, August and November, and the New Zealand data are indexed by the end month in the quarter, i.e. March, June, September and December.

Labour inputs are measured as hours worked for Australia, and as hours paid for New Zealand. These measures are not necessarily the same; employees may work more or less than their paid hours in the reference period due to paid leave, meal breaks, and time spent travelling to work. We, however, assume that, on average, hours worked will be equal to hours paid to facilitate comparisons between the two countries.

4.4.1. Consistency

The QES surveys a subset of industries in New Zealand, which we discuss later, and a subset of enterprises within those industries. The LFS data, on the other hand, is estimated from a sample which is representative of the entire Australian population aged 15 years and over. Statistics New Zealand produces a survey similar to the LFS called the Household Labour Force Survey (HLFS). Thus, to facilitate comparisons between the hours worked data across New Zealand and Australia, we must construct our New Zealand labour data using information from both the QES and the HLFS.

The QES hours paid data are consistent with the QES number of filled jobs data because both types of information are derived from the same source at the same time. The QES number of filled jobs data, however, are not consistent with the employed data produced by the Household Labour Force Survey (HLFS). In particular, the QES industry employment estimates are surveyed from a sample of "economically significant" enterprises, and the HLFS surveys a sample representative of the entire New Zealand population aged 15 years and over.

The QES defines an 'economically significant' enterprise as one that meets at least one of the following criteria:[16]

- has greater than $30,000 annual GST expenses or sales

[15] Using weekly data from a specified period in the middle of the quarter avoids the problem of varying number of pay-periods quarter-to-quarter.
[16] List taken from www.stats.govt.nz

- has more than two full-time equivalent paid employees
- is in a GST-exempt industry
- is part of a group of enterprises
- is a new GST registration that is compulsory, special or forced
- is registered for GST and is involved in agriculture or forestry

In addition, contrary to the LFS and the HLFS, the QES does not encompass the following ANZSIC classified industries:

	Industry (*i*) (Table 4.1)
o Agriculture and Hunting	1
o Commercial Fishing	1
o International Sea Transport	9
o Private Households Employing Staff	Not Included
o Residential Property Operations	Not Included
o Foreign Government Representation	Not Included
o Non-civilian Defence Staff	Not Included

Since the Government Administration and Defence, Property and Business Services, and Other Services industries are not included in our analysis, only the exclusion of Agriculture and Hunting; Commercial Fishing; and International Sea Transport will influence our industry comparisons across New Zealand and Australia.

The number of hours worked in International Sea Transport relative to the total numbers of hours worked in Transport, Storage, and Communication is likely to be small. Excluding the International Sea Transport industry from New Zealand's Transport, Storage and Communication industry, therefore, will not substantially influence the cross-country analysis. Our New Zealand Transport, Storage, and Communication labour data thus excludes labour from the International Sea Transport industry. The exclusion of the Agriculture, Hunting and Fishing industry from the QES, however, requires us to compile a new labour hours worked series for New Zealand's Agriculture, Forestry and Fishing industry.

4.4.2. Agriculture, Forestry, and Fishing

The Household Labour Force Survey (HLFS) provides quarterly total numbers employed in the Agriculture and Fisheries industry from 91:Q2 (INFOS: Table 5500-13N), total employed in the Agriculture, Fishing, and Forestry industry from 85:Q4 to 90:Q4 (INFOS: Table 5500-13H), and total numbers employed in the ANZSIC-classified Agriculture, Forestry, and Fishing industry (INFOS: Table 5500-07) from 96:Q4.

We first proxy total numbers employed in the Agriculture, Forestry, and Fishing industry by assuming that growth in this industry prior to 96:Q4 was equivalent to growth in the Agriculture, Fishing and Forestry data in the period from 88:Q4 to 90:Q4, and equivalent to growth in the Agriculture and Fisheries data from 91:Q2 to 96:Q3. Essentially, we discount the HLFS Agriculture, Forestry, and Fishing total employed data back to 89:Q1 by using growth in close approximations to this industry as the discount rate.

Quarterly hours worked in the Agriculture, Forestry and Fishing industry are then created by assuming that the total number employed in this industry each quarter is the same as that employed in the reference week used by the QES, and by further assuming that 34 hours a week are worked by all of those employed in the industry, thereby ruling out changing labour utilisation rates over time.

The hours worked in the reference week was approximated by numerically solving for the average number of hours worked required to match our data with comparable data in Diewert and Lawrence (1999). For comparison, we use the average proportion of Agriculture, Fishing and Forestry hours worked in an aggregate of industries 1 to 9 (Table 4.1) that is implied by HLFS annual estimates of hours worked between 1989 and 1998 (Table C5 of Diewert and Lawrence (1999)). We then numerically solved for the number of hours worked required to equilibrate this proportion with a comparable proportion computed using our data.

4.4.3. Mining

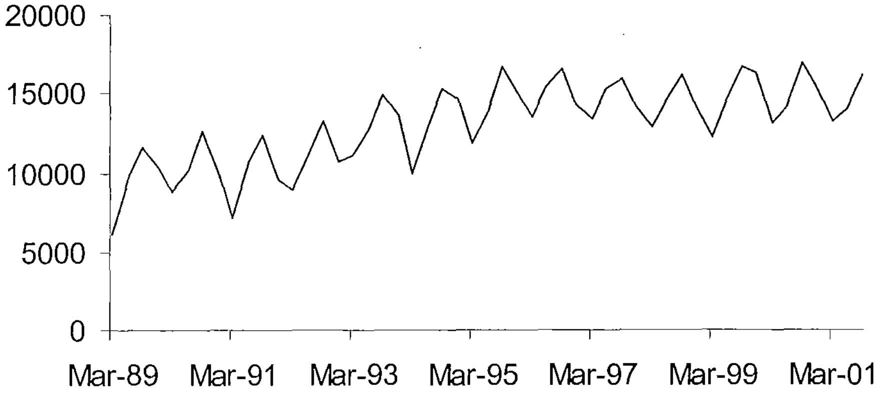
The QES includes Forestry and Mining as a single industry. We separate Mining from this aggregate by calculating annual proportions of Mining hours worked in a Forestry and Mining aggregate created using annual hours worked data from 1989 to 1998 (Table C5 of Diewert and Lawrence (1999)). Using a method analogous that used to extrapolate real GDP in the Cultural and Recreational Services industry above, we then calculate the quarterly compound growth rate of the proportion from Diewert and Lawrence. The time-varying proportion are then applied to our quarterly Forestry and Mining data to obtain quarterly estimates of hours worked in the Mining industry.

4.4.4. All Industries

As mentioned above, the QES labour data are not consistent with the LFS data because the QES is not representative of the entire population over 15 years of age. The HLFS, on the other hand, is comparable to the LFS.

Fortunately, the HLFS produces a Total Hours Worked series (INFOS: Table 5500-10). By aggregating the QES hours paid data, and the data we have created so far, we have hours worked data for all industries excluding Government Administration and Defence; Property and Business Services; Other Services; and the minor industries excluded from the QES. Thus, the difference between an aggregate created using our data and the official HLFS total hours worked data should closely approximate hours worked from Government Administration and Defence; plus Property and Business Services; plus Other Services from the QES.

Figure 4.1: Differences in Total Hours Worked ('000) (HLFS-Construct)



This, however, is not the case (see Figure 4.1). In particular, we find that the HLFS estimates of total hours worked are greater than similar aggregates created using our market sector data plus Government Administration and Defence; Property and Business Services; and Other Services hours paid. The difference also increases over the sample period and follows a seasonal pattern.

As mentioned above, the HLFS uses a methodology analogous to the LFS. Therefore, our New Zealand labour data should, when Government Administration and Defence; Property and Business Services; and Other Services are included, approximate to HLFS total hours worked to facilitate comparisons with the LFS.

We thus construct LFS-comparable labour data as follows:

Let L_t be the HLFS total hours worked estimate in period t for the n industries which comprise the market sector, and l_{it}^* be our estimate of an 'HLFS-equivalent' measure of industry i's labour hours worked in period t, i.e. the sum a QES measure (l_{it}) and an error (e_{it}), then:

$$L_t = \sum_{i=1}^{n} l_{it}^* \tag{4.5}$$

and:

$$l_{it}^* = l_{it} + e_{it} \tag{4.6}$$

Here e_{it} encompasses all methodological differences and measurement errors that lead our estimates to differ from the unobservable HLFS-equivalent measure of hours worked in industry i in period t. Hence we assume that a HLFS survey of industry-level hours worked can be linearly related to a QES survey of the same industry.

Since we have data for l_{it}, we must estimate e_{it} in order to determine the HLFS-equivalent measure of hours worked in each industry (l_{it}^*). To estimate e_{it}, we assume that the error in industry i is equal to a proportion of the aggregate error (ε_t), which is determined by the size of the QES estimate of industry i's labour hours worked relative to a QES measure of total hours worked, i.e. we assume:

$$e_{it} = \frac{l_{it}}{\sum_{i=1}^{n} l_{it}} \varepsilon_t \tag{4.7}$$

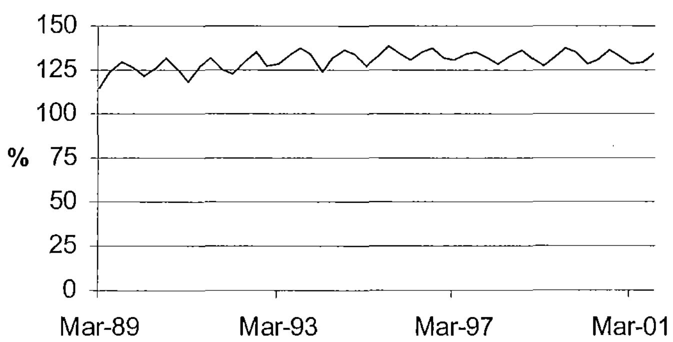
where $\varepsilon_t = L_t - \sum_{i=1}^{n} l_{it} = \sum_{i=1}^{n} e_{it}$.

Therefore, given that we have estimates of l_{it} and the aggregate error ε_t, the HLFS-equivalent measure of hours worked in industry i in period t is:

$$l_{it}^* = l_{it} + \frac{l_{it}}{\sum_{i=1}^{n} l_{it}} \varepsilon_t \tag{4.8}$$

Our HLFS-equivalent, and therefore LFS-comparable, hours worked data are calculated in this fashion for each industry (i) and period (t). Our market sector labour estimates are then these n industries excluding Government Administration and Defence; Property and Business Services; and Other Services: The time-series of the size of the our LFS-comparable market sector labour aggregate relative to our original QES market sector aggregate is displayed in Figure 4.2.

Figure 4.2: The Size of our LFS-comparable market sector hours worked aggregate relative to our original QES market sector aggregate



From Figure 4.2, it is apparent that the original QES measures of the total market sector labour hours worked have been increased by approximately 30% to make their LFS-comparable counterparts. Notice also that the proportion displayed in Figure 4.2 is reasonably constant overtime, implying that the growth rates of the LFS-comparable and QES series are similar. Another important point to note is that these level differences and growth similarities apply to all of the industries that comprise the market sector; Equations (4.7) and (4.8) yield LFS-comparable industry-level data whose shares of the LFS-comparable market sector are equivalent to the original QES shares.

4.4.5. Seasonal Adjustment

Our Australian and New Zealand labour data are seasonally adjusted in the EVIEWS econometrics package using the X12 application.

4.5. Measurement Concerns

To facilitate cross-country comparisons, it is apparent that our data are subject to a large number of transformations, and that these transformations have been made in a less than idea way; if they were not, we would not need to transform the data because the 'real' data would exist. Thus, even in the unlikely event that our raw data are not subject to measurement error, our final data are very likely to be measured with error.

The extent of measurement error in our data, however, is difficult to gauge since we know of no other studies that have constructed quarterly output and labour data which are comparable between New Zealand and Australia. We must, therefore, interpret the data with extreme caution.

We consider our Australian data to be the most accurate reflections of the 'true' data; the labour data are official estimates and the output data are the official estimates multiplied by a scalar (i.e. they are both consistent with official estimates in terms of growth). Of the New Zealand data, we consider the output data to be the most accurate as they are official estimates which are subject to relatively few transformations. The least accurately measured data, in our opinion, are the labour data for New Zealand.

4.6. Summary

Our Australian and New Zealand output and labour data are quarterly GVA measured in 1995/96 basic New Zealand prices and labour hours worked, respectively. We have data from the 11 industries which comprise the market sector ranging from 89:Q1 and 01:Q3. Some of the data have been subject to a large number transformations, we thus suggest that they be interpreted with caution.

Chapter 5

Testing For Convergence: Theory and Econometric Issues

In Chapter 3, we found that the neoclassical model predicts convergence in productivity growth across countries with similar growth fundamentals. We also found that some forms of the NGT model do not predict convergence. In this chapter, we adapt the formal definitions of convergence made by Bernard and Durlauf (1995,1996) and define 2 different types of long-run convergence; 2 types of transitional convergence; and independence. We also outline our convergence testing procedure, where significant evidence of a deterministic process 'driving' the difference between two series is considered supportive of the neoclassical model.

5.1. Definitions

Bernard and Durlauf (1995,1996) offer two definitions of convergence, where I_t denotes information available at time t.

Definition 1. Convergence as catching up. Countries i and j converge between the dates t and $t+T$ if the (log) per capita output disparity at t is expected to decrease in value. If $y_{i,t} > y_{j,t}$,

$$E(y_{i,t+T} - y_{j,t+T} \mid I_t) < y_{i,t} - y_{j,t} \tag{5.1}$$

Definition 2. Convergence as equality of long-term forecasts at a fixed time. Countries i and j converge if the long-term forecasts of (log) per capita output for both countries are equal at a fixed time t,

$$\lim_{k\to\infty} E(y_{i,t+T} - y_{j,t+T} \mid I_t) = 0 \tag{5.2}$$

These definitions of convergence have clear implications for the time-series properties of comparative (log) output per capita levels. If, for example, the difference between two time-series is non-stationary, or has a non-zero mean, neither equivalence in long-run forecasts or diminishing expected differences between the series can hold because discrepancies persist into the infinite horizon. Thus, when the difference between two series is non-stationary, both of Bernard and Durlauf's definitions of convergence are violated (Greasley and Oxley (1998a, 1998b)).

5.2. Testing

Bernard and Durlauf (1996) propose unit root tests to test the null hypothesis of no convergence: Unit root tests typically test a null hypothesis of non-stationarity, and thus when applied to the difference between two series they test the null hypothesis of 'no convergence'. Following Bernard and Durlauf, Greasley and Oxley (1998a, 1998b) propose a procedure for testing convergence between two macroeconomic variables utilising standard unit root tests (Dickey and Fuller (1979,1981)), and tests for unit roots in the presence of structural breaks in the comparative series (Perron (1989) and Zivot and Andrews (1991)).[17]

According to Greasely and Oxley, significant evidence of a unit root in comparative series is indicative of no convergence between the two series.[18] If the no convergence null hypothesis is overturned, however, evidence of a significant trend that reduces the discrepancy between the series would violate Definition 2 of convergence but not Definition 1. Thus, if the null hypothesis of a unit root is overturned, a significant time trend allows the researcher to distinguish between long-run convergence and catching up.

There is a possible problem with this, however. The presence of a significant trend in comparative series will ultimately lead to divergence between the two series when the catch up process is completed, i.e. if a series is converging towards another series according to a linear deterministic process and the series become equal at time $t+k$, then the series will be diverging in all periods such that $k > 0$ (Oxley and Greasely (1997)). Thus, in these circumstances, Bernard and Durlauf's Definition 1 will be satisfied, but divergence has occurred in all periods $T\text{-}k$. Similarly, St Aubyn

[17] Perron (1989) shows that the power of unit root tests can approach zero when deterministic features of the 'true' data generating process, such as structural breaks, are not incorporated into the testing procedure.

[18] Convergence is implicitly assumed to be a deterministic process. For example, as noted by Hall, Robertson and Wickens (1992), two independent non-stationary series which become equal at a point in time do not converge according to Bernard and Durlauf (1996). Thus Bernard and Durlauf's (1996) definition of convergence precludes 'stochastic convergence', or convergence by chance.

(1999) argues that Bernard and Durlauf's Definition 2 is inadequate because the variance between the comparative output per capita levels is not bounded.

Another problem with Bernard and Durlauf's (1995, 1996) definitions is that they do not accommodate conditional convergence. Definition 2 implicitly assumes that the two economies in question have the same technologies and preferences, so that differences in per capita income are purely transitory. We know, however, that each country has different resource endowments, culture, size, and location etc. The assumption of identical steady states for converging economies is, therefore, probably too strong.[19]

5.3. Alternative Definitions

We refine Bernard and Durlauf's (1996) convergence definitions and allow for three types of convergence, divergence, and independence.

Definition 1. Convergence as catching up. Series i and j converge between the dates t and $t+T$ if the disparity between them at t is expected to decrease. If $y_{i,t} > y_{j,t}$ and $E(y_{i,t+T} \mid I_t) > E(y_{j,t+T} \mid I_t)$,

$$E(y_{i,t+T} - y_{j,t+T} \mid I_t) < y_{i,t} - y_{j,t} \tag{5.3}$$

Definition 1.1. Divergence. Series i and j diverge between the dates t and $t+T$ if the disparity between them at t is expected to increase. If $y_{i,t} > y_{j,t}$ and $E(y_{i,t+T} \mid I_t) > E(y_{j,t+T} \mid I_t)$,

$$E(y_{i,t+T} - y_{j,t+T} \mid I_t) > y_{i,t} - y_{j,t} \tag{5.4}$$

Definition 2. Conditional convergence as constancy of long-term forecasts at a fixed time. Series i and j converge if the long-term forecasts of both series are constant and nonzero at a fixed time t,

[19] St Aubyn (1999) and Barro and Sala-i-Martin (1995) allow for a non-zero mean in comparative series when defining convergence. Greasely and Oxley (1998a, 1998b), on the other hand, implicitly relax the zero mean assertion of Bernard and Durlauf's (1996) second definition when outlining their methodology.

$$\lim_{k\to\infty} E(y_{i,t+k} - y_{j,t+k} \mid I_t) = \mu \qquad (5.5)$$

Definition 2.2. Independence (neither convergence or divergence) as stochastic long-term forecasts at fixed time *t*. Series *i* and *j* are independent if the long-term forecasts of the difference between the two series is stochastic at fixed time *t*,

$$\lim_{k\to\infty} E(y_{i,t+k} - y_{j,t+k} \mid I_t) = \mu_t \qquad (5.6)$$

where $\mu_t \sim \mathrm{I}(k)$ and k>0.

Definition 3. Absolute convergence as equality of long-term forecasts at a fixed time. Series *i* and *j* converge if the long-term forecasts of both series are equal at a fixed time *t*,

$$\lim_{k\to\infty} E(y_{i,t+k} - y_{j,t+k} \mid I_t) = 0 \qquad (5.7)$$

Our definitions of convergence have similar empirical implications for the time-series properties of comparative series to those of Bernard and Durlauf (1996). Our definitions, however, are much less restrictive. In particular, our Definition 1 precludes an infinite variance between converging series, and Definition 2 accommodates conditional convergence: Note that Definition 3 is analogous to Bernard and Durlauf's Definition 2.

Definitions 1.1 and 2.2 formalise two types of non-convergence between comparative series; if comparative series don't converge they can diverge (if there is a deterministic trend in comparative series) or be independent (if there is a stochastic trend in comparative series). Thus, we can apply the methodology proposed by Bernard and Durlauf (1996) and Greasley and Oxley (1998a, 1998b) and formally test for three different types of convergence and for divergence.

5.4. Implications For Growth Theory

Recall from Chapter 3 that the neoclassical growth theory motivated by Solow (1956, 1970) and Swan (1956) would suggest that if the two economies had similar growth fundamentals, productivity growth would converge between those two economies. Economies in their long-run steady states according to this model, therefore, must satisfy either Definition 2 (of conditional convergence) or Definition 3 (of absolute convergence). If those economies, however, are in transition to different steady-state levels of productivity, Definitions 1 and 1.1 will be satisfied as there will be a deterministic process 'driving' the economies to their respective steady-states.[20] Thus, with the exception of Definition 2.2, we can interpret all of our definitions as representing implications of the neoclassical growth model.

Recall, however, that there may also be cross-country differences in the fundamental drivers of growth. In this case, we can interpret all of the definitions, with the exception of Definitions 2 and 3, as representing implications of a form of NGT model, where the fundamentals to growth can differ across the economies.

5.5. Methodology[21]

We first difference the series to be tested ($d_t = y_{i,t} - y_{j,t}$) and test for the presence of a unit root in the comparative series using the following Augmented Dickey-Fuller (ADF) regression including a constant and a time-trend (Dickey and Fuller (1981)):[22]

$$\Delta d_t = \beta_0 + \alpha d_{t-1} + \gamma t + \sum_{i=1}^{p} \beta_i \Delta d_{t-i} + \varepsilon_t \tag{5.8}$$

where t is a linear time trend and ε_t is an independently and identically distributed white-noise process. Rejection of the unit root hypothesis (i.e. $\alpha = 0$) is indicative of a form of convergence or divergence, depending on the nature of the deterministic components driving the comparative series. These components are estimated using the following regression equation:

$$d_t = \beta_0 + \gamma t + \varepsilon_t \tag{5.9}$$

Convergence as catching up is implied by a significant trend in the comparative series as in Definition 1. This only holds, however, in the period in which the

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[20] A deterministic process is required to prevent shocks to the comparative series persisting into the forecast horizon.

[21] A schematic representation of the testing procedure is displayed in Figure 5.1 (at the end of this chapter).

[22] We test convergence in levels rather than in logarithms so that productivity differences remain additive in aggregation. The distinction between levels and logarithms is important as non-linear transformations can influence the inferences made in unit-root testing (Francis and McAleer (1998)).

predicted comparative series approaches zero. For example, if the predicted difference between the series changes sign during the sample period, convergence as catching up only occurs for the sub-period where the difference is predicted to approach zero. If the difference is not expected to approach zero, therefore, the two series are defined as divergent.

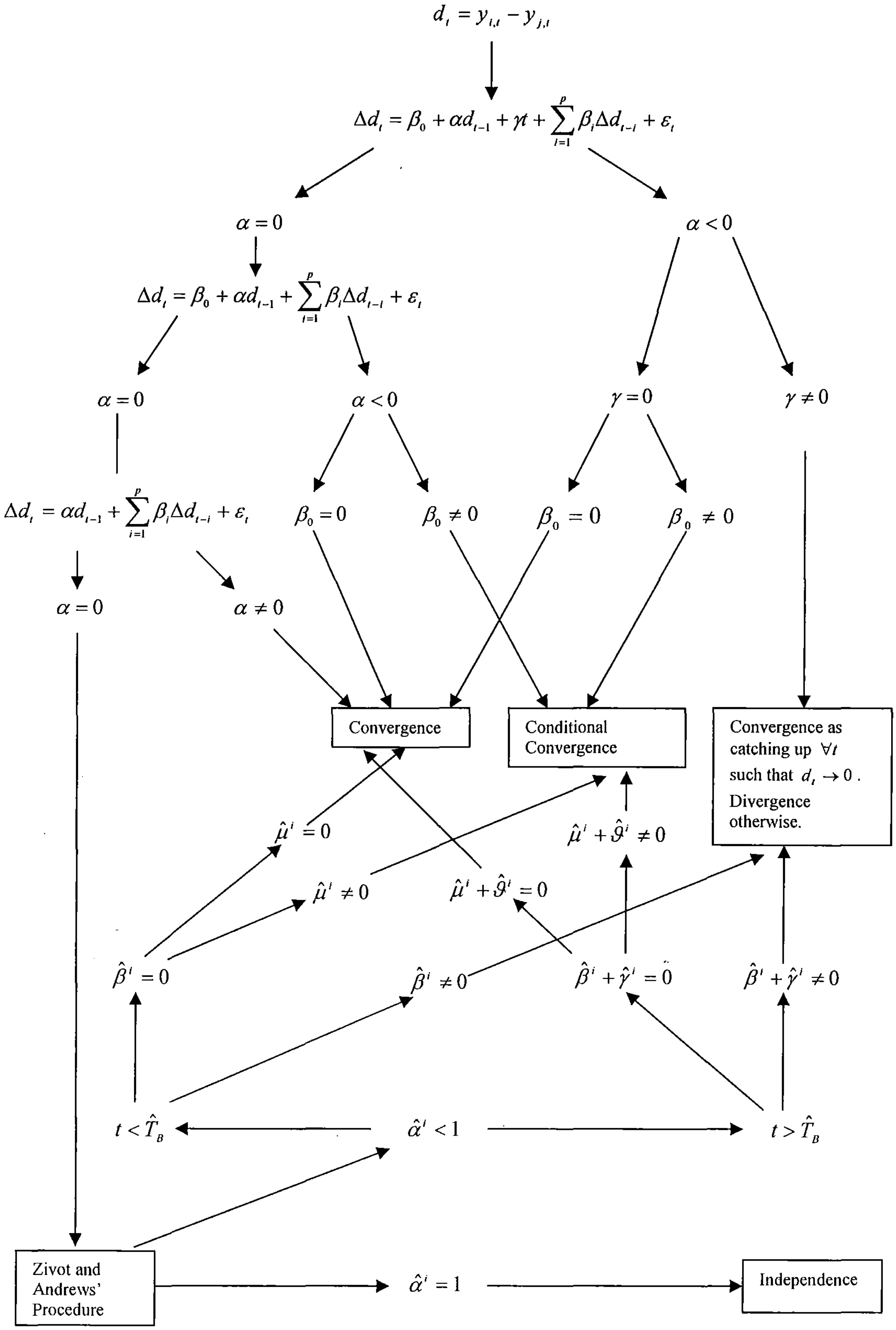
If there is insufficient evidence of a unit root and a time trend in the comparative series, we test for the significance of the constant term; where significance implies conditional convergence. If we cannot reject a zero constant, the 'equality of long-term forecasts' from Definition 3 cannot be rejected and the two series converge in the absolute sense.

Non-rejection of the initial null hypothesis leads to an iterative process in which the deterministic components are systematically excluded from the ADF test.[23] First, we test for a unit root in comparative series using an ADF test with a constant. As above, rejection of the null hypothesis and significant evidence of a constant implies conditional convergence, and rejection of the null and an insignificant constant implicates absolute convergence between the series. Second, if the null hypothesis is not rejected in the ADF test with a constant only, we test for a unit root using an ADF test without any deterministic components. Insufficient evidence of a unit root in the comparative series indicates absolute convergence, and if the null hypothesis cannot be overturned the two series are independent.

Perron (1989) showed that the failure to reject the null hypothesis of a unit root, however, may be a consequence of a structural change in the comparative series, rather than a difference stationary process. Thus, if the null hypothesis cannot be rejected in standard ADF tests, we re-test the series and allow for a single structural break.

[23] Campbell and Perron (1991) show that the exclusion of deterministic components that are in the 'true' data generating process, which are not included in the testing procedure, can cause the power of the test to be reduced. This uncertainty about the deterministic components of the regression leads to an iterative testing procedure if the null hypothesis cannot be overturned (Enders (1995)).

Figure 5.1: The Convergence Testing Procedure[24]



[24] It is apparent that our testing procedure is sequential in nature. Type I errors made in a particular stage of testing will, therefore, carry through to all subsequent stages of the testing procedure. This thesis makes no attempt to correct for this 'pre-testing bias' in the size of our tests.

5.5.1. Structural Change

Perron (1989) showed that a trend stationary series that is subject to an exogenous structural change can be incorrectly classified as having a unit root when using standard ADF tests, which do not account for structural change. He developed a procedure for testing the null hypothesis that a given series has a unit root with drift and an exogenous structural break versus the alternative that the series is stationary about a deterministic trend with an exogenous change in trend function. The key feature of Perron's testing procedure is that the time and nature of the structural change is known by the researcher.

Zivot and Andrews (1992), however, questioned Perron's 'exogenous' assumption and instead treat the structural break as an endogenous occurrence when testing for unit roots; they argue that the break-points selected by Perron were made subjectively on the basis of graphical evidence, rather than being truly exogenous to the testing procedure. Zivot and Andrews, therefore, employ an iterative procedure which tests the null hypothesis of a unit root with drift against the alternative of trend stationarity with a structural change at some unknown point in time.

5.5.2. Testing for Convergence in the Presence of Structural Change

Because conventional unit root tests have low power, rejection of the null hypothesis represents strong evidence in favour of stationarity even in the presence of structural change. Thus, structural change will not have serious implications for those series that are found to be stationary in the above convergence testing methodology.

If the null cannot be overturned, however, the process may be stationary with a structural change (Perron (1989)). Hence, for those comparative series in which we cannot reject the unit root hypothesis, we employ Zivot and Andrews'(1992) iterative procedure to test for a unit root in the presence of an endogenously determined structural change. The procedure we use to determine the breakpoint and to test the unit root hypothesis is outlined below:

- Estimate the following augmented regression equations:

$$\text{Model A: } d_t = \hat{\mu}^A + \hat{\vartheta}^A DU_t(\hat{\lambda}) + \hat{\beta}^A t + \hat{\alpha}^A d_{t-1} + \sum_{j=1}^{k} \hat{c}_j^A \Delta d_{t-j} + e_t \qquad (5.10)$$

$$\text{Model B: } d_t = \hat{\mu}^B + \hat{\beta}^B t + \hat{\gamma}^B DT_t(\hat{\lambda}) + \hat{\alpha}^B d_{t-1} + \sum_{j=1}^{k} \hat{c}_j^B \Delta d_{t-j} + e_t \qquad (5.11)$$

$$\text{Model C: } d_t = \hat{\mu}^C + \hat{\vartheta}^C DU_t(\hat{\lambda}) + \hat{\beta}^C t + \hat{\gamma}^C DT_t(\hat{\lambda}) + \hat{\alpha}^C d_{t-1} + \sum_{j=1}^{k} \hat{c}_j^C \Delta d_{t-j} + e_t$$

(5.12)

where $DU_t(\hat{\lambda}) = 1$ if $t > T\hat{\lambda}$, 0 otherwise; $DT_t(\hat{\lambda}) = t - T\hat{\lambda}$ if $t > T\hat{\lambda}$, 0 otherwise; and $\hat{\lambda}$ is the break fraction, i.e. the time of the break ($\hat{T}_B$) relative to the sample size (T). Models A, B and C are analogous to those proposed by Perron (1989); Model A allows for a change in intercept; Model B allows for a changing trend; Model C allows for both a changing intercept and a changing trend. Following Perron (1989) and Zivot and Andrews (1992), we determine k by working backward from $\bar{k} = 8$ and choosing the first value of k such that the t statistic on $\hat{c}_k = 1.6$ and $\hat{c}_l < 1.6$, where $l > k$.[25]

- The endogenously determined breakpoint ($\hat{T}_B$) is that which corresponds to the minimum test statistic for testing the restriction $\hat{\alpha}^i = 1$ ($t_{\hat{\alpha}^i}$). This test statistic is compared to the left-tail critical values from the asymptotic distribution of $t_{\hat{\alpha}^i}$ computed by Zivot and Andrews (1992) (reprinted in Table 5.1). If the minimum test statistic $t_{\hat{\alpha}^i}$ is less than the critical values in Table 5.1, the comparative series is trend stationary with a single structural change at $\hat{T}_B$ (of a type corresponding to the test statistic minimising model i).

[25] Zivot and Andrews (1992) use a start-lag of 12 to determine k for their quarterly data (and a lag of 8 for annual data). We find little evidence of such long lags in our series, and thus use the start-lag proposed by Perron (1989), i.e. 8.

Table 5.1: Percentage Points of the Asymptotic Distribution of $t_{\hat{\alpha}^i}$ [a]

i	1.0%	2.5%	5.0%	10.0%
A	-5.34	-5.02	-4.80	-3.75
B	-4.39	-4.67	-4.42	-4.11
C	-5.57	-5.30	-5.08	-4.82

a Selected critical values from Zivot and Andrews (1992): Tables 2, 3 and 4.

If a series is found to be stationary with a structural change, it is classified according to the same criteria we use to distinguish between the different types of convergence and divergence above,[26] i.e. significance of $\hat{\beta}^i + \hat{\gamma}^i$ implies convergence as catching-up or divergence: $\hat{\beta}^i + \hat{\gamma}^i = 0$ implies convergence or conditional convergence, depending on the significance of $\hat{\mu}^i$. Comparative series which are found to be non-stationary, on the other hand, are statistically independent. Similar to the above, the deterministic components of the stationary series are estimated using:

$$d_t = \mu^i + \vartheta^i DU_t(\hat{\lambda}) + \beta^i t + \gamma^i DT_t(\hat{\lambda}) + e_t \tag{5.13}$$

5.6. Summary and Implications

In Chapter 3, we found that the neoclassical model predicts cross-country convergence in productivity growth, and that convergence is not necessary in some forms of the NGT growth model. In this chapter, we defined 2 different types of long-run convergence; 2 types of transitional convergence; and independence. With the exception of independence, all of our definitions represent implications of the neoclassical growth model. With the exception of the two types of long-run convergence, on the other hand, we can interpret all of our definitions as being implications of a form of NGT model, where the fundamental drivers of growth are allowed to differ across countries.

We also outlined our procedure for testing for whether a compartive series satisfies our definitions, where significant evidence of a deterministic process 'driving' the series is considered supportive of the neoclassical model. The nature of the process governing the comparative series is tested sequentially using standard unit-root tests and unit-root tests which allow for an endogenously determined structural break.

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[26] See Figure 5.1 for a schematic representation of the testing procedure.

In the next chapter, we apply our definitions and testing methodology to the difference between the Australian and New Zealand market sector productivity aggregates.

Chapter 6

Testing For Convergence: Aggregate, Market Sector

In this chapter, we apply the definitions and testing methodology developed in Chapter 6 to the difference between Australian and New Zealand market sector productivity levels. We find significant evidence of divergence, which does not refute either the neoclassical model, or a type of NGT model. Thus, as argued in Chapters 3 and 5, the divergence indicates either transitional dynamics as the economies convergence to new steady-state levels of productivity, or differences in the fundamental drivers of growth in each country.

6.1. Results

Using the methodology presented in the previous Chapter, we test for convergence between the aggregate productivity series of Australia and New Zealand.[27] We find that the null hypothesis of a unit root is overturned with 5% significance in an ADF test with a constant and a trend (the ADF test statistic is -3.91),[28] thus implying a deterministic process governing the comparative series. From Figure 6.1, [29] we find that the level difference does not tend towards zero over the sample period, with Australian productivity increasing from being approximately 4% higher than New Zealand's the beginning of the sample period to being about 10% higher at the end of the period. The differential between Australian and New Zealand aggregate productivity levels can thus be defined as divergent over the sample period.

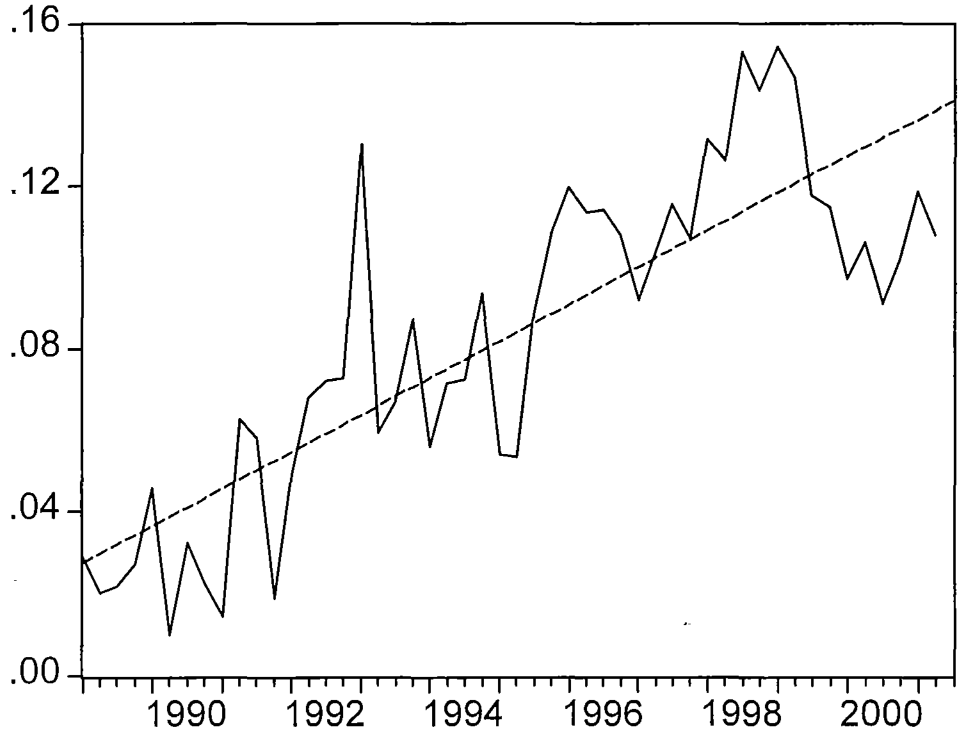
6.2. Summary and Implications

Chapters 3 and 5 show that divergence in comparative productivity levels does not necessarily refute the neoclassical growth model because the deterministic process

[27] Each country's productivity series is computed using the ratio of Tornqvist (1936) output and labour indexes (see Chapter 11 for the details on the construction of these indexes). The indexes are based to 89:Q1 using output and labour indexes corresponding to Equations (9.15) and (9.16).
[28] McKinnon (1996) critical values.
[29] Recall that we test convergence on productivity level differences. For ease of interpretation, however, we display differences in the natural logarithm of productivity; the slope of the trend in this case can be interpreted as the continuously compounding growth differential between the two series, and the value on the vertical axis is an approximation of the proportion by which Australia's productivity is greater than New Zealand's.

driving the comparative series may reflect transitional dynamics as the two countries converge to their new steady-state levels of productivity. In terms of long-term forecasts, however, divergence is not consistent with the implications of the neoclassical growth model, suggesting that other models, perhaps from the NGT literature, may apply in Australia and New Zealand, or even that the two economies do not have similar enough growth fundamentals to be considered comparable. To further gauge these possibilities, we next test whether the any of the industries in Australia and New Zealand can be considered 'representative' of the market sector as a whole, as assumed by the neoclassical growth model.

Figure 6.1: Productivity (log) Difference (Australia-New Zealand)



Chapter 7

Growth Theory: Testing the Assumptions

In Chapter 6, we found that the productivity growth difference between the Australian and New Zealand market sectors may be transitional (as the countries converge to new steady-state levels of productivity) or permanent (as the fundamental drivers of growth in each country are different). The neoclassical growth theory discussed in Chapter 3 and tested in Chapter 6, however, assumes that each firm's productivity is 'representative' of aggregate productivity. In this chapter, we test this assumption using cointegration tests. We find that none of the industries can be considered representative of the market sector in either Australia or New Zealand. In fact, we find more stochastic trends governing industry-level productivity in Australia when compared with New Zealand, thereby suggesting differences in the fundamental drivers of growth across the two countries.

7.1. The Representative Firm

Neoclassical growth theory assumes an aggregate production function, which can considered 'representative' of all firms that exist in a particular economy. If we generalise these assertion to the industry level, where there are k industries (or groups of industries) comprising the market sector, we can test the conditions implicit in standard neoclassical growth theory. If each industry is representative of the aggregate, then it must be the case that:

$$\frac{Y}{X} = \frac{y_i}{x_i} \quad \forall i \in k \tag{7.1}$$

where Y and X are output and labour aggregates, and y and x are industry-level outputs and inputs. If we can assume that the cross-sectional means are time-invariant, simple F-tests for the equality of means across industries can be used to test whether it is appropriate to consider each industry's productivity representative of the market sector. [30] Thus, in this case, we can test:

[30] See, for example, the "equality of means" test in the Eviews package.

$$H_0 : g_1 = g_2 = \cdots = g_k \tag{7.2}$$

where g_i is the (stationary) time-mean of productivity levels from industry or group *i*. This test, however, is somewhat arbitrary since the *k* industries can be redefined so that the resulting industries satisfy (7.1) and (7.2). In any case, if the time dimension of the panel is large, the assumption of time-invariant means may lead to inappropriate inference because, in a growing economy, cross-section means will be non-stationary over longer periods of time.[31]

7.2. A Necessary Condition For the Equivalency of Stochastic Variables Over Time

Engle and Granger (1987) first noted that two or more I(1) series are cointegrated if there is a linear combination of them which is stationary. Implicit in the existence of a long-run equilibrium between cointegrated series is the notion of commonalities in their stochastic trends: Cointegrated series are subject to the same shocks so that an equilibrium relationship, defined by a cointegrating vector, holds in the long-run. In our case, therefore, if (7.1) and (7.2) are to hold overtime it is necessary that all of the variables follow a single stochastic trend, regardless of how they are aggregated (linearly) (Stock and Watson (1988)). This has the further implication of *k*-1 cointegrating vectors in the system of *k* variables being tested.

We know from Chapter 3 that the neoclassical growth model assumes a constant rate of growth of productivity (*g*) in the steady state. By assuming that the representative industry is in its steady-state, therefore, we can model its time-path as a random walk with a deterministic drift-term representing growth in the steady-state, i.e. we can describe the time-path of industry *i*'s productivity as:

$$\Delta\left(\frac{y_{it}}{x_{it}}\right) = g_i + v_{it} \tag{7.3}$$

[31] The problem of non-stationarity may be avoided by re-interpreting (7.2) in terms of mean growth rates, which, if the levels of the variables concerned are I(1), will be stationary. The equivalency of mean growth rates over the sample period can thus be tested using an F-test. Similar to the case with the levels, however, the industries can be arbitrarily re-defined so that (7.2) is satisfied in terms of growth.

where v_t is an independently identically distributed white noise process. The necessary condition for the growth rate analogue of (7.3) to be satisfied, therefore, is:[32]

$$v_{1t} = v_{2t} = \cdots = v_{kt} = v_t \tag{7.4}$$

which further implies k-1 cointegrating vectors within a system of k variables.

7.3. Testing For Cointegration

We test for cointegration using Johansen's (1988) maximum likelihood technique. Johansen showed that a Vector Autoregressive (VAR) model of the form:

$$z_t = A_0 + A_1 z_{t-1} + \cdots + A_p z_{t-p} + \mu_t \tag{7.5}$$

where x_t = the $(n \times 1)$ vector of variables

A_0 = an $(n \times 1)$ vector of intercept terms

A_i = $(n \times n)$ matrices of coefficients

μ_t = the $(n \times 1)$ vector of error terms

could be represented as the following Vector Error Correction Mechanism (VECM):

$$\Delta z_t = A_0 + \pi z_{t-p} + \sum_{i=1}^{p-1} \beta_i \Delta z_{t-i} + \mu_t \tag{7.6}$$

where $\pi = -(I - \sum_{i=1}^{p} A_i)$

$$\beta_i = -(I - \sum_{j=1}^{i} A_j)$$

Johansen further showed that the rank of the matrix π represents the number of cointegrating vectors r amongst the variables in the vector z. Johansen (1995)

[32] Norrbin (1995) similarly tests the possibility of a single stochastic trend, which he refers to as 'technology', governing the time-path of disaggregated US industry production data.

extended his previous work by considering five variations of the above model, each with different assumptions regarding the deterministic terms in the cointegrating relations. We have assumed a drift term and a deterministic trend in (7.3), precluding a non-zero trend in our system. In addition, we relax the nature of the long-run relationship between the variables and include a trend in the cointegrating space.[33] The VECM we wish to test, therefore, allows a constant and a trend in the cointegrating space, and an unrestricted trend in the VAR. The VAR in each country can then be written as:

$$p_t = A_0 + A_1 t + A_1 p_{t-1} + \cdots + A_q p_{t-q} + \varepsilon_t \tag{7.7}$$

where p_t = the $(k \times 1)$ vector of productivity levels

A_0 = an $(k \times 1)$ vector of intercept terms

A_1 = an $(k \times 1)$ vector of deterministic trends

A_k = are $(k \times k)$ matrices of coefficients

ε_t = the $(k \times 1)$ vector of error terms

The VECM with unrestricted intercepts and restricted trends in the cointegrating space then becomes:

$$\Delta p_t = \beta_0 + \alpha(\beta' p_{t-k} + \gamma t) + \sum_{j=1}^{k-1} \beta_j \Delta p_{t-j} + \varepsilon_t \tag{7.8}$$

where $\alpha\beta' = \pi = -(I - \sum_{j=1}^{k} A_j)$

$\beta_i = -(I - \sum_{m=1}^{k} A_m)$

[33] Deterministic cointegration renders I(1) variables stationary. Stochastic cointegration, on the other hand, requires only trend stationarity amongst linear combinations of variables; stochastic cointegration is discussed in Perron and Campbell (1993). Testing for stochastic cointegration requires restricting trends to the cointegrating space (Johansen (1995)).

and α and β are $(k \times r)$ vectors of the speed of adjustment coefficients and cointegrating parameters , respectively: Notice also that γ is a $(r \times 1)$ vector.

7.4. Estimation

Before testing for cointegration within a system of variables, we must first determine the lag length (q) of our VAR. As first noted by Granger and Newbold (1974), the distributions of estimated parameters for non-stationary series are non-standard. We, therefore, cannot test hypotheses concerning the number of lags using conventional testing procedures. Instead, the optimal lag length q is chosen as the number of lags in the VAR model (Equation (7.7)) which minimises the Swartz-Bayesian Information Criterion (SBC) for the Australian and New Zealand productivity systems;[34] the results are displayed in Table 7.1. We find that the SBC is minimised in a VAR with a lag length of 1 in all cases.

Table 7.1: Lag Length (q) Suggested by SBC

Lag Length	Australia	New Zealand
0	-54.09	-54.48
1	-58.13*	-54.37*
2	-54.49	-55.43
3	-57.28	-55.74

* Minimises the SBC

The number of lagged differences of the variables to be included in the VECM for each system is q-1 (Equation (7.10)). The results in Table 7.1 suggest, therefore, that our VECMs for the 2 systems include at least one lagged difference of each endogenous variable. The cointegration trace test statistics from maximum likelihood estimation of the VECM with one lag of the differenced endogenous variables included are displayed in Table 7.2.[35]

There is significant evidence (at the 5% level) of a maximum of 3 cointegrating vectors governing Australia's industry-level productivity, and 8 cointegrating vectors

[34] The SBC generally chooses shorter lag lengths than other information criterion (see Ender (1995) for a discussion). We choose this criterion because our lag length is limited by a small sample size.
[35] The trace statistic tests the null hypothesis of a number of vectors less than r against a general alternative. The maximal eigenvalue statistic, on the other hand, tests the null hypothesis of a number of vectors of less than r against a specific alternative hypothesis of r+1 vectors. Given the restricted nature of the alternative hypotheses in maximal eigenvalue tests, it is not surprising that the number of cointegrating vectors revealed by the statistic is generally less than the number implied by the trace statistic. We maximise the possibility of retaining our null hypothesis by testing using trace statistics: For a further discussion of these two tests see Enders (1995).

governing New Zealand's productivity. This has the further implication that productivity follows at least 8 stochastic trends in Australia and 3 stochastic trends in New Zealand (Stock and Watson (1988)).[36]

Table 7.2: Johansen Cointegration Tests for the Australia and New Zealand

H(0)	Australia	New Zealand
$r = 0$	422.2**	485.7**
$r \leq 1$	327.4**	373.2**
$r \leq 2$	243.3**	291.3**
$r \leq 3$	179.5	224.7**
$r \leq 4$	124.0	175.5**
$r \leq 5$	84.0	132.7**
$r \leq 6$	59.6	97.8**
$r \leq 7$	37.9	66.2*
$r \leq 8$	22.2	40.5
$r \leq 9$	11.2	22.6
$r \leq 10$	3.5	7.9

** Significant at the 1% level.
* Significant at the 5% level.

7.5. Summary and Implications

There are eleven industries which comprise the market sectors of Australia and New Zealand. Standard neoclassical growth theory assumes that the evolution of productivity in these industries is determined by a single process in the long-run. The evidence supporting this assumption does not seem to hold empirically for our sample period. Moreover, since productivity has less cointegrating vectors in Australia than in New Zealand, we can say that there are more stochastic sources of productivity growth in the Australian market sector when compared with New Zealand. It appears, therefore, that the productivity divergence at the market sector level may not be due to a general divergence across all industries, but rather a confusing mixture of growth outcomes from each of those industries.

In the next chapter, we further explore this possibility by testing for convergence between Australia and New Zealand across similarly defined industries.

[36] Stock and Watson showed that the number of stochastic trends in a system of variables is the number of variables in that system minus the number of cointegrating relationships between the variables in the system. The number of stochastic trends in a system of stochastic variables is simply the number of variables in which each variable in the system can be expressed.

Chapter 8

Testing for Convergence: Industry-level Results

Cointegration testing from Chapter 7 reveals that none of the eleven industries which comprise the market sectors of Australia or New Zealand are 'representative' of the market sectors as a whole. In particular, we find that the divergence at the market sector level may not be due to a general divergence across all industries, but rather a confusing mixture of growth outcomes from each of those industries. In this chapter, we test for convergence at the industry-level using our definitions and testing methodology from Chapter 5. As suggested by Chapter 7, we find a multitude of different growth outcomes across the industries, thereby further questioning the comparability of the fundamental drivers of growth between Australia and New Zealand.

8.1. Results

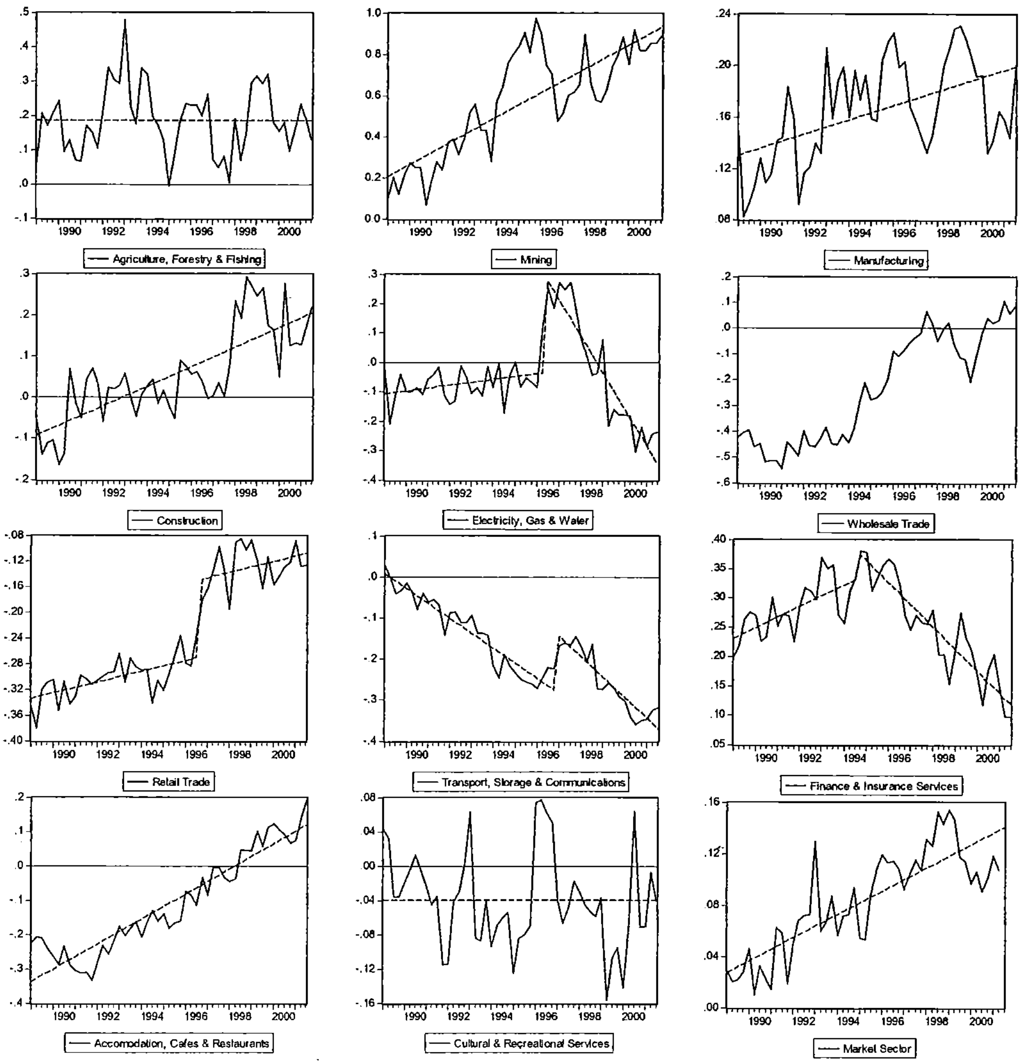
We test for convergence using the definitions and methodology proposed in Chapter 5. Table 8.1 displays the results of the ADF convergence tests for comparative productivity between the Australian and New Zealand industries. We find that all comparative industries, with the exception of Electricity, Gas and Water; Wholesale Trade; Retail Trade; Transport, Storage and Communication; and Finance and Insurance Services, are governed by deterministic processes according to ADF tests. If we allow for an endogenously determined structural change, however, only the comparative productivity in the Wholesale Trade industry can be classified as stochastic (Table 8.2).

Figure 8.1 displays the comparative (log) productivity of all of the industries which comprise the market sectors of Australia and New Zealand, along with the significant deterministic components of those series (Table 8.4).[37] We find that there is a general trend of faster productivity in the Australian industries, as we would expect from our previous analysis, but the relative growth outcomes of the industries

[37] For ease of interpretability, the deterministic components are estimated and displayed using differences in the natural logarithm of productivity from each industry (see Footnote 25). This does not affect the classification of the comparative productivity levels according to similar estimates made using comparative levels of productivity.

are diverse. We thus analyse each of the comparative industries in turn, and classify them according to the nature of their deterministic components (Table 8.3): We define the productivity leader is the country with higher productivity in a given industry, and the absolute size of the coefficient attached to the deterministic time trend reflects the speed of the convergence (divergence) process.

Figure 8.1: Productivity (log) Differences (Australia-New Zealand)



8.1.1. Agriculture, Forestry and Fishing

Evidence from the 1990s suggests that Australian and New Zealand productivity in the Agriculture, Forestry and Fishing industry have generally grown at a constant rate, i.e. there is no trend in the comparative series. Australia's productivity level is

(18.6%) higher on average than that of New Zealand so that this industry satisfies the definition of conditional convergence, where Australia is the productivity leader.

Table 8.1: Convergence Test Statistics for Cross-Country Differences in Productivity(Australia-New Zealand)[a]

	ADF Test Statistics		
Industry	Deterministic Components in ADF Test		
	Trend and Constant	Constant	None
Agriculture, Forestry & Fishing	-4.14*		
Mining	-3.57*		
Manufacturing	-3.66*		
Electricity, Gas & Water	-1.94	-1.77	-1.53
Construction	-4.11*		
Wholesale Trade	-2.68	-0.53	-1.41
Retail Trade	-3.18	-1.55	-1.27
Accommodation, Cafes & Restaurants	-3.58*		
Transport, Storage & Communication	-2.51	-0.84	1.05
Finance & Insurance Services	-0.34	-2.45	-0.37
Cultural & Recreational Services	-4.31**		
Market Sector	-3.91*		

a The number of lagged differences in the ADF tests (*p*) is chosen to maximise the SBC.
** Significant at the 1% level according to MacKinnon (1996) critical values.
* Significant at the 5% level according to MacKinnon (1996) critical values.

8.1.2. Mining

Australia's productivity level is (21.0%) higher than that of New Zealand at the beginning of the sample period. Thus, given the positive deterministic trend in the comparative series, the Mining industry satisfies the definition of divergence. The coefficient attached to the deterministic trend is the largest of those displayed in Table 8.4, with the exception of the Electricity, Gas and Water industry (following 1996:Q2), indicating relatively fast divergence in productivity levels across the Mining industries; divergence occurs at a rate of 1.5% per quarter. By the end of the sample period, Australia's productivity is approximately 90% higher than New Zealand's.

8.1.3. Manufacturing

Similar to the Mining industry, productivity in the Manufacturing industry in Australia began (13.0%) higher than in New Zealand, and remained higher for the entire sample period, so that this industry fits the definition of divergence. Table 8.4 shows that the speed of this divergence, however, is the slowest of those displayed (0.1% per quarter).

Table 8.2: Zivot and Andrews' Minimum Test Statistics[a]

Industry	$\hat{T}_B$	$t_{\hat{a}^1}$
Electricity, Gas and Water	1996:2	-6.55**
Wholesale Trade	1995:3	-4.43
Retail Trade	1996:3	-5.91**
Transport, Storage & Communication	1996:4	-4.59*
Finance & Insurance Services	1994:3	-6.01**

a All minimum test statistics displayed are from Model C (see Appendix A).
** Significant at the 1% level according to critical values in Table 5.2.
* Significant at the 10% level according to critical values in Table 5.2.

8.1.4. Electricity, Gas and Water

New Zealand's productivity was (11.0%) higher in the Electricity, Gas and Water industry until 1996, with Australia catching up to New Zealand at the relatively low rate of 0.3% per quarter. Following 1996, however, there was a substantial increase, 23.5%, in the relative levels of productivity, making Australia the productivity leader until 1998. From 1996 to the end of the sample period, New Zealand's productivity growth out-striped that of Australia, with the deterministic process defined to be convergence as catching up until 1998, and divergent for the remainder of the sample period; the rate of the divergence is 3.1% per quarter, the fastest any of the processes displayed in Table 8.4. In fact, by the end of the sample period, Australia's productivity was approximately 40.0% lower than New Zealand's.

Table 8.3: The Classification of Comparative Productivity

Industry	Classification	Period
Agriculture, Forestry & Fishing	Conditional Convergence	1989:1 to 2001:3
Mining	Divergence	1989:1 to 2001:3
Manufacturing	Divergence	1989:1 to 2001:3
Electricity, Gas & Water	Conditional Convergence	1989:1 to 1996:2
	Convergence as Catching up	1996:3 to 1998:3
	Divergence	1998:4 to 2001:3
Construction	Convergence as Catching up	1989:1 to 1992:4
	Divergence	1993:1 to 2001:3
Wholesale Trade	Independence	1989:1 to 2001:3
Retail Trade	Convergence as Catching up	1989:1 to 1995:3
Accommodation, Cafes & Restaurants	Convergence as Catching up	1989:1 to 1998:1
	Divergence	1998:2 to 2001:3
Transport, Storage & Communication	Convergence as Catching up	1989:1 to 1989:1
	Divergence	1989:2 to 2001:3
Finance & Insurance Services	Divergence	1989:1 to 1994:3
	Convergence as Catching up	1994:4 to 2001:3
Cultural & Recreational Services	Conditional Convergence	1989:1 to 2001:3
Market Sector	Divergence	1989:1 to 2001:3

8.1.5. Construction

New Zealand is the productivity leader in the Construction industry at the beginning of the sample period with its productivity 9.0% higher than Australia's. The deterministic process governing the comparative series, however, indicates convergence as catching up until 1992, when Australia becomes the productivity leader, and divergence thereafter. The rate at which the industries diverge, 0.6%, is faster than that seen in market sector productivity.

8.1.6. Wholesale Trade

There is little evidence of a deterministic trend in comparative productivity of the Wholesale Trade industry. Thus, according to our definitions of convergence, the cross-country productivity differential of this industry can be classified as independent. Looking at Figure 8.1, however, suggests a positive drift in the comparative series so that, although the process is not deterministic, we can say that Australia becomes the productivity leader over the sample period. This shift in relative productivity levels is one the most substantial of those displayed given that Australia's productivity was approximately 40.0% lower than New Zealand's at the beginning of the period.

Table 8.4: The Deterministic Components of the I(0) Series[a]

		$d_t = \mu + \vartheta DU_t(\hat{\lambda}) + \beta t + \gamma DT_t(\hat{\lambda}) + e_t$			
	$\hat{T}_B$	μ	ϑ	β	γ
Agriculture, Forestry & Fishing		0.186159			
Mining		0.208270		0.014511	
Manufacturing		0.130376		0.001383	
Electricity, Gas & Water	1996:2	-0.107366	0.342313	0.002476	-0.033426
Construction		-0.092281		0.005941	
Retail Trade	1996:3	-0.334218	0.120170	0.002131	
Accommodation, Cafes & Restaurants		-0.337034		0.009152	
Transport, Storage & Communication	1996:4	0.007701	0.142473	-0.009128	-0.003339
Finance & Insurance Services	1994:3	0.230750	0.051090	0.004566	-0.014005
Cultural & Recreational Services		-0.039401			
Market Sector		0.027555		0.002266	

a All coefficient estimates displayed are significant at the 5% level according to the t-distribution, with standard errors adjusted for autocorrelation and heteroskedasticity (Newey and West (1987)). Those coefficients that were found to be insignificant were removed from the estimation.

8.1.7. Retail Trade[38]

New Zealand is the productivity leader in the Retail Trade industry for the entire sample period. The deterministic process is classified as convergence as catching up over the period, indicating relatively strong growth in Australian productivity. Although the speed of the catch-up process is the second lowest of those displayed in Table 8.4, relative productivity was boosted by a one-off increase of 12.0% in 1996 favouring Australia.

8.1.8. Accommodation, Cafes and Restaurants

New Zealand begins the sample period as the productivity leader in the Accommodation, Cafes and Restaurants industry, but is overtaken by Australia in 1998. The deterministic process in the comparative series is classified as catching up in the period until 1998, and as divergence from 1998 until the end of the sample period. The speed of divergence, 0.9%, is above the speed of the market sector productivity divergence. The shift in productivity levels in this industry is relatively large; Australia's productivity level is approximately 30% less than New Zealand's at the beginning of the period and is more than 10% higher than New Zealand's at the end of the period.

8.1.9. Transport, Storage and Communication

Australia begins the sample period as the productivity leader in this industry, but is overtaken by New Zealand after just one quarter. The comparative series thus displays convergence as catching up for one quarter in 1989, and divergence thereafter. The rate at which the comparative series are diverging by the end of the period is the third fastest, -1.2%, of those displayed in Table 4. The divergent process, however, is interrupted by a one-off increase in relative productivity levels of 14.2% favouring Australia: This was followed by a resumption of the divergence process at a rate greater than prior to the break. The shift in productivity levels of this industry is large, with Australia beginning as the productivity leader and having 40% less productivity than New Zealand at the end of the sample period.

[38] Notice that the Zivot and Andrews testing procedure shows a change in intercept and a change in slope for testing for a unit-root in the Retail Trade differential. When estimating the deterministic components of this series, however, the changing trend is found to be insignificant at the 5% level.

8.1.10. Finance and Insurance Services

Australia is the productivity leader for the entire sample period in the Finance and Insurance Services industry, with Australian productivity being approximately 20.0% higher than New Zealand's in 1994. The deterministic process is classified as divergent in the period to 1994 and as convergence as catching up thereafter. The rates of the divergence and catching up processes are 0.4% and -0.94% respectively, so that the rate of the catch-up following 1994 is greater than the rate of the initial divergence.

8.1.11 Cultural and Recreational Services

New Zealand is the productivity leader for the entire sample period in the Cultural and Recreational Services industry with productivity levels 4.0% higher in New Zealand on average.

8.2. Summary and Implications

In Chapter 3, we found that the neoclassical growth model of Solow (1956,1970) and Swan (1956) predicts convergence between countries with similar long run fundamentals. At the industry level, the model thus predicts convergence across industries with similar fundamentals. When we test the theory at the industry level across Australia and New Zealand, however, only the Agriculture, Forestry, and Fishing and Cultural Recreational Services industries display conditional convergence over the entire sample period. The remainder of the industries, with the exception of Wholesale Trade (whose comparative productivity series is defined as independent), are evolving according to deterministic processes, with some defined catching up, others as divergent, and some as both catching up and divergent. In most of the industries which comprise the market sector, therefore, we cannot refute either the neoclassical model, or a form of NGT model where the fundamental drivers of growth across the two countries are different.

As suggested by the cointegration analysis in Chapter 7 we thus find a number of trends driving the divergence of productivity at the market sector level. As to the existence of steady-state levels of productivity specific to each industry, this implies that the transition to those steady-state levels is far from complete in most of the industries. If, however, the fundamental drivers of growth are different across the industries, the growth differentials we see in our short sample period may persist into the long-run. It is thus unclear how, and by how much, each of the industries contribute to the market sector divergence from the cointegration and convergence analyses.[39]

To aid us in understanding how each industry influences aggregate productivity growth, we require a decomposition of aggregate growth into its industry-level contributors. Thus, the next chapter discusses some conventional methods of decomposing aggregate productivity growth.

[39] We can, however, say the convergent industries, Agriculture, Forestry, and Fishing and Cultural Recreational Services, have contributed little (if any) to the market sector divergence.

Chapter 9

Aggregation and Decomposition: Some Issues[40]

Chapter 8 found a large number of different growth outcomes across the Australian and New Zealand industries. This chapter discusses some conventional methods of decomposing aggregate productivity growth which allow us to quantify the sources of aggregate growth. We find that the conventional decompositions make some assumptions in aggregation. We also find that, unless certain conditions are met, aggregate and disaggregate productivity can be considered distinct concepts, which require separate analyses.

9.1. Conventional Decompositions

Over the last decade many researchers have sought to allocate aggregate productivity growth between the industries and firms from which the aggregate is comprised.[41] The common start-point for many of these decomposition methods is to aggregate individual firms, using a weighted average of each firm's productivity level (or the natural logarithm of each firm's productivity level). Aggregate productivity (P) over n firms is thus initially expressed as:

$$P = \sum_{i \in n} \vartheta_i \, p_i \qquad (9.1)$$

where the weights (ϑ) applied to each firm's productivity (p) are the corresponding firm's share of an (output or input) aggregate.[42]

If we assume that the size and composition of n can change over time, the change in productivity between periods 0 and 1 can be written as:

[40] Most of the discussion about conventional productivity decomposition methods follows a similar exposition in Balk (2001). Also see Fox (2002) for a more a diverse range of productivity decompositions than those discussed here. In Chapters 9 and 10, 'productivity' is referred to as either TFP or labour productivity.
[41] Haltiwanger (2000, 2002) and Ahn (2001) summarize the results so-far.
[42] It is usually the case that the researcher uses output shares as weights when analysing TFP (Haltiwanger (1997)), and labour shares when analysing labour productivity (Griliches and Regev (1995); Baily et al (2001); and Bland and Will (2002), for example).

$$\Delta P^{0,1} = \sum_{i \in C} \vartheta_i^1 p_i^1 - \sum_{i \in C} \vartheta_i^0 p_i^0 + \sum_{i \in E} \vartheta_i^1 p_i^1 - \sum_{i \in EX} \vartheta_i^0 p_i^0 \tag{9.2}$$

where C denotes continuing firms that exist in both periods, E denotes firms that enter in period 1, EX denotes firms that exit in period 0, and the weights (ϑ) sum to 1 in both periods. This expression can be re-written as either:

$$\Delta P^{0,1} = \sum_{i \in C} \Delta \vartheta_i^{0,1} p_i^0 + \sum_{i \in C} \vartheta_i^1 \Delta p_i^{0,1} + \sum_{i \in E} \vartheta_i^1 p_i^1 - \sum_{i \in EX} \vartheta_i^0 p_i^0 \tag{9.3}$$

or:

$$\Delta P^{0,1} = \sum_{i \in C} \Delta \vartheta_i^{0,1} p_i^1 + \sum_{i \in C} \vartheta_i^0 \Delta p_i^{0,1} + \sum_{i \in E} \vartheta_i^1 p_i^1 - \sum_{i \in EX} \vartheta_i^0 p_i^0 \tag{9.4}$$

depending on the base period chosen for the index.[43] The first term in both expressions is the 'between' component that reflects changing shares, and the second term represents the 'within' component, reflecting productivity change. This leaves the researcher with a choice between two, equally valid, methods of allocating productivity changes between economic units. It is possible, however, to avoid the choice between which of the two decompositions to use by re-writing either of these expressions as:

$$\Delta P^{0,1} = \sum_{i \in C} \Delta \vartheta_i^{0,1} p_i^0 + \sum_{i \in C} \vartheta^0 \Delta p_i^{0,1} + \sum_{i \in C} \Delta \vartheta_i^{0,1} \Delta p_i^{0,1} + \sum_{i \in E} \vartheta_i^1 p_i^1 - \sum_{i \in EX} \vartheta_i^0 p_i^0 \tag{9.5}$$

Thus productivity can be decomposed into between effects, within effects, and a cross-term, which accounts for changes in both share and productivity changes. Because the initial and end period shares add up to one, we can enter an arbitrary scalar a into (9.5).

$$\begin{aligned} \Delta P^{0,1} &= \sum_{i \in C} \Delta \vartheta_i^{0,1} (p_i^0 - a) + \sum_{i \in C} \vartheta^0 \Delta p_i^{0,1} + \sum_{i \in C} \Delta \vartheta_i^{0,1} \Delta p_i^{0,1} \\ &\quad + \sum_{i \in E} \vartheta_i^1 (p_i^1 - a) - \sum_{i \in EX} \vartheta_i^0 (p_i^0 - a) \end{aligned} \tag{9.6}$$

[43] Equation (9.4) is analogous to the decomposition proposed by Baily et al (1992).

This leads us to a productivity decomposition analogous to that proposed by Haltiwanger (1997), where a is chosen as the initial level of aggregate productivity (P), i.e:

$$
\begin{aligned}
\Delta P^{0,1} = &\sum_{i\in C} \Delta \vartheta_i^{0,1} (p_i^0 - P^0) + \sum_{i\in C} \vartheta^0 \Delta p_i^{0,1} + \sum_{i\in C} \Delta \vartheta_i^{0,1} \Delta p_i^{0,1} \\
&+ \sum_{i\in E} \vartheta_i^1 (p_i^1 - P^0) - \sum_{i\in EX} \vartheta_i^0 (p_i^0 - P^0)
\end{aligned}
\tag{9.7}
$$

Another method of decomposing productivity which avoids the problems associated with the choice between (9.3) and (9.4) is to take the arithmetic mean of productivity over the initial and end periods following Bennet (1920).[44] In this case, (9.3) and (9.4) can be re-written as:

$$
\Delta P^{0,1} = \sum_{i\in C} \Delta \vartheta^{0,1} \frac{1}{2}\left(p_i^1 + p_i^0\right) + \sum_{i\in C} \frac{1}{2}\left(\vartheta_i^1 + \vartheta_i^0\right)\Delta p_i^{0,1} + \sum_{i\in E} \vartheta_i^1 p_i^1 - \sum_{i\in EX} \vartheta_i^0 p_i^0 \tag{9.8}
$$

Notice that the averaging of shares and productivity levels avoids the need for the cross-term seen in (9.5). Similar to (9.7), we can also add a scalar into some of the terms in (9.8), a natural choice is aggregate productivity averaged over the two periods.

Foster et al (1998) find the decomposition with the cross-term effects more appealing than the decompositions that average initial and end period shares and productivity: For example, the decompositions without the cross-term confound within effects and between effects, since both effects incorporate a share or productivity level from the second period. Measurement considerations, however, suggest the decomposition without the cross-term is preferred (Haltiwanger (2000, 2001)).[45] It becomes apparent that there is no unique decomposition of productivity change defined by (9.2). This leads us to Balk's (2002) conclusion that " the outcome of any decomposition exercise will depend to some extent on the particular expression favoured by the researcher."

[44] See, for example, Grilliches and Regev (1995); Bernard and Jones (1996), with a decomposition to industry-level; and Baily et al (2001). Diewert (1998) shows that the Bennet indicator approximates any superlative indicator (such as Fisher (1922) or Tornqvist (1936)), under certain conditions.
[45] This decomposition is less sensitive to random measurement errors.

9.2. A Critique

Consider (9.1), the start-point for all of the productivity decompositions discussed in the preceding section. By making explicit the share (ϑ) and productivity (p) variables in this equation, it can be written as either:

$$P = \sum_{i \in n} \frac{x_i}{X} \frac{y_i}{x_i} \tag{9.9}$$

with shares based on inputs, or, as:

$$\ln(P) = \sum_{i \in n} \frac{y_i}{Y} \ln\left(\frac{y_i}{x_i}\right) \tag{9.10}$$

with output-based shares and the natural logarithm of productivity replacing the productivity levels in (9.1):[46] Note that y_i and x_i are firm-level output and input indexes respectively,[47] and:

$$Y = \sum_{i \in n} y_i \tag{9.11}$$

and:

$$X = \sum_{i \in n} x_i \tag{9.12}$$

Now consider assumptions implicit in (9.9) and (9.10). Re-writing these expressions yields:

$$P = \sum_{i \in n} \frac{y_i}{X} \tag{9.13}$$

[46] This is analogous to the aggregation implicit in Haltiwanger (1997).

[47] The output concept is typically either real value added or real gross output, we make no distinction. The shares can be derived from either nominal or real aggregates; for example, the share of firm i in the industry aggregate could be industry i's share of nominal output or real output. This exposition uses shares of real industry aggregates in all cases, without loss of generality. The implications of using nominal shares are discussed later in the chapter.

with shares based on inputs (Equation (9.9)), and:

$$P = \prod_{i \in n} \left(\frac{y_i}{x_i} \right)^{\vartheta_{yi}} \tag{9.14}$$

where ϑ_{yi} is firm i's share of aggregate output (Equation (9.10)).

We know that an aggregate productivity index is the ratio an output index to an index of inputs. The output and input indexes implied by (9.14), a multiplicative aggregation, are:

$$Y_G = \prod_{i \in n} y_i^{\vartheta_{yi}} \tag{9.15}$$

and:

$$X_G = \prod_{i \in n} x_i^{\vartheta_{yi}} \tag{9.16}$$

which are the share weighted geometric means of firm-level outputs and inputs, respectively. It is evident that the multiplicative aggregation implied by the logarithmic forms of the conventional productivity decomposition confounds output and input variables in aggregation so that its corresponding productivity aggregate is the ratio of an output index to a less than ideal input index; firm-level inputs are weighted with output shares.[48] This is not desirable, unless, of course, output shares and input shares are equal.[49] In contrast, the additive aggregation method (Equation (9.12)), leads to a productivity index which is the ratio of intuitively appealing output and input indexes (Equations (9.11) and (9.12)). This aggregation, however, also makes an important assumption when aggregating firm-level productivity.

A potential problem when aggregating according to (9.12) is that the inputs specific to each firm can no-longer be distinguished. Instead, all input variables are included as part of the input aggregate (*X*). Changes in the inputs used by a particular firm will, therefore, show up as changes in the input aggregate, thereby providing misleading results when allocating productivity changes amongst firms if the inputs of

[48] Notice that the converse applies for input share-weighted multiplicative indexes.
[49] This is discussed later in the chapter.

each firm do not grow at the same rate. Essentially, the input aggregate is considered representative of each firm's input in this aggregation.

Consider, for example, a case where the inputs used by one of the n firms which comprise an industry increases, ceteris paribus. When aggregate productivity change is subsequently allocated to each of the firms as in (9.2), the increase in inputs is divided amongst the n firms. The aggregate productivity reduction induced by the rise in the aggregate input is, therefore, divided amongst each of the firms, even if they exit the industry over the period. In this case, the aggregate productivity reduction originated in only one of the firms, yet the productivity change decomposition attributes the reduction to each of the n firms. This is a consequence of the share-weighting of firm-level productivity levels at the outset of the decomposition; a reduction in the share of the input aggregate for one firm implies an increase in the shares of all other firms, because the shares must always sum to one by assumption.

The above highlights some important short-comings with aggregating productivity levels according to weighted averages of firm-level productivity levels; if output shares are used as weights as in the multiplicative aggregation, the initial aggregation does not yield an intuitively appealing measure of productivity unless output shares and input shares are equal, and in additive aggregations with input-weighted productivity levels, the aggregate input is considered representative of each individual firm's input.[50]

Under what circumstances does aggregating firm-level productivity imply an intuitively appealing productivity measure? The answer to this question depends on whether the shares used to weight the productivity levels of each firm are in nominal or real terms.

9.2.1. Nominal Shares

Letting p be a firm specific price index; P be the aggregate price index; w be a firm-level input cost index; and W be the aggregate input cost index, each firm's share of

[50] Fox (2002) notes some further problems associated with the conventional aggregate productivity decompositions. He shows that aggregates formed can be misleading because the shares used to weight firm level productivity are allowed to change between periods 0 and 1. The resulting index, therefore, confounds productivity changes with share changes and thus does not satisfy the monotonicity test from index number theory (Diewert (1992)): Monotonicity requires that increases in quantities between two periods yield an increase the index aggregating those quantities.

nominal activity becomes:

$$\frac{p_i y_i}{PY} \tag{9.17}$$

for an output share, and:

$$\frac{w_i x_i}{WX} \tag{9.18}$$

for an input share.

For the nominal analogues of (9.9) and (9.10) to create productivity measures that are a ratio of output to input indexes specific to each firm, then it must be the case that:

$$\frac{W}{w_i} X = x_i \quad \forall i \in n \tag{9.19}$$

in additive decompositions (Equation (9.9)), and:

$$\frac{w_i P}{p_i W} \frac{Y}{X} = \frac{y_i}{x_i} \quad \forall i \in n \tag{9.20}$$

in multiplicative decompositions (Equation (9.10)).[51]

9.2.2. Real Shares

Real shares impose a greater restriction on the implied levels of inputs and productivity; real shares effectively assume price equality across all firms. From (9.13) and (9.14), it is apparent that conventional additive decomposition assumes that the aggregate input is representative of each firm's input, i.e. it assumes:

$$X = x_i \qquad \forall i \in n \tag{9.21}$$

If the multiplicative decomposition (Equation (9.14)), on the other hand, is to yield an

[51] Notice that our critique of the conventional decompositions still holds when nominal shares are used: The additive decomposition assumes that the firm i's input is a proportion of the aggregate input and the multiplicative decomposition assumes that firm i's output and input shares of nominal activity are equal.

intuitively appealing measure in the aggregate, each firm's input and output shares must be the same, i.e. it assumes:

$$\frac{Y}{X} = \frac{y_i}{x_i} \quad \forall i \in n \tag{9.22}$$

As mentioned above, when these equalities are compared with the analogous conditions for the case of nominal shares, we find that real shares assume that factor prices are equal across firms, similarly for output prices.

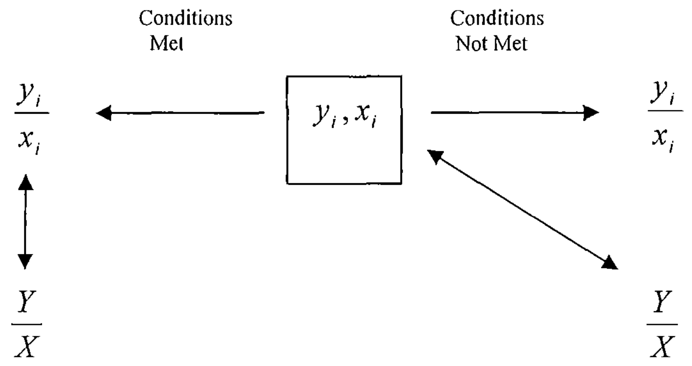
9.3. Summary and Implications for Productivity Analyses

Conventional productivity decomposition methodologies first aggregate firm-level productivity levels into an aggregate productivity variable, and then allocate aggregate growth back to each individual firm. We have seen that the initial aggregation in these decompositions yields productivity aggregates which either confound inputs across firms or imply an output-weighted input index (or, equivalently, an input-weighted output index). In particular, for the assumptions implicit in the initial aggregation of firm-level productivity to be compelling certain conditions must be met, depending on type of aggregate output and input indexes and share types assumed by the researcher.

The conditions implicit in the conventional decomposition yield an important dichotomy regarding the decomposition of aggregate productivity growth, which is displayed schematically in Figure 9.1. If the relevant conditions are met, for example, aggregate productivity can be directly inferred from firm-level productivity. If, on the other hand, the conditions are not met, firm-level productivity and aggregate productivity can be considered distinct concepts, which require separate analyses.

This dichotomy is a direct result of problems incurred when aggregating outputs and inputs. Specifically, a firm's contribution to aggregate productivity growth depends, critically, on the share of that particular firm in both the output and input aggregates. If the share is the same for inputs and outputs, for example, aggregation can commence in the conventional fashion (i.e. the left hand side of Figure 9.1). If, on the other hand, the shares of a firm in the output and input aggregate differ, the firm's outputs and inputs must be considered both in terms of firm-level productivity, as in the productivity analyses of the individual industry in Chapter 8, and in terms of the size of its shares in the output and input aggregates (i.e. the right hand side of Figure 9.1).

Figure 9.1: The Productivity Decomposition Dichotomy



Given the aggregation problems inherent in the conventional productivity decompositions, we propose 2 alternative decompositions of productivity growth in the next chapter.

Chapter 10

Some Alternative Decompositions

In Chapter 8, we concluded that we needed a decomposition of productivity growth to quantify how each industry influences aggregate growth. In Chapter 9, we discussed some conventional forms productivity decomposition. We found that the act of aggregating productivity in these decompositions can produce misleading results. In this chapter, we propose two alternative decompositions which overcome these problems and allow a more detailed, and more flexible, description of the sources of aggregate productivity growth.[52]

10.1. Case 1: Additive Output and Input Indexes

The following decomposes aggregate productivity growth if output (Y) and input (X) indexes are additive,[53] i.e. if:

$$Y = \sum_{i \in n} y_i \tag{10.1}$$

and:

$$X = \sum_{i \in n} x_i \tag{10.2}$$

10.1.1. Contributors to Growth

Let the growth rates of outputs (r_y) and inputs (r_x) between periods 0 and 1 be written as:

[52]Fox (2002) notes that some conventional productivity-change decompositions are not invariant to changes in the units in which the variables are measured. They are, therefore, usually expressed as growth decompositions, i.e. both sides are normalised on the initial level of productivity. In this section, we propose growth decompositions rather than productivity change decompositions, as detailed in the previous chapter.

[53] The sum of chain-weighted outputs and input indexes will, in general, not be additive; chain-weighed series are always additive in the reference period and in the period immediately following the reference period only. See www.abs.gov.au for a discussion of fixed-weight and chain-weight price and quantity indexes. Here we assume that outputs and inputs are measured in the same units over time. Implicit in the additive decomposition, therefore, is an assumption that the outputs and inputs are measured using fixed-based quantity indexes.

$$r_y = \frac{\Delta Y^{0,1}}{Y^0} = \frac{\sum_{i \in C} \Delta y_i^{0,1}}{Y^0} + \frac{\sum_{i \in E} y_i^1 - \sum_{i \in EX} y_i^0}{Y^0} \tag{10.3}$$

and:

$$r_x = \frac{\Delta X^{0,1}}{X^0} = \frac{\sum_{i \in C} \Delta x_i^{0,1}}{X^0} + \frac{\sum_{i \in E} x_i^1 - \sum_{i \in EX} x_i^0}{X^0} \tag{10.4}$$

where the aggregate growth rate has been decomposed into its n firm-level contributors in both cases, and the composition of the industry changes over time as firms enter and exit.[54]

Contributions to aggregate growth will, inevitably, depend on the size of each firm's contribution to the aggregate level. It is thus important to analyse the relationship between the various contributors to aggregate growth over period, and the relative contributions to the level of the aggregate at the start and end of that period. By letting firm i's shares of aggregate output (ϑ_y) and aggregate input (ϑ_x) be:

$$\vartheta_{iy} = \frac{y_i}{Y} \tag{10.5}$$

and:

$$\vartheta_{ix} = \frac{x_i}{X} \tag{10.6}$$

we can re-express (10.3) and (10.4) in terms of shares of the relevant aggregate, i.e:

$$r_y = (1 + r_y)\sum_{i \in C} \Delta \vartheta_{iy}^{0,1} + \sum_{i \in C} \vartheta_{iy}^0 r_{iy} + (1 + r_y)\sum_{i \in E} \vartheta_{iy}^1 - \sum_{i \in EX} \vartheta_{iy}^0 \tag{10.7}$$

and:

$$r_x = (1 + r_x)\sum_{i \in C} \Delta \vartheta_{ix}^{0,1} + \sum_{i \in C} \vartheta_{ix}^0 r_{ix} + (1 + r_x)\sum_{i \in E} \vartheta_{ix}^1 - \sum_{i \in EX} \vartheta_{ix}^0 \tag{10.8}$$

[54]Notice that the first term in each of growth rates is the sum of the continuing firms' Percentage Point Contribution (PPC) to output and input growth, respectively. The second terms in both expressions are the PPCs to growth from the entry and exit of firms over the period. Most statistical agencies publish PPCs of disaggregated industries to the growth of an aggregate of those industries.

We find that we can express the growth of the output and input aggregates as the sum of a 'share' effect and a 'growth' effect for the three different types of firms, each of which we will discuss in turn.

Consider the first terms in (10.7) and (10.8), the share effects. A positive share differential for a continuing firm, for example, increases the firm's contribution to growth by the share differential grown by the same rate as the aggregate. Thus, without aggregate growth, the share effect is simply the difference in shares between the two periods. Essentially, the share effect allocates growth based on whether a firm is growing faster than the aggregate; a firm that is growing at a different rate than the aggregate will change its share of the aggregate and thus have a non-zero share effect.

The second terms of (10.7) and (10.8), the growth effects, on the other hand, allocate growth in the aggregate to continuing firms according to their share of the aggregate.[55] Thus the growth effect allocates growth under the assumption that all firms grow at the same rate, so that shares of the aggregate do not change over the period.

Together, the share effect and the growth effect allocate aggregate growth to each of the continuing firms. In this context, we can think of the growth effect as being an allocation of aggregate growth when all firms grow at the same rate so that the continuing firms' shares of the aggregate do not change, and the share effect as adjusting this 'balanced growth' effect to reflect growth rate differentials across the firms.

The last two terms in (10.7) and (10.8) are the effects of entering and exiting firms, and have similar interpretations to those corresponding to the continuing firms. Consider the first of these 'reallocation' terms. This is the effect from entering firms. It allocates growth according to the proportion of entering firms in the aggregate at the end of the period; the entering firms share is grown at the same rate as the aggregate. In contrast to the analogous term for the continuing firms, the share effect encompasses only those firms that do not exist at the beginning of the period. Thus,

[55] The share is taken at the beginning of the period, thus implying a Laspeyers-type fixed-base index. If, on the other hand, we had normalised changes in the aggregates on the end of the period, we would have a Paasche-type current-base index. We have chosen to normalise on the beginning of the period because this is consistent with index number theory, i.e. indexes are typically expressed as the ratio of a variable at the end of a period to the variable at the beginning of a period.

the final term in (10.7) and (10.8), the growth effect, acknowledges the fact that the exiting firms have reduced growth by attributing a negative amount of aggregate growth to the exiting firms.

10.1.2. Productivity Growth Decomposition

The start-point for our first decomposition is to calculate aggregate productivity as the ratio of an output aggregate to an input aggregate, i.e:

$$P = \frac{Y}{X} \tag{10.9}$$

The change in productivity between the periods 0 and 1 can, therefore, be written as:

$$\Delta P^{0,1} = \frac{Y^1}{X^1} - \frac{Y^0}{X^0} \tag{10.10}$$

The growth rate of aggregate productivity is then:

$$\frac{\Delta P^{0,1}}{P^0} = \frac{1}{1+r_X}\left(\frac{\Delta Y^{0,1}}{Y^0} - \frac{\Delta X^{0,1}}{X^0}\right) \tag{10.11}$$

Substituting (10.7) and (10.8) into this yields a decomposition of productivity growth:

$$\begin{aligned}\frac{\Delta P^{0,1}}{P^0} = \frac{1}{1+r_X}&((1+r_y)\sum_{i\in C}\Delta\vartheta_{iy}^{0,1} + \sum_{i\in C}\vartheta_{iy}^{0}r_{iy} + (1+r_y)\sum_{i\in E}\vartheta_{iy}^{1} - \sum_{i\in EX}\vartheta_{iy}^{0}\\ &-((1+r_x)\sum_{i\in C}\Delta\vartheta_{ix}^{0,1} + \sum_{i\in C}\vartheta_{ix}^{0}r_{iy} + (1+r_x)\sum_{i\in E}\vartheta_{ix}^{1} - \sum_{i\in EX}\vartheta_{ix}^{0}))\end{aligned} \tag{10.12}$$

It is apparent that this decomposition allows us much flexibility in analysing the relative contributors to productivity growth.

10.2. Case 2: Multiplicative Output and Input Indexes

Our second decomposition of productivity growth assumes that the output and input indexes which comprise aggregate productivity are multiplicative,[56] i.e:

$$Y = \prod_{i \in n} y_i^{\vartheta_{iy}} \tag{10.13}$$

and:

$$X = \prod_{i \in n} x_i^{\vartheta_{ix}} \tag{10.14}$$

where the shares (ϑ) now reflect the relative size of the firm in nominal or real activity.

10.2.1. Contributors to Growth

Allowing the shares between periods 0 and 1 to change as in the conventional decompositions, the growth rate of aggregate 'output' (r_y) between periods 0 and 1 be written as:[57]

$$r_y = \ln(Y^1) - \ln(Y^0) = (\sum_{i \in C} \Delta \vartheta_{yi}^{0,1} \ln(y_i^0) + \sum_{i \in C} \vartheta_{yi}^0 \Delta \ln(y_i)^{0,1} + \sum_{i \in C} \Delta \vartheta_{yi}^{0,1} \Delta \ln(y_i)^{0,1}$$
$$+ \sum_{i \in E} \vartheta_{yi}^1 \ln(y_i^1) - \sum_{i \in EX} \vartheta_{yi}^0 \ln(y_i^0)) \tag{10.15}$$

or:

$$r_y = \ln(Y^1) - \ln(Y^0) = (\sum_{i \in C} \Delta \vartheta_{yi}^{0,1} \frac{1}{2}(\ln(y_i^1) + \ln(y_i^0)) + \sum_{i \in C} \frac{1}{2}(\vartheta_{yi}^1 + \vartheta_{yi}^0) \Delta \ln(y_i)^{0,1}$$
$$+ \sum_{i \in E} \vartheta_{yi}^1 \ln(y_i^1) - \sum_{i \in EX} \vartheta_{yi}^0 \ln(y_i^0)) \tag{10.16}$$

---

56 This decomposition is consistent with chain-weighted output and input indexes, which are constructed using weighted geometric means (the Fisher (1922) and Tornqvist (1936) indexes, for example).

57 Making use of the approximation: $\ln(x^1) - \ln(x^0) \approx \frac{\Delta x^{0,1}}{x^0}$.

As with the conventional decompositions above, we show two methods of isolating between-firm and within-firm effects; one method has a cross-term, and the other is the average of two different decompositions following Bennet (1920). Similarly, for the growth rate of the aggregate 'input' (r_x), i.e:

$$r_x = \ln(X^1) - \ln(X^0) = (\sum_{i\in C} \Delta \vartheta_{xi}^{0,1} \ln(x_i^0) + \sum_{i\in C} \vartheta_{xi}^0 \Delta \ln(x_i)^{0,1} + \sum_{i\in C} \Delta \vartheta_{xi}^{0,1} \Delta \ln(x_i)^{0,1}$$
$$+ \sum_{i\in E} \vartheta_{xi}^1 \ln(x_i^1) - \sum_{i\in EX} \vartheta_{xi}^0 \ln(x_i^0))$$

(10.17)

or:

$$r_x = \ln(X^1) - \ln(X^0) = (\sum_{i\in C} \Delta \vartheta_{xi}^{0,1} \frac{1}{2}(\ln(x_i^1) + \ln(x_i^0)) + \sum_{i\in C} \frac{1}{2}(\vartheta_{xi}^1 + \vartheta_{xi}^0) \Delta \ln(x_i)^{0,1}$$
$$+ \sum_{i\in E} \vartheta_{xi}^1 \ln(x_i^1) - \sum_{i\in EX} \vartheta_{xi}^0 \ln(x_i^0))$$

(10.18)

The interpretation of these two growth indexes is analogous to those made in the conventional productivity decompositions from Chapter 9; the first and second terms of the four equations are the between-firm and within-firm growth effects from continuing firms, respectively. Notice, therefore, that these decompositions make apparent Fox's (2002) critique of the conventional productivity decompositions; since shares of the aggregate are allowed to change in going from period 0 to period 1, these indexes comprise a growth index and a share-change index. Leaving this point aside for the moment, we proceed with our decomposition of productivity growth using these 'output growth' and 'input growth' indexes.

10.2.2. Productivity Growth Decomposition

Similar to our other productivity decomposition, we first calculate aggregate productivity as the ratio of the assumed output and input indexes, i.e:

$$P = \frac{Y}{X} \tag{10.19}$$

Taking the natural log of this yields:

$$\ln(P\ ) = \ln(Y\ ) - \ln(X\ ) \tag{10.20}$$

The growth in productivity between the periods 0 and 1 can, therefore, be written as:

$$\Delta \ln(P\ )^{0,1} = \ln(Y^1) - \ln(Y^0) - (\ln(X^1) - \ln(X^0)) \tag{10.21}$$

Substituting (10.16) and (10.18), the 'output growth' and 'input growth' indexes, into this yields:

$$\begin{aligned}\Delta \ln(P\ )^{0,1} &= \sum_{i \in C} \Delta \vartheta_{yi}^{0,1} \frac{1}{2}(\ln(y_i^1) + \ln(y_i^0)) + \sum_{i \in C} \frac{1}{2}(\vartheta_{yi}^1 + \vartheta_{yi}^0) \Delta \ln(y_i\ )^{0,1} \\ &+ \sum_{i \in E} \vartheta_{yi}^1 \ln(y_i^1) - \sum_{i \in EX} \vartheta_{yi}^0 \ln(y_i^0) - (\sum_{i \in C} \Delta \vartheta_{xi}^{0,1} \frac{1}{2}(\ln(x_i^1) + \ln(x_i^0)) + \sum_{i \in C} \frac{1}{2}(\vartheta_{xi}^1 + \vartheta_{xi}^0) \Delta \ln(x_i\ )^{0,1} \\ &+ \sum_{i \in E} \vartheta_{xi}^1 \ln(x_i^1) - \sum_{i \in EX} \vartheta_{xi}^0 \ln(x_i^0))\end{aligned} \tag{10.22}$$

Again, by allowing shares to change over the period as in the conventional decompositions, the resulting 'productivity' decomposition is in fact a decomposition of productivity growth and of share-change (Fox (2002)). This can be further seen by noting that, interestingly, (10.22) can be written the product of a Tornqvist (1936) productivity growth index, a Tornqvist-type share-change index, and an index of entering and exiting firms where shares are allowed to change,[58] i.e:

$$\frac{P^1}{P^0} = \left(\frac{\prod_{i \in C} \left(\frac{y_i^1}{y_i^0} \right)^{\frac{1}{2}(\vartheta_{iy}^1 + \vartheta_{iy}^0)}}{\prod_{i \in C} \left(\frac{x_i^1}{x_i^0} \right)^{\frac{1}{2}(\vartheta_{ix}^1 + \vartheta_{ix}^0)}} \right) \left(\frac{\prod_{i \in C} \left(\frac{\vartheta_{iy}^1}{\vartheta_{iy}^0} \right)^{\frac{1}{2}(y_{iy}^1 + y_{iy}^0)}}{\prod_{i \in C} \left(\frac{\vartheta_{ix}^1}{\vartheta_{ix}^0} \right)^{\frac{1}{2}(x_{iy}^1 + x_{iy}^0)}} \right) \left(\frac{\dfrac{\prod_{i \in E} y_i^{1\,\vartheta_{iy}^1}}{\prod_{i \in EX} y_i^{0\,\vartheta_{iy}^0}}}{\dfrac{\prod_{i \in E} x_i^{1\,\vartheta_{ix}^1}}{\prod_{i \in EX} x_i^{0\,\vartheta_{ix}^0}}} \right) \tag{10.23}$$

[58] Tornqvist indexes are the convention in productivity measurement (see, for example, OECD (2001)) for an exhaustive exposition of the OECD's recommendations on productivity measurement).

Our productivity growth index, which is devoid of share effects is, therefore:

$$\left(\frac{P^1}{P^0}\right)^* = \left(\frac{\prod_{i\in C}\left(\frac{y_i^1}{y_i^0}\right)^{\frac{1}{2}(\vartheta_{iy}^1+\vartheta_{iy}^0)}}{\prod_{i\in C}\left(\frac{x_i^1}{x_i^0}\right)^{\frac{1}{2}(\vartheta_{ix}^1+\vartheta_{ix}^0)}}\right)\left(\frac{\frac{\prod_{i\in E} y_i^{1\,\vartheta_{iy}^1}}{\prod_{i\in EX} y_i^{0\,\vartheta_{iy}^0}}}{\frac{\prod_{i\in E} x_i^{1\,\vartheta_{ix}^1}}{\prod_{i\in EX} x_i^{0\,\vartheta_{ix}^0}}}\right) \tag{10.24}$$

Notice that the first term in our productivity growth index is a standard productivity growth index, i.e. the ratio of a Tornqvist output growth index to a Tornqvist input growth index. Our index provides a more detailed description of productivity growth than standard productivity indexes, however, by adding the second term in (10.24), which is the effect from the entering and exiting firms. Re-expressing Equation (10.24) in terms of logarithms yields our preferred productivity growth decomposition when output and input indexes are multiplicative, i.e:

$$\begin{aligned}\Delta\ln(P^*)^{0,1} &= \sum_{i\in C}\frac{1}{2}(\vartheta_{yi}^1+\vartheta_{yi}^0)\Delta\ln(y_i)^{0,1}+\sum_{i\in E}\vartheta_{yi}^1\ln(y_i^1)-\sum_{i\in EX}\vartheta_{yi}^0\ln(y_i^0)\\ &-(\sum_{i\in C}\frac{1}{2}(\vartheta_{xi}^1+\vartheta_{xi}^0)\Delta\ln(x_i)^{0,1}+\sum_{i\in E}\vartheta_{xi}^1\ln(x_i^1)-\sum_{i\in EX}\vartheta_{xi}^0\ln(x_i^0))\end{aligned} \tag{10.25}$$

10.3. A Comparison With Conventional Decompositions

Essentially, the difference between our productivity decompositions and conventional decompositions of the previous chapter is start-point of each analysis. Conventional decompositions begin by aggregating firm-level productivity indexes into an aggregate productivity index. We have seen that this act of aggregation does not produce a sensible aggregate productivity index in the multiplicative case, and loses information pertaining to the inputs specific to each firm in the additive case. In contrast, our decomposition aggregates firm-level outputs and inputs separately, and then creates an industry-level productivity measure. We, therefore, shift the problem from aggregating industry-level productivity to constructing a sensible productivity aggregate. Moreover, since shares are allowed to change in conventional productivity-change decompositions, only the (constant share) within effects and reallocation effects (from the entry and exit of firms) can be interpreted as productivity changes.

10.4. Implications

The different start-points for the conventional productivity decompositions of the preceding chapter and our alternative decompositions provide two distinct decompositions of growth, each with its merits. In conventional decompositions, aggregate growth is allocated to each firm so that contributions to growth from changes in firm-level productivity can be recovered. Our decompositions, however, allocate growth back to firm-level output and input contributions, which cannot be readily interpreted as productivity: We thus consider firm-level productivity and aggregate productivity as distinct concepts, as in the dichotomy discussed in Chapter 9.3.

Conventional decompositions, therefore, are readily interpretable but, due to the assumptions made in aggregation, may allocate growth in a misleading fashion. In contrast, our decompositions allocate growth back to its firm of origin, but the firm-sources of growth cannot be interpreted as productivity. When decomposing growth, therefore, it is evident that the researcher must trade-off the interpretability of the decomposition with its accuracy.

In the next chapter, we decompose Australian and New Zealand market sector productivity growth.

Chapter 11

Country-specific Productivity Growth Decompositions

In this chapter, we decompose Australian and New Zealand market sector productivity growth. The availability of data across the two countries necessitates the use of a multiplicative decomposition with real shares as weights. Testing the assumptions implicit in this type of conventional decomposition from Chapter 9 reveals that our multiplicative decomposition from Chapter 10 is preferred. Applying our decomposition to the Australian and New Zealand market sectors reveals that a relatively large proportion of New Zealand's growth can be attributed to the Transport, Storage and Communication industry, and that a relatively large proportion of Australian growth can be attributed to the Mining and Wholesale Trade industries. Labour effects in New Zealand's market sector also act to reduce productivity growth relatively more than in Australia, thereby suggesting differences in the production processes of the two countries.

11.1. Testing the Conventional Decomposition

Chapter 9 provides us with a framework in which to analyse the validity of the assumptions made by the different forms of the conventional productivity decompositions. In particular, we found that the use of nominal or real shares in aggregation is governed by whether we can assume the equivalency of prices across firms, and the validity of conventional additive and multiplicative decompositions hinges on whether certain relationships exist between firm-level variables and the aggregate. Unfortunately, comparable data for output and factor prices are not readily available for both Australia and New Zealand. We must, therefore, use a decomposition methodology which employs real shares as weights.

Recall also that our industry-level output data for Australia and New Zealand are chain-volume measures (Chapter 4.3), and that chain-volume measures are not generally additive.[59] This lack of additivity in our output measure, therefore, necessitates a multiplicative decomposition of productivity growth.

Hence, if we now generalise our previous analysis to the industry level, where there are k industries (or groups of industries) in the market sector, we can test the conditions implicit in conventional multiplicative decompositions of productivity growth with real shares as weights, i.e. we can test whether:

$$\frac{Y}{X} = \frac{y_i}{x_i} \quad \forall i \in k \tag{11.1}$$

Recall that this condition is equivalent to the 'representative industry' implicitly assumed by standard neoclassical growth theory, and that, fortunately, we have already tested and rejected the assumption in both the Australian and New Zealand market sectors (Chapter 7). We thus employ our, less restrictive, methodology to decompose the market sector productivity growth of Australia and New Zealand.

11.2. Country-Specific Growth Indexes

The construction of productivity indexes for the two countries requires multiplicative Tornqvist output and input indexes, which are consistent with our multiplicative decomposition of productivity growth from the preceding chapter: Notice that the 'reallocation' terms, which were present at the firm-level, do not enter into the analysis where the smallest economic unit is an industry, since all industries exist for the entire sample period. Our Tornqvist output (Y) and labour (X) growth indexes for the Australian and New Zealand market sectors are thus:

$$\frac{Y^t}{Y^{t-1}} = \prod_{i=1}^{k} \left(\frac{y_i^t}{y_i^{t-1}} \right)^{\frac{1}{2}(\vartheta_{iy}^t + \vartheta_{iy}^{t-1})} \tag{11.2}$$

and:

$$\frac{X^t}{X^{t-1}} = \prod_{i=1}^{k} \left(\frac{x_i^t}{x_i^{t-1}} \right)^{\frac{1}{2}(\vartheta_{ix}^t + \vartheta_{ix}^{t-1})} \tag{11.3}$$

---

[59] See Footnote 53.

where, as mentioned in the previous section, the shares (ϑ) are of real aggregates,[60] i.e output and labour shares for industry i in period t are:

$$\vartheta_{iy}^{t} = \frac{y_i^t}{\sum_{i=1}^{k} y_i^t} \tag{11.4}$$

and:

$$\vartheta_{ix}^{t} = \frac{x_i^t}{\sum_{i=1}^{k} x_i^t} \tag{11.5}$$

These output and labour indexes are then formed into the following productivity growth index for both countries:

$$\left(\frac{P^t}{P^{t-1}}\right) = \left(\frac{\prod_{i=1}^{k}\left(\frac{y_i^t}{y_i^{t-1}}\right)^{\frac{1}{2}(\vartheta_{iy}^{t}+\vartheta_{iy}^{t-1})}}{\prod_{i=1}^{k}\left(\frac{x_i^t}{x_i^{t-1}}\right)^{\frac{1}{2}(\vartheta_{ix}^{t}+\vartheta_{ix}^{t-1})}}\right) \tag{11.6}$$

Taking natural logarithm of this yields a decomposition of productivity growth:[61]

$$\Delta\ln(P)^t = \sum_{i=1}^{k}\left(\left(\frac{1}{2}(\vartheta_{iy}^{t}+\vartheta_{iy}^{t-1})\Delta\ln(y_i)^t - \frac{1}{2}(\vartheta_{ix}^{t}+\vartheta_{ix}^{t-1})\Delta\ln(x_i)^t\right)\right) \tag{11.7}$$

We thus find that productivity growth can be decomposed into an 'output' effect and a 'labour' effect from each of the industries comprising the market sector. This decomposition, therefore, allows us to allocate aggregate productivity growth back to output and labour contributors from each industry in the market sector, and makes apparent our discussion at the end of Chapter 9: Industry-level variables influence aggregate growth via their own growth, and via their growth relative to the other

[60] Recall that chain-weighted indexes are not generally additive (Footnote 53). We assume them additive, however, when computing the denominator in our shares since adequate price data are not available. Notice also that our real output shares are equivalent to nominal output shares in the reference (and following) period, due to the nature of chain-weighted indexes.

[61] Note: $\Delta(z)^t = z^t - z^{t-1}$.

variables which form the aggregate (i.e. through shares).

11.2.1. Country-Specific Level Indexes

Before decomposing market sector productivity growth for each country, it will be informative to view the level indexes corresponding to our growth indexes (Equations (11.2); (11.3); and (11.7)). To construct level indexes, we apply the output and labour growth indexes (Equations (11.2) and (11.3)) to a particular level in a particular period known as the base period (*B*). If, for example, we base our level indexes to the first period in the sample, then the output level and input level indexes in any period $T=B+t$ are:

$$Y^T = \prod_{j=1}^{t}\left(\prod_{i=1}^{k}\left(\frac{y_i^{B+j}}{y_i^{B+j-1}}\right)^{\frac{1}{2}(\vartheta_{iy}^{B+j}+\vartheta_{iy}^{B+j-1})} y^B\right) \tag{11.8}$$

and:

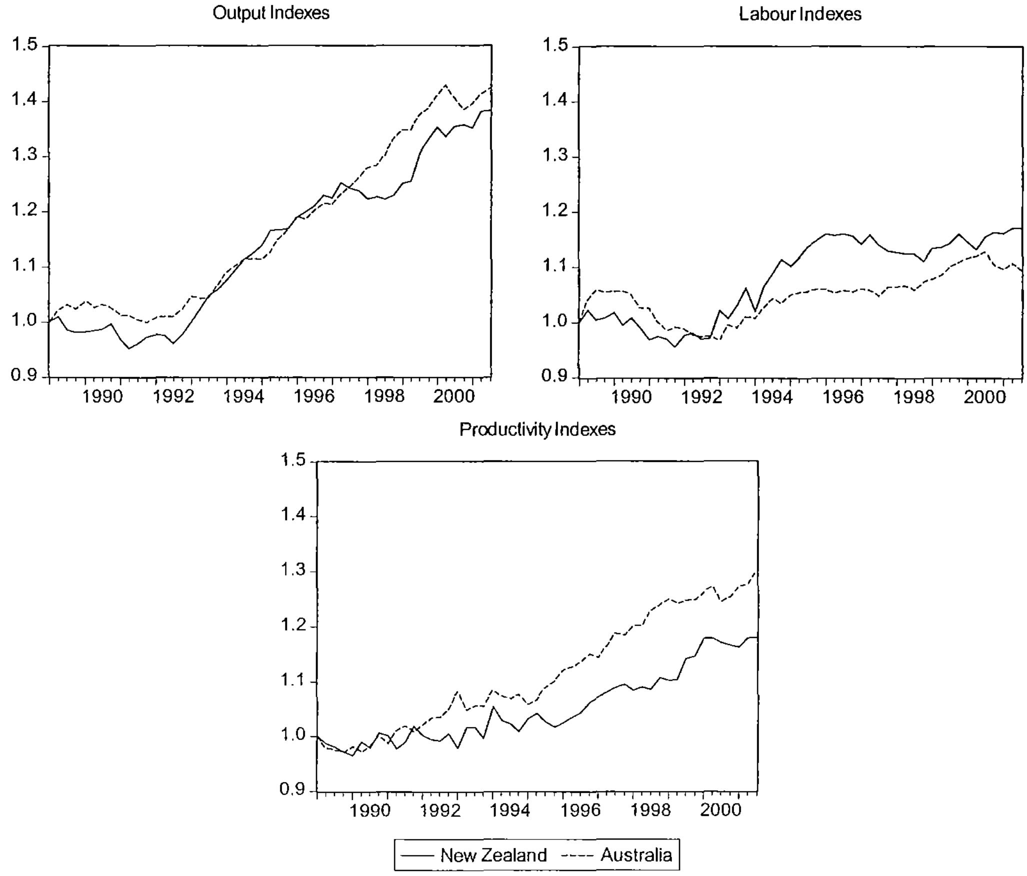
$$X^T = \prod_{j=1}^{t}\left(\prod_{i=1}^{k}\left(\frac{x_i^{B+j}}{x_i^{B+j-1}}\right)^{\frac{1}{2}(\vartheta_{ix}^{B+j}+\vartheta_{ix}^{B+j-1})} x^B\right) \tag{11.9}$$

The productivity level index in period *T* is, therefore:

$$P^T = \frac{Y^T}{X^T} \tag{11.10}$$

Figure 11.1 displays output, labour, and productivity level indexes for the Australian and New Zealand market sectors. From the figure it is evident that Australian and New Zealand output indexes are broadly similar over the sample period, and that New Zealand has had relatively strong labour growth over the period. The divergence in productivity at the market sector level, therefore, appears to be driven by labour differences across the two countries, as suggested by Philpott (1996); Malony (1998); and IMF (2002).

Figure 11.1: Market Sector Indexes For Australia and New Zealand (89:Q1=1)



11.3. Results of the Growth Decomposition

The results of applying our productivity growth decomposition (Equation (11.7)) to the market sectors of Australia and New Zealand are displayed in Table 11.1. We find that output effects dominate the labour effects for the market sector, with both countries' output growth effects augmenting growth, and labour growth effects acting to slow growth as we would expect. The output effects for the Australian and New Zealand market sectors are 133.8% and 195.6%, respectively. Hence labour growth slowed productivity relatively more in New Zealand than in Australia.[62]

[62] This means that, given productivity growth for each country, New Zealand's growth would increase relatively more than Australia's if labour were kept constant.

Table 11.1: Contributors to Productivity Growth (89:Q1 to 01:Q3)[a]

Industry	Australia			New Zealand		
%	Output Effect	Labour Effect	Industry Total	Output Effect	Labour Effect	Industry Total
Agriculture, Forestry & Fishing	8.7	0.0	8.6	28.8	-18.6	10.2
Mining	17.0	0.8	17.8	1.1	-1.0	0.0
Manufacturing	15.7	2.1	17.7	27.2	-2.4	24.8
Electricity, Gas & Water	3.5	2.4	5.9	0.1	7.0	7.1
Construction	6.0	-8.5	-2.5	-2.6	-12.8	-15.4
Wholesale Trade	13.0	3.6	16.6	21.2	-17.5	3.8
Retail Trade	14.0	-11.7	2.3	15.4	-22.4	-7.1
Accommodation, Cafes & Restaurants	4.7	-9.8	-5.1	3.9	-19.9	-16.0
Transport, Storage & Communication	28.7	-7.1	21.6	70.7	-2.4	68.3
Finance & Insurance Services	17.8	-1.2	16.6	15.1	5.1	20.2
Cultural & Recreational Services	4.8	-4.4	0.4	14.7	-10.7	4.0
Total	133.8	-33.8	100.0	195.6	-95.6	100.0

a Average contributions as a proportion of total average quarterly productivity growth for Australia and New Zealand. The total average quarterly growth rates for Australia and New Zealand are 0.5276% and 0.3313%, respectively. Numbers may not add due to rounding.

The size of the contributions to market sector productivity growth by the industries varies across the two countries. A feature of both market sectors is that a relatively large proportion of growth can be attributed to the Transport, Storage, and Communication industry, with this industry accounting for approximately one fifth of Australian growth and more than two thirds of New Zealand's growth. It is also apparent that more industries add to market sector productivity growth in Australia; all industry contributions to productivity growth are of the same sign with the exception of Retail Trade, which adds to Australia's growth while reducing New Zealand's growth. Other idiosyncrasies between the two countries include a relatively large proportion of Australia's growth accounted for by the Mining and Wholesale Trade industries.

Industry total effects certainly mask the sources of each industry's contribution to growth, however. It is thus important to gauge the relative sizes of output effects and labour effects in each individual industry's contribution to market sector productivity growth.

With the exception of the output effect in New Zealand's Construction industry, each industry's output effect contributes to productivity growth in both countries. Industries with relatively large output effects in both countries are Manufacturing; Wholesale Trade; Retail Trade; Transport, Storage and Communication; and Finance and Insurance Services. The single largest output effect in both countries is that of the Transport, Storage and Communication industry; without the output effect of this particular industry, productivity growth would have been 28.7% lower in Australia and, an astonishing, 70.7% lower in New Zealand. Other New Zealand industries that had relatively large output effects were Agriculture, Forestry and Fishing and Manufacturing, with output effects for these industries contributing 28.8% and 27.2%, respectively. The Australian Mining and Finance and Insurance Services industries also had relatively large positive output effects of 17.0% and 17.8%, respectively.

Output effects, however, are only half of the overall growth story. Labour effects have had a large influence over the productivity growth of both Australia and New Zealand, with these effects acting to reduce growth in Australia and New Zealand by 33.8% and 95.6%, respectively. Industries with particular large negative labour effects in both countries were: Construction; Retail Trade; and Accommodation, Cafes and Restaurants. The Agriculture, Forestry and Fishing; Mining; Manufacturing; and Wholesale Trade industries, on the other hand, added to growth in Australia whilst reducing it in New Zealand. Note further that the labour effect from the Electricity, Gas and Water industry acted to increase productivity growth in both countries, and that labour effects in the Finance and Insurance industry enhanced growth in New Zealand and retarded it in Australia.

11.4. Summary and Implications

Chapters 7 and 8 suggest a number of different growth outcomes across Australian and New Zealand industries. Applying our multiplicative decomposition of aggregate productivity growth from Chapter 10 to the Australian and New Zealand market sectors shows a large proportion of growth being attributed to the Transport, Storage and Communications in New Zealand, and relatively large proportions of Australia's productivity growth being attributed to the Mining and Wholesale Trade industries. These results are consistent with our findings from Chapter 8, i.e. we found that the speed of divergent processes, and the shifts in relative productivity levels, were large in the Transport, Storage and Communications; Mining; and Wholesale Trade industries.

We also found that labour growth slowed productivity growth in New Zealand's market sector more than in the Australian market sector, thus supporting the findings of Philpott (1996); Malony (1998); and the IMF (2002) from Chapter 2 and our graphical evidence from Figure 11.1. Production processes in New Zealand, therefore, appear to have become relatively labour intensive when compared with those of Australia.

We know, however, that the intensity to which the factors of production are used is integral in distinguishing different types of production processes. A large proportion of the divergence attributed to labour intensity differences across Australia and New Zealand would, therefore, suggest differences in the fundamental drivers of growth across the two countries over our sample period.

The country-specific effects discussed in this chapter, however, do not quantify the various contributors to the divergence. In the next chapter, we thus propose an index of relative productivity growth, which allows us to quantify the contributions that output and labour differences across countries make to the market sector divergence.

Chapter 12

An Index of Productivity Divergence

In the previous chapter we analysed the productivity of Australia and New Zealand using country-specific output and labour effects. These country-specific effects, however, do not address how each of the industries which comprise the market sector contribute to the productivity gap between Australia and New Zealand. In this chapter, we propose an index of relative productivity growth. Decomposing this index shows that differences across most of the industries add to the divergence, with particularly large contributions from differences across the Mining and Wholesale Trade industries. We also find that labour differences across the two countries contribute a substantial amount to the divergence, thereby supporting our conjecture that the production processes of the Australia and New Zealand market sectors are different.

12.1. The Index

We define an index of the relative productivity growth between the two countries as:[63]

$$R_{mn} = \frac{\left(\dfrac{P_m^t}{P_m^{t-1}}\right)}{\left(\dfrac{P_n^t}{P_n^{t-1}}\right)} = \frac{\left(\dfrac{\prod_{i=1}^{k}\left(\dfrac{y_{i,m}^t}{y_{i,m}^{t-1}}\right)^{\frac{1}{2}(\vartheta_{iy,m}^t+\vartheta_{iy,m}^{t-1})}}{\prod_{i=1}^{k}\left(\dfrac{x_{i,m}^t}{x_{i,m}^{t-1}}\right)^{\frac{1}{2}(\vartheta_{ix,m}^t+\vartheta_{ix,m}^{t-1})}}\right)}{\left(\dfrac{\prod_{i=1}^{k}\left(\dfrac{y_{i,n}^t}{y_{i,n}^{t-1}}\right)^{\frac{1}{2}(\vartheta_{iy,n}^t+\vartheta_{iy,n}^{t-1})}}{\prod_{i=1}^{k}\left(\dfrac{x_{i,n}^t}{x_{i,n}^{t-1}}\right)^{\frac{1}{2}(\vartheta_{ix,n}^t+\vartheta_{ix,n}^{t-1})}}\right)} \qquad (12.1)$$

where m and n denote Australian and New Zealand variables, respectively. Taking the natural logarithm of this expression yields a decomposition of productivity growth differentials between the two countries:

[63] Bernard and Jones (1996) construct an analogous measure of growth differentials, where output and input indexes are additive.

$$\ln(R_{mn}) = \sum_{i=1}^{k}((\frac{1}{2}(\vartheta_{iy,m}^{t} + \vartheta_{iy,m}^{t-1})\Delta\ln(y_{i,m})^{t} - \frac{1}{2}(\vartheta_{iy,n}^{t} + \vartheta_{iy,n}^{t-1})\Delta\ln(y_{i,n})^{t}) - (\frac{1}{2}(\vartheta_{ix,m}^{t} + \vartheta_{ix,m}^{t-1})\Delta\ln(x_{i,m})^{t} - \frac{1}{2}(\vartheta_{ix,n}^{t} + \vartheta_{ix,n}^{t-1})\Delta\ln(x_{i,n})^{t})) \qquad (12.2)$$

Since relative productivity growth can be decomposed into output and labour growth contributions from each industry in both countries, this decomposition affords us a multitude of potential sources of productivity growth differentials across countries. The results of decomposing Australia's productivity growth relative to productivity growth in New Zealand using Equation (12.2) are displayed in Table 12.1, where output effects represent contributions to the divergence from differences in output growth across the two countries (the first two terms from Equation (12.2)) and labour effects represent contributions from differences in labour growth across the two countries (the last two terms from Equation (12.2)).

12.2. Results

We find that the single most important factor leading to aggregate divergence between the Australian and New Zealand market sectors is the Mining industry; without the Mining industry, the average market sector productivity growth discrepancy between the countries would have been 47.9% less. Similarly, most of the other industries contributed to Australia's relatively high growth performance, with particularly large contributions from differentials in the Construction; Wholesale Trade; Retail Trade; and Finance and Insurance Services industries. Those industries that attenuated the market sector divergence were Transport, Storage and Communication and Cultural and Recreational Services; differentials in these industries acted to reduce market sector divergence by about two thirds, most of which being due to differentials in the Transport, Storage and Communication Sector.

Output effect differentials accounted for less than one third, 29.4%, of the market sector growth divergence, with the Mining (43.9%); Construction (20.6%); and Finance and Insurance (22.3%) industries having particularly large output contributions to the divergence, and the Agriculture, Forestry, and Fishing; Transport, Storage and Communication (-42.3%); and Cultural and Recreational industries (-12.0%), notably reducing the divergence. In fact, we find that 6 of the 11 industries have output effects which add to the market sector divergence.

The majority of market sector divergence, however, can be attributed to cross-country labour growth differences, 70.6%. Labour effects in the Agriculture, Forestry and Fishing and Wholesale Trade industries add the most to divergence, with their combined effect accounting for 70.4% of Australia's relatively high productivity growth. Overall, the labour effects from 5 industries act to reduce market sector divergence.

Table 12.1: Output and Labour Contributors to Productivity Growth Difference (89:Q1 to 01:Q3)[a]

%	Output Effect	Labour Effect	Industry Total
Agriculture, Forestry & Fishing	-25.4	31.3	5.9
Mining	43.9	3.9	47.9
Manufacturing	-3.9	9.6	5.7
Electricity, Gas & Water	9.2	-5.3	3.8
Construction	20.6	-1.3	19.2
Wholesale Trade	-0.9	39.1	38.2
Retail Trade	11.7	6.4	18.1
Accommodation, Cafes & Restaurants	6.2	7.3	13.4
Transport, Storage & Communication	-42.3	-14.9	-57.2
Finance & Insurance Services	22.3	-11.7	10.5
Cultural & Recreational Services	-12.0	6.3	-5.8
Total	29.4	70.6	100.0

a The proportions are ratios of average quarterly contributions to the average total quarterly growth differential between Australian and New Zealand productivity over the entire sample period. The average total quarterly growth differential is 0.1963%. Numbers may not add due to rounding.

12.3. Summary and Implications

Relative productivity growth decompositions, suggest that the relative performances of all industries, with the exception of Transport, Storage and Communications and Cultural and Recreational Services, contribute to the divergence at the market sector level, with differences in the Mining and Wholesale Trade being particularly large contributors, as suggested by the analyses from Chapters 8 and 11. It is also apparent from the decompositions that labour differences across the two countries contributed more to the market sector divergence than output differences, with particularly large contributions to the divergence from labour growth differences across the Wholesale Trade and Agriculture, Forestry and Fishing industries.

The cross-country differences in labour growth concur with our findings from Chapter 11, namely that New Zealand production processes have become relatively labour intensive over our sample period. These cross-country differences in production processes further imply that the fundamental drivers of growth across Australia and New Zealand are different, as suggested by the analyses from Chapters 7 and 8.

It is evident that the production processes of the Australian and New Zealand market sectors differ over our sample period. Given these differences, it is also likely that the structure of production will differ across the two market sectors. To gauge how cross-country structural differences impinge on the relative productivity index posited in this chapter, we propose an index which controls for cross-country structural differences in the next chapter.

Chapter 13

Accounting For Structural Differences

In the previous chapter we found that labour growth differences across Australia and New Zealand account for a large proportion of divergence in market sector productivity, thereby suggesting differences in nature of the production processes of the two countries. In this chapter, we further analyse this possibility by decomposing the relative productivity growth index from Chapter 12 into a 'structural difference' index and a 'growth difference' index. We find that differences in the structure of the two economies account for a non-trivial amount of the market sector divergence, and that growth differences across all but 3 of the industries add to the divergence.

13.1. A Basis For Comparison

Implicit in any cross-country growth comparison is an assumption that the countries in question have similar compositions to be meaningfully compared.[64] There are, however, four different types of shares in the index of relative productivity growth from the preceding chapter (Equation (12.1)), each of which can influence the measured divergence. Hence, if we define industry shares of market sector aggregates to be proxies for the structure of an economy, we find that structural differences across the countries can have a potentially large influence on relative productivity growth outcomes. Thus, to gauge the importance of structural differences across the two countries, we can re-write Equation (12.1) as the product of a 'structural difference' index and a 'growth difference' index:[65]

[64] This is what Fox (2002) calls the "productivity paradox": Fox highlights a paradox inherent in aggregate comparisons by showing that the same growth can occur in each component of two aggregates but aggregate growth can differ, due to the relative sizes of the components in each of the aggregates. This is an instance of Simpson's Paradox: There is a large literature from a multitude of disciplines discussing various aspects of the paradox (for an economic perspective, see Saari (1987)).
[65] Our growth difference index is analogous to index proposed by Caves, Christensen and Diewert (1982) for multilateral comparisons.

$$R_{mn} = \prod_{i=1}^{k} \left(\frac{\left(\left(\frac{y_{i,m}^{t}}{y_{i,m}^{t-1}} \right) \left(\frac{y_{i,n}^{t}}{y_{i,n}^{t-1}} \right) \right)^{\frac{1}{2}(\delta_{iy,m}^{t} - \delta_{iy,n}^{t})}}{\left(\left(\frac{x_{i,m}^{t}}{x_{i,m}^{t-1}} \right) \left(\frac{x_{i,n}^{t}}{x_{i,n}^{t-1}} \right) \right)^{\frac{1}{2}(\delta_{ix,m}^{t} - \delta_{ix,n}^{t})}} \frac{\left(\frac{\left(\frac{y_{i,m}^{t}}{y_{i,m}^{t-1}} \right)}{\left(\frac{y_{i,n}^{t}}{y_{i,n}^{t-1}} \right)} \right)^{\frac{1}{2}(\delta_{iy,m}^{t} + \delta_{iy,n}^{t})}}{\left(\frac{\left(\frac{x_{i,m}^{t}}{x_{i,m}^{t-1}} \right)}{\left(\frac{x_{i,n}^{t}}{x_{i,n}^{t-1}} \right)} \right)^{\frac{1}{2}(\delta_{ix,m}^{t} + \delta_{ix,n}^{t})}} \right) \tag{13.1}$$

where $\delta_{iz,q}^{t} = \frac{1}{2}(\vartheta_{iz,q}^{t} + \vartheta_{iz,q}^{t-1})$ with $z = (x, y)$ and $q = (m, n)$.

Taking the natural logarithm of this expression yields an alternative decomposition to Equation (12.2), which allows us to separate a 'structural difference' effect and 'growth difference' effect from industry output and labour contributions to the aggregate divergence, i.e:

$$\begin{aligned} R_{mn} = \sum_{i=1}^{k} (& (\delta_{iy,m}^{t} - \delta_{iy,n}^{t}) \frac{1}{2} (\Delta \ln(y_{i,m})^{t} + \Delta \ln(y_{i,n})^{t}) - (\delta_{ix,m}^{t} - \delta_{ix,n}^{t}) \frac{1}{2} (\Delta \ln(x_{i,m})^{t} + \Delta \ln(x_{i,n})^{t}) \\ & + \frac{1}{2} (\delta_{iy,m}^{t} + \delta_{iy,n}^{t}) (\Delta \ln(y_{i,m})^{t} - \Delta \ln(y_{i,n})^{t}) - \frac{1}{2} (\delta_{ix,m}^{t} + \delta_{ix,n}^{t}) \Delta \ln(x_{i,m})^{t} - \Delta \ln(x_{i,n})^{t})) \end{aligned} \tag{13.2}$$

The first two terms of the expression represent the structural difference effects from output structure differences and labour structure differences across the two countries, respectively. The last two terms, on the other hand, represent growth difference effects from output growth differences and labour growth differences, respectively. We consider both the structural difference and growth difference effects in turn.

Structural difference effects show the contribution to aggregate divergence from differences in the structure of the two economies. Essentially, the structural difference effect is the contribution that differences in shares of the aggregate across countries have on the aggregate divergence, where growth is constant and equal to an arithmetic average of growth across both of the countries. In the case of our Australian and New Zealand relative productivity growth index, for example, industries with larger output shares of the market sector in Australia have larger contributions to the market sector divergence, and industries with larger labour shares in New Zealand will have larger contributions to the divergence, ceteris paribus.

Growth difference effects, on the other hand, show the contribution to aggregate divergence from growth differences across the two countries, where the structure across both countries is kept constant and equal to the arithmetic average of the 'structure' (i.e. the shares of the relevant aggregate) across the two countries. Faster output (labour) growth in an industry in Australia relative to New Zealand, for example, will lead to a greater (lower) contribution to the aggregate productivity divergence, ceteris paribus.

13.2. Results

Table 13.2 displays a decomposition of the market sector divergence in Australian and New Zealand productivity into both growth difference effects and structural difference effects.

Table 13.1: Structural and Growth Contributors to Productivity Growth Difference (89:Q1 to 01:Q3) [a]

%	Growth Effect	Structural Effect	Total
Agriculture, Forestry & Fishing	14.9	-9.0	5.9
Mining	26.5	21.3	47.9
Manufacturing	13.2	-7.5	5.7
Electricity, Gas & Water	4.5	-0.6	3.8
Construction	27.5	-8.3	19.2
Wholesale Trade	51.4	-13.2	38.2
Retail Trade	28.6	-10.5	18.1
Accommodation, Cafes & Restaurants	19.8	-6.4	13.4
Transport, Storage & Communication	-42.4	-14.8	-57.2
Finance & Insurance Services	-0.5	11.0	10.5
Cultural & Recreational Services	-3.9	-1.8	-5.8
Total	139.7	-39.7	100.0

a The proportions are ratios of average quarterly contributions to the average total quarterly growth differential over the entire sample period. The average total quarterly growth differential is 0.1963%. Numbers may not add due to rounding.

Growth difference effects across the two countries have the largest impact on the market sector divergence, with the combined effect raising the divergence by 39.7% higher than when the structure of Australian and New Zealand market sectors are allowed to differ. The growth difference effects across the industries display a similar pattern to total effects, where the Mining; Construction; Wholesale Trade; and Retail Trade industries contribute most to the divergence, and the Transport, Storage and Communication industry greatly reduces the divergence. Overall, the industry-level growth difference effects show that 3 industries (Transport, Storage and Communication; Finance and Insurance Services; and Cultural and Recreational Services) act to reduce the divergence.

Total structural difference effects act to reduce the divergence by 39.7%. If we consider growth difference effects as restricting how each economy allocates its resources, it is not surprising that relaxing this restriction attenuates the market sector divergence where structure is fixed. In fact, the structural difference effects act to reduce the divergence in market sector productivity attributed to all of the industries with the exception of the Mining and Finance and Insurance Services industries. Structural differences in the Electricity, Gas and Water and Cultural and Recreational Services industries contribute the least to the market sector divergence, indicating that these industries have similar structure in both countries.

13.2.1. A Decomposition of the Growth Effects

The growth effects displayed in Table 13.1 combine output and labour growth effects. In Table 13.2, we display the output differential and labour differential effects to the overall growth effect.

As mentioned above the growth effects from all industries, with the exception of Transport, Storage and Communication; Finance and Insurance Services; and Cultural and Recreational Services, act to increase the market sector divergence, with particularly large contributions from growth differences across the Mining; Construction; Wholesale Trade; and Retail Trade industries.

Table 13.2 shows that three quarters of the growth difference effect can be attributed to labour growth differences across the two countries, as suggested by the country-specific and divergence analyses from Chapters 11 and 12. Labour growth differences across the Agriculture, Forestry and Fishing; Wholesale Trade; Retail Trade; and Accommodation, Cafes and Restaurants industries had a particularly large contribution to the growth difference effect at the market sector level. Labour growth in the Electricity, Gas, and Water; Transport, Storage and Communication; and Finance and Insurance Services industries, on the other hand, acted to reduce the total growth difference effect.

Table 13.2: Output and Labour Contributors to Productivity Growth Effect (89:Q1 to 01:Q3) [a]

%	Output Effect	Labour Effect	Total
Agriculture, Forestry & Fishing	-7.1	17.8	10.7
Mining	16.0	3.0	19.0
Manufacturing	3.0	6.5	9.5
Electricity, Gas & Water	7.3	-4.1	3.2
Construction	11.8	7.9	19.7
Wholesale Trade	6.7	30.1	36.8
Retail Trade	7.2	13.3	20.5
Accommodation, Cafes & Restaurants	3.7	10.5	14.2
Transport, Storage & Communication	-22.2	-8.2	-30.4
Finance & Insurance Services	8.1	-8.5	-0.3
Cultural & Recreational Services	-9.8	7.0	-2.8
Total	24.7	75.3	100.0

a The proportions are ratios of average quarterly contributions to the average total quarterly growth difference effect over the entire sample period. The average total quarterly growth effect is 0.274%. Numbers may not add due to rounding.

The output growth differences across all industries, with the exception of Agriculture, Forestry and Fishing; Transport, Storage and Communications; and Cultural and Recreational Services, acted to increase the total growth difference effect, with the Mining and Construction industries being the largest contributors to the divergence.

13.2.2. A Decomposition of Structural Differences

In Table 13.3, we decompose the total structural difference effect into its output and labour difference effects: Notice that, since the overall structural difference effect reduces market sector divergence, a positive contribution from output represents a relatively large share of output in the market sector in New Zealand and a positive contribution from labour represents a relatively large share of labour in the market sector of Australia, and vice versa.

Above, we found that structural difference effects act to reduce the divergence in market sector productivity attributed to all of the industries, with the exception of the Mining and Finance and Insurance Services industries. We also found that the structural differences across the Electricity, Gas and Water and Cultural and Recreational Services industries were relatively small. Overall, the sizes of the structural difference effects indicates a relatively large proportion of resources devoted to Mining and Finance and Insurance Services in Australia, and a relatively large proportion of resources devoted to the Transport, Storage and Communication; Wholesale Trade; Retail Trade; and Agriculture, Forestry and Fishing industries in New Zealand.

Table 13.3: Output and Labour Contributors to Productivity Structural Effect (89:Q1 to 01:Q3) [a]

%	Output Effect	Labour Effect	Industry Total
Agriculture, Forestry & Fishing	38.9	-16.2	22.7
Mining	-54.4	0.6	-53.8
Manufacturing	20.3	-1.5	18.8
Electricity, Gas & Water	2.5	-0.9	1.5
Construction	-10.4	31.2	20.9
Wholesale Trade	25.9	7.2	33.2
Retail Trade	-4.1	30.6	26.5
Accommodation, Cafes & Restaurants	-2.5	18.6	16.1
Transport, Storage & Communication	28.5	8.8	37.3
Finance & Insurance Services	-27.5	-0.3	-27.8
Cultural & Recreational Services	-4.3	8.8	4.6
Total	13.0	87.0	100.0

a The proportions are ratios of average quarterly contributions to the average total quarterly structural difference effect over the entire sample period. The average total quarterly growth effect is -0.078%. Numbers may not add due to rounding.

Output structural differences further show a relatively large proportion of production in New Zealand being based in the Agriculture, Forestry, and Fishing; Manufacturing; Wholesale Trade; and Transport, Storage and Communication industries. The Australian economy, on the other hand, has relatively large Mining; Construction; and Finance and Insurance Services industries.

The majority, 87%, of the total structural difference effect, however, can be attributed to differences in the structure of labour across the two countries. The industries with particularly large differences in the structure of their labour were Construction; Retail Trade; Accommodation, Cafes and Restaurant industries, all of which had larger labour shares in Australia; and the Agriculture, Forestry and Fishing industry, which had a larger share of labour in New Zealand.

13.3. Summary and Implications

In this chapter we proposed an alternative decomposition of relative productivity growth, which controls the market sector divergence for structural differences across Australia and New Zealand. We found that differences in the structure of the two market sectors acted to reduce market sector divergence: Structural differences were particularly large across the Mining; Transport, Storage and Communications; Wholesale Trade; Retail Trade; Finance and Insurance Services; and Agriculture, Forestry and Fishing industries.

In the cases of the Mining and Transport, Storage and Communication industries, Australia and New Zealand are allocating resources to industries where it has relatively high growth. New Zealand, however, appears to have too many resources devoted to its relatively low-growth industries, such as Wholesale Trade and Retail Trade. As with the analyses from Chapters 11 and 12, we also found that labour differences across the two countries accounted for a large proportion of the divergence.

In Chapters 11 and 12, we argued that the labour growth differences across Australia and New Zealand imply differences in the fundamental drivers of growth across the two economies. The evidence presented in this chapter supports this conjecture by highlighting significant structural differences across the Australian and New Zealand market sectors.

Chapter 14

A Synthesis

This chapter provides a synthesis of our findings regarding the productivity divergence between Australia and New Zealand, and discusses the implications of those findings for cross-country growth comparisons between Australia and New Zealand.

In Chapter 2, we began by reviewing New Zealand's recent aggregate growth performance. The literature reviewed indicates an improvement in New Zealand's TFP performance since the reforms of the 1980s and early 1990s. New Zealand's real GDP per capita growth performance also seems to have improved following the reforms, but not when compared to other OECD countries, particularly Australia (Dalziel (1999); Greasely and Oxley (1999); and IMF(2002)). Productivity differences explain a large proportion of the cross-country variation in real GDP per capita across New Zealand and Australia, and New Zealand's relatively poor performance is largely attributed to a shift to labour intensive production techniques following the ECA (Philpott (1996); Malony (1998); and IMF (2002)). A disaggregate analysis of New Zealand's growth is suggested by some researchers.

In Chapter 3, we reviewed the reasons why Australia's productivity might grow faster than New Zealand's suggested by two different types of aggregate growth model; the neoclassical and NGT models. Essentially, both models would suggest a disproportionate improvement in the fundamentals of long-run growth favouring Australia. The predicted persistence of this productivity discrepancy, however, differs across the two types of growth model, with convergence in productivity growth being a testable implication of the neoclassical growth model.

In Chapter 6, we gauged the persistence of the discrepancy between Australian and New Zealand market sector productivity using time-series tests of the convergence hypothesis proposed in Chapter 5. Though the neoclassical model could not be refuted over our short sample period, convergence in terms of long-term forecasts was rejected. The aggregate convergence tests, therefore, could not determine the nature and persistence of the growth discrepancy between Australia and

New Zealand in the long-run, or whether the two economies had similar enough growth fundamentals to be considered comparable.

Cointegration tests, however, allowed us to test the representative firm (industry) assumption implicit in neoclassical theory. From the results of these tests (Chapter 7) it was evident that the productivity of the industries comprising the market sectors of Australia and New Zealand do not have a common stochastic trend, indicating that none of the industries can be considered representative of the market sector. Moreover, the Australian market sector was found to have more stochastic trends than that of New Zealand, thereby questioning the comparability of the two economies at the market sector level; we found significant evidence of 8 stochastic trends in Australia and 3 stochastic trends in New Zealand. We thus next tested for convergence at a more disaggregate level in Chapter 8.

We found that only 2 of the 11 industries in the market sector were classified as being (conditionally) converged (Agriculture, Forestry and Fishing and Cultural and Recreational Services). With the exception of the Wholesale Trade industry, whose productivity is independent across the two countries, relative productivity levels of the remainder of the industries display evidence of transition to new steady-states and of structural change. The diversity of productivity level and growth differences across the industries calls into question whether the fundamentals of growth in the respective economies are comparable. This was perhaps most apparent in the Mining industry, where we found that Australian Mining productivity was more than 80% higher than New Zealand's at the end of the sample period.

Cointegration and industry-level productivity analyses showed a diverse range of growth outcomes across Australia and New Zealand: This supports Philpott's (1996) conclusion that a disaggregate analysis of New Zealand's recent growth performance is preferred. Given the diversity of growth outcomes across the two counties, we thus next turned to a quantitative analysis of the sources of productivity growth to further characterise the productivity growth performances of Australia and New Zealand.

In Chapter 10, we found that conventional productivity decomposition methods make some assumptions in aggregation, which, if certain conditions are not met, would yield misleading results when allocating growth: It was further noted that, if these conditions are not met, disaggregate and aggregate productivity analyses should be considered distinct concepts. We thus posited two flexible decompositions of productivity growth in Chapter 10 which overcame these problems, and offered us a more detailed analysis of the contributors to aggregate productivity growth.

Applying one of these decompositions to the Australian and New Zealand market sectors (Chapter 11) showed a large proportion of growth being attributed to the Transport, Storage and Communications in New Zealand, and relatively large proportions of Australia's productivity growth being attributed to the Mining and Wholesale Trade industries. We also found that labour growth slowed New Zealand's market sector productivity relatively more than in the Australian market sector, thus supporting Philpott's findings. With the sources growth in both economies characterised, we then proposed a decomposition of how differences across the industries impinged on the market sector divergence in Chapter 12.

Relative productivity growth decompositions suggested that the relative performances of all industries, with the exception of Transport, Storage and Communications and Cultural and Recreational Services, contribute to the divergence at the market sector level, with differences in the Mining and Wholesale Trade being particularly large contributors. It was also apparent from the decompositions that labour differences across the two countries contributed more to the market sector divergence than output differences, with particularly large contributions to the divergence from the Wholesale Trade and Agriculture, Forestry and Fishing industries.

In Chapter 13, we proposed an alternative decomposition of relative productivity growth, which controls the market sector divergence for structural differences across Australia and New Zealand. Applying this decomposition, we found that differences in the structure of the two market sectors acted to reduce the divergence: Structural differences were particularly large across the Mining; Transport, Storage and Communications; Wholesale Trade; Retail Trade; Finance and Insurance Services; and Agriculture, Forestry and Fishing industries.

In the cases of the Mining and Transport, Storage and Communication industries, Australia and New Zealand are allocating resources to industries where it has relatively high growth. New Zealand, however, appeared to have too many resources devoted to its relatively low-growth industries, such as Wholesale Trade and Retail Trade. Again, as with the previous analyses, we found that labour differences across the two countries had a large effect on the divergence: labour difference effects accounted for approximately 75% of total growth differences after controlling for differences in structure, and differences in the structure of labour accounted for 87% of the total structural differences after controlling for growth differences.

Our decompositions of relative productivity growth thus support the broad conclusions of Philpott (1996); Malony (1998); and IMF (2002). In particular, we confirmed that labour growth differences across Australia and New Zealand contributed a substantial amount to the cross-country divergence, indicating that production in New Zealand has become increasingly labour intensive over the previous decade. We also added to the literature regarding the divergence in productivity between Australia and New Zealand by quantifying the impact that each industry has on the market sector divergence, and by illustrating that the structure of the each economy is idiosyncratic.

These idiosyncrasies are further seen by noting that, regardless of the degree of substitutablity between labour and the other factors of production in each economy, a shift to labour intensive production techniques in New Zealand, while Australia becomes intensive in other factors of production, is indicative of differences in the fundamental drivers of growth across those economies. Comparisons between Australia and New Zealand drawn on the basis of similarities in the fundamentals of growth (as in standard neoclassical growth theory), therefore, may not provide us with many insights into the relative growth performance of the two countries.

Because of non-trivial differences in the number of stochastic sources of growth, and the structure, of the Australian and New Zealand economies, we suggest that cross-country productivity growth comparisons between Australia and New Zealand either be made at a disaggregated level, or at the aggregate level while controlling for structural differences. In both these cases, it appears that market sector productivity in Australia grows faster than in New Zealand because of cross-country differences in the growth outcomes of most of the industries, with a particularly proportion of the divergence attributed to differences across the Mining and Wholesale Trade industries. It is also apparent that the divergence is largely attributed to a shift to labour intensive production techniques in New Zealand.

Differences in the intensity to which each industry uses labour, however, suggest discrepancies in the fundamental drivers of growth across the two countries, thereby questioning whether they are indeed comparable. Comparisons between Australia and New Zealand, therefore, describe why Australia grows faster than New Zealand, but do not comment on the relevance of those comparisons. Further research, which better characterises the production processes and the fundamental drivers of growth in each economy, will thus guide us in deciding on the extent to which the two countries, or industries within those two countries, are comparable.

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Appendix A

Selected Test Statistics for Zivot and Andrews Procedure (1994:1 to 1997:4)

Model A	Electricity, Gas & Water	*k*	Wholesale Trade	*k*	Retail Trade	*k*	Transport, Storage & Communications	*k*	Finance & Insurance Services	*k*
94:Q1	-2.33	5	-3.22	7	-3.36	8	-3.19	6	-0.67	4
94:Q2	-2.2	5	-3.35	7	-3.03	8	-2.74	6	-0.62	4
94:Q3	-2.64	5	-3.34	7	-2.11	8	-2.52	6	-0.56	4
94:Q4	-2.51	5	-3.08	7	-2.25	8	-2.54	6	-0.39	4
95:Q1	-2.38	5	-3.46	7	-2.05	8	-2.59	6	-0.06	4
95:Q2	-2.52	5	-3.8	7	-2.29	8	-2.83	6	-0.14	4
95:Q3	-2.65	5	-4.43	7	-2.68	8	-3.02	6	-0.11	4
95:Q4	-2.5	5	-3.83	7	-2.9	8	-3.31	6	-0.27	4
96:Q1	-2.82	5	-3	7	-3.16	8	-3.78	6	-0.45	4
96:Q2	-1.98	5	-3.72	7	-4.06	8	-3.71	6	-0.67	4
96:Q3	-1.2	5	-3.36	7	-4.61	8	-3.26	6	-0.91	4
96:Q4	-1.25	5	-2.8	7	-3.44	8	-3.29	6	-0.84	4
97:Q1	-1.07	5	-2.52	7	-2.9	8	-3	6	-0.56	4
97:Q2	-0.93	5	-2.5	7	-2.43	8	-2.71	6	-0.54	4
97:Q3	-2.1	1	-2.75	0	-1.16	8	-2.58	6	-0.03	4
97:Q4	-2.62	1	-3.02	0	-1.23	8	-2.4	6	-0.05	4
B										
94:Q1	-2.19	5	-3.2	7	-3.66	8	-3.49	6	-2.18	4
94:Q2	-2.22	5	-3.14	7	-3.76	8	-3.48	6	-2.35	4
94:Q3	-2.25	5	-3.1	7	-3.82	8	-3.45	6	-4.26	0
94:Q4	-2.3	5	-3.08	7	-3.72	8	-3.44	6	-4.41	0
95:Q1	-2.36	5	-2.59	0	-3.62	8	-3.44	6	-5.8	1
95:Q2	-2.42	5	-2.61	0	-3.42	8	-3.44	6	-3.58	6
95:Q3	-2.5	5	-2.63	0	-3.27	8	-3.42	6	-3.88	6
95:Q4	-2.61	5	-2.66	0	-3.12	8	-3.38	6	-4.06	6
96:Q1	-2.75	5	-2.69	0	-3.06	8	-2.57	3	-3.98	6
96:Q2	-2.96	5	-2.72	0	-1.48	3	-2.58	3	-3.53	6
96:Q3	-3.16	5	-2.74	0	-1.43	3	-2.6	3	-2.96	6
96:Q4	-3.27	5	-2.76	0	-1.42	3	-2.63	3	-3.92	0
97:Q1	-3.39	5	-2.77	0	-1.47	3	-2.68	3	-3.81	0
97:Q2	-3.43	5	-2.77	0	-1.55	3	-2.71	3	-3.75	0
97:Q3	-3.39	5	-2.76	0	-2.46	8	-2.74	3	-3.67	0
97:Q4	-3.27	5	-2.72	0	-1.79	3	-2.75	3	-3.61	0
C										
94:Q1	-2.34	5	-3.73	7	-3.82	8	-2.41	3	-4.4	0
94:Q2	-2.28	5	-3.71	7	-3.73	8	-2.37	3	-4.55	0
94:Q3	-2.7	5	-3.52	7	-1.63	3	-2.51	3	-6.01	1
94:Q4	-2.69	5	-3.07	7	-1.7	3	-2.53	3	-3.68	6
95:Q1	-2.7	5	-3.49	7	-1.82	3	-2.58	3	-3.54	6
95:Q2	-3.02	5	-3.79	7	-2.83	8	-2.81	3	-3.81	6
95:Q3	-3.5	5	-4.38	7	-2.89	8	-2.98	3	-3.78	6
95:Q4	-3.82	5	-3.16	3	-2.09	3	-3.27	3	-3.66	6
96:Q1	-5.85	5	-2.37	1	-2.73	8	-3.83	3	-3.56	6
96:Q2	-6.55	6	-3.83	7	-3.05	8	-4	3	-3.51	6