ECONOMIC and LABOUR PRODUCTIVITY GROWTH:

A Regional Analysis of the States of Australia and the USA

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ABBREVIATIONS

A = 'Technical Change'

ACT = Australian Capital Territory

BEA = Bureau of Economic Analysis

BEC = Bureau of the Census

BLS = Bureau of Labour Statistics

COR = Capital Output Ratio

EE = Electronic and Electrical Equipment

EMPL = Employment

GSP = Gross State Product

HRSW = Hours Worked

K = Capital

L = Labour

LP = Labour Productivity

MFP = Multifactor Productivity

NIPA = National Income and Product Account

NSW = New South Wales

NT = Northern Territory

OECD = Organisation for Economic Cooperation and Development

POP = Population

PWT = PennWorld Trade Table

QLD = Queensland

r = Interest Rate

SA = South Australia

SIC = Standard Industry Classification

SNA = Standard National Accounts

TAS = Tasmania

TFP = Totalfactor Productivity

USA = United States of Australia

VIC = Victoria

w = Wage Rate

WA = Western Australia

Y = Output

ABSTRACT

One of the main underlying sources of economic growth is productivity. An economy can grow by either accumulation of its inputs, namely labour and capital, or improvements in productivity. The latter implies that more can be produced with the same amount of inputs, generating a greater amount of income that can be distributed among the economy's population. With rising per capita incomes, an economy can provide higher living standards and well-being.

This thesis analyses variations in economic and productivity trends among the states of Australia and the USA. It investigates whether disparities in GSP per capita, labour and multifactor productivity among the states have declined (converged) or widened (diverged), during this period. The analysis is undertaken at a national level as well as for specific industries to identify the sectoral sources of the various trends. Further, in an interstate analysis the performance of individual states is examined to identify those that may have had a major role in accounting for the observed trends. The analysis employs both cross - section and time - series techniques.

Contrary to earlier studies, this thesis finds that lately the interstate dispersion of per capita incomes and productivity has stopped decreasing. In Australia, once the Mining sector (which is a special case) is excluded from the analysis, the levels of GSP per capita and labour

productivity in the various states are found to have neither converged nor diverged.

Convergence trends among the US states observed prior to the 1990s have not only slowed down but even reversed into divergence. Divergence in labour productivity started during the 1980s in the service industries and was followed by the Manufacturing sector (and here in particular by the Electronic and Electrical Equipment industry) during the 1990s. There appears to be a belt of states in the West (and a few states in the North-East) which started off relatively poorly but managed to catch-up with the richer states due to an above average growth performance in labour productivity and multi factor productivity. Some of these states did not only manage to catch-up with richer ones but continued to surge ahead, causing the observed increase in the interstate dispersion in recent years.

Policy makers, especially those in the states that are falling behind need to develop policies that will lead to an increase in the rate of productivity growth. In order to achieve this they must foster industries, which are conducive to higher growth rates and adopt policies that would increase the productivity of the labour force. These policies will need to create an environment in which productivity enhancing innovation can be sustained. States need to engage in research and development activities to ensure the invention and the adoption of new technologies.

STATEMENT OF ORIGINALITY

This work has not previously been submitted for a degree or diploma in any university. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

Gudrun Meyer-Boehm
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CHAPTER ONE

INTRODUCTION

1.1. SIGNIFICANCE OF THE RESEARCH TOPIC

Average income levels of the countries around the world differ significantly and these differences are reflected in large variations in living standards. Even today we see a number of developing countries with per capita incomes below the poverty line as defined in developed countries such as the USA or Australia. In its 2002 *World Development Report* the World Bank reports a GNP per capita for the US of US$ 34,100 (Rank 3), while Australia ranks 19 with US$ 24,970. In comparison Ethiopia reports a GNP per capita of only US$ 660 (rank 202) and India's GNP per capita is US$ 2340 (rank 153) (World Bank, 2002).

Economic growth can be desirable as it allows higher standards of living. Economies with sustained growth are also likely to succeed in achieving a significant increase in their societies' well-being. Economies that do not grow tend to experience economic stagnation and an increase in poverty rates.

Countries do not only have different income levels: their incomes also grow at different rates. Based on the "rule of 70", just a small change in the growth rates can make a large difference over time. Average income

of an economy will, with a growth rate of just 1% per year, double every 70 years, whereas an economy growing at 2% (just 1% more), is likely to double its income in half the time (35 years).

One of the main underlying sources of economic growth is *productivity.* An economy can grow by either accumulation of its inputs, namely labour and capital, or improvements in productivity of these inputs. The latter implies that more can be produced with the same amount of inputs, generating a greater amount of income that can be distributed among the economy's population. Commonly, productivity is referred to as labour productivity and defined as output per labour input, where the latter is often measured as number of hours worked, number of employed workers, or number of the working population. With rising per capita incomes, an economy can provide higher living standards and well-being. This is why there has been so much interest in economic growth by policy makers. Productivity growth and ways to improve the efficiency of production represent a key issue for policy makers. Policies promoting productivity improvements will help an economy to achieve higher income per capita and living standards.

1.2. THEORETICAL BACKGROUND

To explain why incomes in some economies are so much higher than in others one must look at the factors that determine a nation's economic and productivity growth rates. Yet, the determinants and drivers of

economic and productivity growth are complex. This makes the analysis a difficult task and it has been subject to a large amount of theoretical and empirical research.

Classical economists, such as Smith (1776), Ricardo (1817), and Malthus (1798) were among the first to study economic growth and provide possible explanations of the determinants of economic growth. While they primarily focused on land as an input, their ideas also included the interplay between per capita income and the growth rate of population, the role of physical capital, and the effects of technological progress through increased labour specialisation, to mention just a few.

Solow (1957) and Swan (1956) made an important contribution to the modern *economic growth theory*, with the development of *the exogenous growth model*. It is commonly referred to as the neoclassical growth model, as it is based on a neoclassical production function, with constant returns to scale and diminishing returns to each input. One prediction of the model is that economies with relatively low initial income levels tend to exhibit faster growth rates, which enable them to catch-up to or converge towards richer countries. This 'convergence' hypothesis has proved useful in gaining some understanding of the economic growth dynamics across countries or regions which is provides a useful framework for policy makers. Another prediction of the Solow-Swan model is that per capita growth may eventually cease, as diminishing returns to capital imply that the effect of accumulation of capital occurs at

a constantly declining rate. In other words, the neo-classical model cannot explain sustained long - term growth.

The neo-classical growth theorists acknowledged this pitfall and augmented the production function by a shift factor, representing *exogenous technological progress*. Although the augmented model can give an explanation of sustained growth it cannot explain the causes of technological progress.

An alternative explanation of sustained growth is provided by *endogenous growth models*. These move beyond the neoclassical model by providing an endogenous mechanism for long-run productivity growth. Technical progress is seen as the result of a number of factors. In the broadest sense technology depends on *ideas*, such as the invention of the electric light, the automobile or computer chips. It is those ideas which increased productivity, allowing us to enjoy higher living standards today than earlier generations. While the two frameworks — neoclassical and endogenous growth theories — focus on different aspects of economic growth they both contribute to an understanding of the growth process and its dynamics.

1.3. PREVIOUS EMPIRICAL WORK

Empirical applications of the growth models commonly study growth dynamics for individual countries at an *aggregate level*. Cross section

studies include Abramovitz (1986), Baumol (1986) and Mankiw, Romer and Weil (1992) and their findings provide general support for the convergence hypothesis. Evidence of convergence is less frequently found in time series studies such as Bernard & Durlauf (1995) and Oxley & Greasly (1995).

Growth trends at a highly aggregated level however are likely to mask important underlying distribution dynamics and combining data sets can give a misleading picture of the individual entities. This phenomenon is commonly referred to as the Simpson Paradox (Simpson 1995). Combining data creates a *weighted* – not absolute – average of the contributing groups. In other words aggregated data do not shed sufficient light on questions like the following. Is it specific sectors or industries that help a particular country to boost its economic growth rate or is this due to particular regions or states, or is it a combination of both? It is therefore interesting to study growth trends for specific industries and also to carry out interstate comparisons.

To find an answer to the above questions researchers have analysed growth trends at a *state and sectoral level*. An extensive comparative analysis *at the state level* is undertaken by Sala-i-Martin (1996). He conducts a study of income per capita and LP for the *States* of the US, Europe, and the prefectures of Japan during 1880-1988 and finds convergence to hold in all three cases. Bernard and Jones (1996b) and Dollar and Wolff (1993) investigate growth trends for OECD countries *in*

specific industries and find that the predicted convergence trend holds at the aggregate level, but is not so clear cut for specific industries.

1.4.   STATEMENT OF THE RESEARCH QUESTION

This study will investigate economic and productivity trends at a *state and industry level*. It focuses on growth dynamics among the Australian and US states within specific industries.

In particular, the study addresses the following questions:

1. Is it true that the convergence pattern previously observed among the states of Australia and those of the USA during much of the twentieth century has disappeared and turned into a divergence pattern during the last two or so decades?

2. If the answer to question (1) above is yes, is it possible to trace the causes of the divergence to any particular state(s), any particular industr(ies), and any particular time period(s)?

3. Do the answers to questions (1) and (2) above depend on whether the analysis focuses on income per head, labour productivity, or multifactor productivity?

4. Do the answers to questions (1) to (3) above depend on whether cross - section or time - series techniques are employed?

1.5.   OUTLINE OF THE STUDY

Chapter Two gives an overview of the theoretical framework and previous empirical research. Chapter Three addresses questions (1) - (3) above for Australia. It examines differences in the economic and LP growth performances of the six states of Australia over the period 1984/85 to 1998/99. The results indicate that while considerable cross - state variations exist in the growth rates of income per capita, the rates of LP growth have been far more similar to one another. Further, it appears that differences in the industrial structures of the various states play a key role during the period studied. Most importantly, when Mining is excluded it is found that the levels of GSP per capita and LP in the various states of Australia have tended to neither converge nor diverge over the past fifteen years. Instead the growth paths have been remarkably similar. While a more in depth analysis of the underlying sources of different growth dynamics would be useful data availability limits further research.

Chapters Four to Six address questions (1) - (4) for the USA. The analysis of the states of the US offers a greater pool for the researcher, as there a firstly more states which are likely to be more diversified and secondly more and more detailed data is available at a state and sectoral level. Chapter Four focuses on the aggregate trends among the US states.

The findings suggest that the convergence process observed prior to the 1990s was no longer robust in recent years. In particular, there is

evidence that the dispersion of LP has increased over time. This trend was strongest during the 1990s in the Manufacturing industry and could be further traced to the Electronic and Electrical industry. The widening of the dispersion of productivity was due to a group of states in the West of the country which reported above average growth rates in multi factor productivity, which enabled them to grow faster than the national average.

Chapter Five delves deeper into the sources of variations across these States by analysing growth dynamics for sub-industries in the Manufacturing industry. Chapter Six narrows the focus even more by studying trends of multifactor productivity in the Electronic and Electrical Equipment industry.

The results suggest that we may be witnessing a period of turbulence in the relative ranking of the US states, in particular in the area of high-technology. Innovations and technical progress do not spread evenly through the states but tend to congregate in certain regions. In particular, there appears to be a belt of states in the Western part of the country (together with a few more states in the North East regions) which by and large have benefited more from the reported surge in productivity growth than the remaining states.

Chapter Seven contains a summary and a discussion of policy implications as well as possible directions for future research.

CHAPTER TWO

METHODOLOGY AND BACKGROUND

2.1. INTRODUCTION

The first half of this chapter will give a brief overview of the theoretical framework underpinning research on economic growth. In particular, Section 2.2 describes the neo - classical and endogenous growth models. The former model provides a useful framework in two respects. Firstly, it helps to shed light on the underlying dynamics of labour productivity (LP) growth by separating it into its sources, that is, growth in technical progress and capital deepening. Secondly, it provides an analytical framework to explain how economies develop relative to each other that is, whether they become more or less evenly distributed (convergence analysis), as it predicts that poorer countries tend to grow faster than richer ones. The neo - classical framework has been a benchmark in the growth literature, due to its simplicity and intuition, but because of some shortcomings it has not been deemed entirely satisfactory.

In particular, technology, a central component in the neo - classical growth theory, is assumed to be exogenous. Technological improvements are not modelled in the neo-classical framework and differences in technologies across economies remain unexplained.

However, technical progress can be the result of a number of factors. E*ndogenous models* extend the neo - classical theory by creating an economic model of technology and technological improvements. In these models technical progress is assumed to be endogenous. In the broadest sense technology depends on *ideas*, such as the invention of the electric light, the automobile or computer chips. It is those ideas which increase productivity thereby allowing us to enjoy much higher living standards today than some decades ago. While these two approaches focus on different aspects of economic growth they both contribute to the understanding of the growth process and its dynamics.

The second half of Chapter Two provides an overview of some of the empirical literature in this area. Section 2.3.1 involves a discussion of studies using the neo - classical growth accounting framework traditionally used to separate economic and LP growth trends into its sources. This kind of analysis has been applied to several countries, such as the US, European countries, Australia, and also less developed countries.

Section 2.3.2 will then turn to studies investigating the convergence hypothesis. Three main criteria for classification can be distinguished here. *Firstly*, researchers apply the concept of convergence to different *countries*, as well as to regions and states within a given national economy. *Secondly*, they investigate the dynamics at both the aggregate

and industry levels. *Last but not least* they apply different econometric techniques. The discussion will now turn first to the theories of growth.

2.2.   THE NEO - CLASSICAL AND ENDOGENOUS GROWTH MODELS

2.2.1. The Neo - Classical Growth Model

Classical economists such as Smith (1776), Ricardo (1817) or Malthus (1798) were among the first to study economic growth and its determinants.   However, it was Solow (1957) and Swan (1956) who pioneered growth modelling in the post World War II era.   Their model is known in the literature as the neo - classical growth model. On the one hand, the Solow - Swan model gives an explanation as to why countries around the world have different income levels. Output will increase as a result of use of more inputs but also as a result of use of more productive inputs. In other words, countries investing a larger fraction of their resources in capital in particular and countries that use their inputs more productively tend to be richer than countries that fail to do so.

On the other hand it provides a possible explanation as to why countries have different *growth rates* in output or productivity. One of the key assumptions in the model is that of diminishing returns to capital, which implies that poorer countries are more likely to exhibit faster rates of

growth which enables them to catch-up with (converge to) richer economies.

The Solow - Swan growth model is based on a production function which relates output (Y) to capital (K) and labour (L) used. Typically constant returns to scale and decreasing returns to each input are assumed.

(2.1) $Y = F(K, L)$

Assuming the Cobb-Douglas functional form, we have:

(2.2) $Y = K^{\alpha} L^{\beta}$

where α and β are elasticities between zero and one. Under the assumption of constant returns to scale, these add up to one ($\alpha + \beta = 1$).

Solow (1957) acknowledges that growth depends not only on the quantity and quality of primary inputs, but also on the efficiency of their use. He therefore augments the basic framework by including a shift factor (A).

(2.3) $Y = A K^{\alpha} L^{\beta}$

An increase in A, reflecting more efficient production, is likely to shift the production function upwards and increase output.

Solow interprets the shift factor as a measure of "*the cumulated effect of shifts* [of the production function] *over time*" (Solow, 1957, p. 312). According to Solow, this "multiplicative factor" represents neutral technical change. Here it is written in the form of Hicks-neutral technological progress. In contrast, Harrod-neutral or labour-augmenting technical progress is written as $Y = K^{\alpha} (A\ L)^{\beta}$. Further, changes in the shift factor (A) are assumed to be exogenous. Therefore the model is sometimes also referred to as the exogenous growth model.

Equation (2.4) is obtained by rewriting equation (2.3) in the form of growth rates

(2.4) $dlnY = dlnA + \alpha\ dlnK + \beta\ dlnL$

where d = first difference and ln = natural logarithm

Solving for growth in the shift factor yields:

(2.5) $dlnA = dlnY - \alpha\ dlnK - \beta\ dlnL$

The left hand side of equation (2.5) is widely known as the "Solow residual". While A itself does not carry any interesting information, changes in A indicate shifts in the relation between measured aggregate

inputs and outputs which can be assumed to have been caused by changes in technology (Lipsey & Carlaw 200). In practice, it is often seen as a measure of growth in multifactor productivity (MFP) or total factor productivity (TFP) (Jones, 1997).[1] Note however that it captures the effects of all the other factors that may determine output growth other than changes in the quantity of capital or labour inputs. For example, growth in A may arise from technological progress, in the form of advances in technology or organisational efficiency, which make physical capital or labour more productive than before (Law (2000)).

It could also arise from increases in another factor of production (eg. human capital) which is not yet captured in the model (Jorgenson (1995), Griliches (1994)). Additionally, the traditional model assumes labour and capital inputs are each homogenous. Since this is not the case in reality, also compositional changes in either capital or labour will result in a change in A. Lipsey and Carlaw (2000) categorise the various views into three groups: (1) the conventional view (Law (2000)), that MFP actually captures the rate of technical change, (2) the Jorgenson and Griliches view (Jorgenson (1995), Griliches (1994)) that MFP is mainly associated with externalities and scale effects, eg from human capital or research and development and difficult to measure, and a third group which is sceptical that MFP measures anything useful. In other words, the measure MFP must be interpreted with care or as Griliches (1995, p. 6)

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[1] For simplicity MFP will be used here.

concludes "all of the pioneers of this subject were quite clear about the tenuousness of such calculations and that it may be misleading to identify the results as 'pure' measures of technical progress."

From the profit maximisation problem

(2.6)   max $Y = F(K,L)$

                s.t.: $Y = rK + wL$

where r = rate of return to capital, w= wage rate

The following equations can be derived

(2.7) (a) $(\partial Y/\partial K) = \alpha \, (Y/K) = r$

(2.7) (b) $(\partial Y/\partial L) = \beta \, (Y/L) = w$

After regrouping it can be seen that alpha and beta, which are the elasticities of output with respect to capital and labour respectively, are equal to the shares of labour income and capital income in total GDP. Implicitly the share weights are assumed to be equal across economies and time, otherwise comparisons would be dangerous (Fox, et al 2002).

(2.8) (a) $\alpha = r \, (K/Y)$

(2.8) (b) $\beta = w \, (L/Y)$

The effects of technical change on output (dlnA) can then be obtained as the difference between output growth and the share weighted growth of both inputs, capital and labour.

Investment, one of the key variables in the neo - classical model, enters the model through the capital accumulation equation (2.9). Investment in capital enables the capital stock to be expanded, increasing both the capacity to produce and also the efficiency of production and both effects will cause an increase in output. In other words, countries that invest a larger fraction of their resources in capital tend to have higher income per capita levels.

(2.9) $K_t = (1-\delta) K_{t-1} + I_t$

where δ = depreciation ratio, I = gross investment and t = time

2.2.2. The Neo - Classical Growth Model and Growth Accounting

The Solow model provides a useful framework to separate growth in labour productivity into its sources. By transforming equation 2.4, one can identify the sources of labour productivity growth. Subtracting dlnL from Equation 2.4 gives,

(2.10) $d\ln y = d\ln A + \alpha \, d\ln k$

where $d\ln y = d\ln Y - d\ln L$ and $d\ln k = d\ln K - d\ln L$

Equation (2.10) expresses formally, that growth in labour productivity (dlny) depends on a more efficient use of the inputs — expressed as growth in technical change (dlnA) — and on capital deepening — expressed as growth in the amount of capital per worker (dlnk).

2.2.3. The Neo - Classical Growth Model and Convergence

One prediction from the Solow-Swan growth model is convergence that is the poorer the economy starts off, relative to its long-run steady state, the faster will be its growth rate. This property derives from the assumption of diminishing returns to capital. Economies that have less capital per worker tend to have higher rates of return from capital investment, which leads to higher growth rates.

The literature distinguishes between two types of convergence, absolute and conditional convergence. From equation 2.10 it can be seen that growth in output per worker (y) depends on growth in capital per worker (k). Capital itself depends on the rate of investment and the depreciation rate (δ) (equation 2.9). Under the assumption of a constant labour force participation rate, growth in output per worker also depends on growth in

population. The *absolute convergence hypothesis* states the following: if a group of countries, all of which are structurally similar, in the sense that they have the same values for investment and depreciation rate and population growth and only differ in terms of their initial level of output or output per worker, then *all* economies should converge to the same capital – labour ratio and output per capita growth rate. By contrast, the *conditional convergence hypothesis* states that if countries vary in the above determinants, then they should still converge to the same growth rate, but not necessarily at the same capital – labour ratio. They do not converge to the *same* steady state capital- labour ratio but to their *own* steady state.

The Solow Swan model predicts conditional convergence. The convergence is conditional because the steady state levels of capital and output per worker depend, in the Solow Swan model, on the investment, depreciation and population growth rate (equation 2.10), which tend to vary among the economies. In other words, the model predicts conditional convergence in the sense that a lower starting value of output per worker tends to generate a higher growth rate, once we control for the determinants such as different investment rates. Empirically this implies that convergence is more likely to occur the more homogeneous economies are, such as regions or states within a country.

The neo - classical framework has been a benchmark in the growth literature. It fails to offer a persuasive explanation of the productivity

slowdown during the 1970s and 1980s. Secondly, in the absence of technical progress the assumption of diminishing returns to scale implies that an increase in per capita growth can only be of a temporary nature rather than a *long term* increase. Once countries have reached their steady state, where the marginal product of capital becomes zero, without technical progress economic growth will stop. Only with technical progress can sustained economic growth be realised. *Thirdly and most importantly*, the neo - classical model assumes technical progress to be exogenous and cannot explain what determines growth in the efficiency factor (A). To overcome these shortcomings researchers have extended the basic Solow model.

2.2.4. Endogenous Growth Models

Endogenous growth models move beyond the neo - classical model by providing an endogenous mechanism for long-run technological progress. One limitation of the neo - classical growth model is the assumption of exogenous technical progress. It cannot explain what causes a firm to use its inputs more efficiently and hence produce more output with the same amount of inputs.

Endogenous models address this issue by explaining that technical progress within the model. Romer (1994) states that the endogenous growth theory   *"distinguishes itself from the neo-classical growth theory by emphasising that economic growth is an endogenous outcome of an*

economic system, not the result of forces that impinge from outside" (p. 3). The models are based on the assumption of increasing returns to scale due to spill-over effects from "ideas", in contrast to constant returns as assumed in the neo - classical model.

How do ideas generate spill - over effects in production? In a seminal paper, Romer (1986) formalises the process of invention and innovation that drives technical progress. He argues that technological and organisational improvements emanate from new ideas, which are generated by those engaging in research and development (R&D). A key characteristic of ideas is that they are *non - rival*. Once an idea has been created, anyone can take advantage of it, or in other words if one person uses the idea of another person, the latter does not lose that idea. Further, most of the ideas are also *non-excludable*, such as results from basic R&D. It is well known that goods that are non-rival and non-excludable (also known as public goods) involve substantial spill - over benefits or positive externalities. These spill - over effects imply increasing returns to scale, as for instance a doubling in the inputs will more than double the output for society as a whole.

In the Lucas model (Lucas, 1988) endogenous growth is knowledge based. Lucas argues that, investment in human capital through education and training will not only increase the return for the individual but also be beneficial for the society as a whole. In other words, the productivity of a worker is not only enhanced by his individual skills but also by the

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average skills of his fellow workers. Further, education is subject to dynamic feedback, that is as we learn more, it becomes easier to acquire further knowledge and skills. Once we have learned to read, the acquisition of further information and skills is facilitated through book learning (Dowrick, 2002). In other words, similar to ideas, investment in human capital generates spill - over benefits and positive externalities allowing increasing returns to scale. For similar reasons Coe and Helpman (1995) argue that technological improvements may also depend on R&D activities in other countries.

While the theoretical approach of endogenous models provides a plausible explanation, it is a difficult task to measure the concept of ideas or human capital empirically. R&D expenditures are commonly used as an input into the production function for ideas. Alternatively, patent counts may also be a feasible proxy for new ideas. Often expenditure on education and training are incorporated, as a proxy for human capital. Yet, those measures may not be accurate as not all ideas are patented and not all ideas are the result of R&D initiatives.

Still, despite the difficulties in the measurement of ideas, endogenous models focus on understanding the economic forces underlying technological change and provides an explanation of why different economies have different levels of technology.

2.2.5. Endogenous Growth Models and Convergence

In contrast to the neo - classical framework, endogenous growth models do not predict convergence as it assumes constant or even increasing returns to capital. In addition, convergence and other equilibrating trends could be outweighed by 'adverse backwash effects' (Richardson, 1969). He demonstrates that innovations and technical progress may not spread evenly through an economic or regional system but will tend to perpetuate the agglomeration advantages of already prosperous economies and help them to surge even further. Similarly, Myrdal (1957) argues that "*The play of the forces in the market normally tend to increase, rather than decrease, the inequalities between regions" (p. 26)*. Myrdal explains that the agglomeration of economic activities may have started originally due to access to certain resources or facilities and tend to become self-sustaining, while backward regions in a country fail to attract new activities that may generate autonomous economic growth.

Richardson (1969) gives several reasons to explain these dis-equilibrating forces. If marginal returns to capital are higher in low income economies the capital market may be too inflexible and inefficient for capital to flow there. Further, high income regions may be likely to save more as a result of higher incomes and these savings may again be re-invested in the economy fostering economic growth. Migration may have a harmful effect for the age structure in the poor region, if their young and well trained residence move to high income and high wage economies. More important, economic backwardness of low income economies may

result in non-economic influences harmful to growth. Low levels of education, lack of aspiration and incentives are incompatible with high rates of economic development and are likely to deteriorate the situation of the disadvantaged economy even further (Richardson, 1969).

While increasing returns to scale in endogenous growth models, prevent a tendency of economies to converge, the assumption that low income economies have higher returns to capital is also not a guarantee for convergence. Other economic forces may outweigh the equilibrating tendency, favouring the rich economies at the expense of the poor.

2.2.6. Summary

The neo - classical model provides a useful framework in two respects. Firstly, it helps to shed light on the underlying dynamics of LP growth by separating it into its sources, namely growth in technical progress and capital deepening. Secondly, the exogenous model provides a possible analytical framework to explain how economies develop relative to each other, that is whether they become more or less evenly distributed (convergence analysis). It predicts that poorer countries tend to grow faster and catch-up with richer ones.

Several shortcomings of the neo - classical growth model, particularly the assumption of exogenous technical progress, induced researchers to develop and extend the Solow - Swan model. In the endogenous growth

framework, technological progress is determined within the model. In the broadest sense technology depends on *ideas*, such as the invention of the electric light, the automobile or computer chips. It is those ideas and the associated spill-over effects that help to explain why different countries have different technology levels. Still, while both frameworks focus on different aspects of economic growth they both contribute to the understanding of the growth process and its dynamics.

2.3. EMPIRICAL EVIDENCE

The neo - classical model as described in Section 2.2 is useful for researchers in two respects. Firstly, it provides an analytical framework to estimate the contributions of growth of the various inputs, and growth in technical progress to growth in output (growth accounting analysis). Secondly, it provides a possible analytical framework to explain how economies develop relative to each other, that is whether they become more or less evenly distributed (convergence analysis).

The empirical literature applying the neo - classical model is vast and the following section can only provide an overview of some of the studies. Section 2.3.1 reviews studies using the growth accounting framework (Equation 2.5) to estimate growth in technology and its contribution to output growth. Section 2.3.2 summarises some of the studies investigating the empirical relevance of the convergence hypothesis.

2.3.1. Empirical Evidence: Growth Accounting

Solow (1957) himself has applied his model as specified in Equation 2.5 to the US to estimate the contributions of growth in capital, labour and technology to growth in output at the *aggregate level*. He investigates GNP data between 1909 - 1949 and finds a remarkable seven-eighth of the increase in output per capita is due to technical change, and the remaining one-eighth the result of higher capital intensity.

Other researchers have applied the growth accounting framework based on Solow's model to other countries. Christensen, Cummings, and Jorgenson (1980) study 8 countries, namely Canada, France, Germany, Italy, Japan, the Netherlands, the United Kingdom and the United States between 1947-1973. On average, growth in MFP contributed a substantial one-third to the overall growth in output. Dougherty (1991) analyses a similar set of OECD countries, except for the Netherlands for a more recent period, 1960 - 1989. Overall, growth in MFP is significantly smaller than during the earlier period 1947-1973, reflecting the worldwide productivity slowdown during this period. Still, growth in MFP accounts for more than 30 % of growth in output.

Elias (1990) applies the growth accounting framework to seven countries in Latin America during 1940 - 1980. The share of overall growth accounted for by MFP was around 30% for Argentina, Brazil, Chile, Columbia, and Mexico. In contrast, the MFP share in total growth for Peru and Venezuela is zero and 9.6 %, respectively. The results for the East

Asian countries of Hong Kong, Singapore, South Korea and Taiwan during 1966 - 1990 vary even more. According to Young (1994), MFP contributions to output growth only played a significant role in Hong Kong. Singapore even experienced negative growth in TFP.

The above studies all apply the growth accounting framework to a group of countries. Further studies on the US were undertaken by Griliches and Jorgenson (1967). They look at growth trends of the US during 1945 - 1965. On average they find that growth in MFP contributes 46% of growth in output. They also extend the classical model by introducing a number of measurement innovations in the data used. For instance, they use capital service flows rather than capital stock data to take account of possible changes in the quality of the input. Once they correct their data for measurement errors the Solow residual reduces to less than 3%.

Jorgenson and Stiroh (2000) (JS), Oliner and Sichel (2000) (OS) and Gordon (2000), all focus on the US as well. JS and OS report that around two third of the *acceleration* in LP was due to capital deepening. Further the authors report that capital deepening is the result of an acceleration in the IT capital in particular. Gordon (2000) argues that MFP growth was not a key contributor, as according to him some of the growth in output was due to a cyclical component.

Dowrick (1997) uses the growth accounting framework to study sources of output growth for Australia during 1965/66 - 1993/94. He looks at three

sub-periods, the 1960s, 1970s and 1980s. While for the earlier period the contribution of MFP to LP growth was 60% it declined to 48% during the 1970s —the period of the worldwide productivity slowdown — and increased to 83% in the 1980s. Parham (2002) looks at a slightly longer time span 1964/65 - 1999/00 and reports a similar pattern. The contribution of MFP to LP growth in earlier decades was around 50%; it declined during the 1970s/80s and increased again to around 60% during the most recent decade.

The study by Simon and Wardrop (2002) also focuses on Australia, between 1990-91 to 2000-01. Similar to JS and OS for the USA, they also distinguish between the contribution of IT capital and 'other' capital. Over the whole period, MFP growth was the largest single contributor with 37%, followed by IT capital with a contribution of 25% to growth in output.

In summary, the growth accounting framework is a commonly applied method to estimate growth in MFP and its contributions to output growth. Overall, most of the empirical studies estimate the Solow residual to be of quite a substantial size. Some of the growth in output can also be accounted for by investment in capital and particularly in IT related capital. Contributions of MFP seem to play a more dominant role in developed countries, whereas in developing countries, such as the Latin American countries, investment in capital seems to be the primary source of output growth. As economies report different growth rates in inputs and MFP the question arises as to how they will develop over time relative to

each other. In other words, do economies become more or less evenly distributed? Studies addressing this research question are summarised in the next section.

2.3.2. Empirical Evidence: Convergence

Researchers are not only interested in the rate of growth of a particular economy, but also in how economies develop relatively to each other. The concept of diminishing returns to capital, a key assumption in the neo - classical framework, provides one explanation as to why there might be a tendency for poorer countries to grow relatively faster than richer ones (Conditional convergence). The following studies, summarised in Table 2.1 and 2.2 on p. 40-43, give a brief overview of the research undertaken, investigating the empirical relevance of this catch-up hypothesis.

In general, evidence on whether the disparities between economies decrease, depends on, *firstly*, the sample selected. Convergence tends to be more likely to hold among relatively homogenous countries such as the member countries of the OECD. *Secondly*, convergence also depends on the selected time frame, as the speed of convergence may vary over time. During periods of long recessions or war, convergence tends to slow down to pick up during periods of recovery. *Thirdly,* the reported results also vary with the methodology used. With cross-section techniques convergence is more likely to be observed, while with time-

series techniques it is found less frequently. As shown by Bernard and Durlauf (1996) it is possible for a set of economies to exhibit convergence in a cross section sense, but to still diverge from a time-series point of view, as cross section tests are based on much weaker restrictions than time series tests. *Last but not least*, convergence also depends on the level of aggregation. The catch-up tendency appears to be less clear cut at the industry level. The following two sections will provide empirical evidence for the four arguments stated here.

2.3.3. International Studies

Cross-Section

Abramovitz (1986) is one of the first to test convergence of LP of 17 *countries* between 1870-1979. He finds evidence of convergence as there exists a strong negative correlation between the initial level and the growth rate of LP. Further, the dispersion in income levels across the countries decreases as the coefficient of variation (CV) — a measure of dispersion — declines from 0.5 to 0.15.

Similarly, Baumol and Wolff (1988) test 19 European countries between 1950 - 1980 and find that regardless of the country grouping there is convergence between 1950-1970, although catch-up takes place at different speeds.

Baumol (1986) also looks at the OECD countries using a similar data set as Abramovitz (1986) and finds evidence of convergence for LP among the OECD countries during 1870-1979. Convergence does not hold once he increases the sample size to 72 countries. He argues that convergence occurs among groups of countries that tend to be relatively similar in their economic situation, such as the OECD countries.

Dowrick and Nguyen (1989) analyse income, LP and MFP trends for the OECD and other countries between 1950 - 1980. They find that while LP levels had diverged between countries since the 1970s, convergence in MFP remained robust after testing for parameter stability, sample selection bias and many other measurements. They conclude, that:

> "Although income levels have not converged for the wider sample, TFP catch-up has been operating…the reason that incomes within the wider group of countries have not converged is the tendency for poorer countries to have lower investment ratios relatively to rapidly expanding populations" (Dowrick and Nguyen, 1989, p. 1018, 1021-22).

Mankiw, Romer and Weil (MRW) (1992), deLong (1988), de la Fuente (1997) come to the same conclusion as Baumol that convergence depends very much on the sample of countries selected. While MRW find convergence in LP for 22 OECD countries during 1960-1985, convergence is not significant for a sample of 75 and 98 countries. For

similar reasons deLong (1988) finds divergence for 23 countries, but convergence once he excludes four of the poorest countries (Argentina, Chile, Portugal, Spain), which not only fail to catch-up, but fall behind. De la Fuente (1997) also finds evidence of convergence clubs as convergence holds across the European countries but there is an increase in dispersion, once he includes most of the remaining countries in the world.

Quah's (1993) analysis supports the idea of convergence clubs, yet he undertakes a dynamic distribution analysis and studies GDP per capita for 118 countries. Quah reports that there is a tendency towards polarisation of the countries into rich and poor, in other words, convergence occurs only within the high and low - income countries.

Time - Series

The above studies all apply a cross-section methodology. Bernard and Durlauf (1995) test for convergence in a *time-series framework.* They both apply cointegration techniques to test for common trends in real output per capita for 15 OECD countries from 1900 to 1987. While they do not find evidence of convergence, most of the countries exhibit substantial cointegration, indicating that there is a set of common long-run factors which jointly determines international output growth among the 15 countries.

Similarly, Oxley and Greasley (1995) apply a Dickey-Fuller unit-root based test to study GDP per capita trends during 1870-1992 for Australia, UK and the USA. Although they find evidence of a unit root and consequently divergence in a time-series sense for all three pair-wise tests, the statistical findings support the convergence hypothesis once the authors incorporate discontinuities in the Australian and UK growth record, such as the depression during 1881 in Australia.

Linden (2002) applies a time-series analysis to GDP per capita data for 15 OECD countries, focusing on a *later time span* (1949-1997), including the 1990s. Interestingly, in line with the earlier research he finds evidence that the European countries and Japan converge to the USA before 1980, but for some countries the picture has altered since the beginning of 1980. There is even some evidence of divergence in the more recent period.

Freeman and Yerger (2000) apply both time-series and cross - section analysis to a sample of OECD countries during 1950 - 1998. They find contrary results for the different methodologies. Before 1970 they find convergence in a cross - section but not in a time - series sense. After 1970, cross-section convergence has disappeared but now there is evidence of time - series convergence.

Bernard and Jones (1996b) apply both cross-section and time-series convergence techniques. Similar to Yerger and Freeman (2000) they

analyse growth trends among the OECD countries, but focus on *MFP dynamics*. They find convergence of MFP to hold during 1970 - 1987 with both cross - section and time- series estimates.

Industry Analysis

All of the above literature has focused on the *aggregate level* only, except for Bernard and Jones (1996b) or Barro and Sala-I-Martin (1991). Bernard and Jones study convergence at the *industry level*. They report that the convergence found at the aggregate level is not so clear cut at the industry level. While convergence holds for most of the non-manufacturing industries, manufacturing itself reports evidence of divergence.

Other studies at the industry level include research by Dollar and Wolff (1993), Caree, Klomp and Thurik (2000) and Melanchroinos and Spence (2001). All three studies confirm the results found by Bernard and Jones (1996b), that convergence at the industry level is not strong. Dollar and Wolff (1993) study productivity trends across 14 OECD countries during 1970s - 1987 and report that convergence is evident at the aggregate level, but that the results vary for each industry. Caree, Klomp and Thurik (2000) analyses LP trends for 18 OECD countries during a similar time span —1972 - 1992 and their results show large inter - industry differences in the extent of convergence. Melanchroinos and Spence (2001) investigate productivity trends for the Manufacturing industries

across 13 countries of the EU during 1978-1994, and conclude that 'catch - up' holds for LP but is not evident in MFP.

In summary, all of the above studies investigate how *countries* develop relative to each other in terms of income per capita, LP and MFP. The evidence on whether they become more similar, as predicted by the neo - classical growth model, is mixed. Both convergence and divergence were found. Three patterns can be reported. *Firstly*, convergence depends on the *sample selected* and appears to hold for more homogeneous economies — convergence clubs — such as the OECD countries, but not for poorer countries. *Secondly,* the degree of convergence varies for different time periods. While convergence was much stronger during earlier decades, it appears to have ceased lately. *A third pattern* observed is, that convergence occurs less frequently in a time-series framework than with cross-section techniques. *Last but not least*, convergence also depends on the level of aggregation. The catch-up tendency appears to be less clear cut at *the industry level*.

2.3.4. Inter – Regional Studies

The debate on the empirical relevance of the convergence hypothesis at the *international* level prompted researchers to investigate growth dynamics in an *inter-regional* — state by state— analysis. They were hoping to shed more light on the catch-up hypothesis and why it does or why it does not occur. On the one hand it can be argued that states within

a country tend to be more homogenous and based on the conditional convergence hypothesis (p.18) more likely to converge. On the other hand, Myrdal (1957) states that the play of the forces in the market normally tends to increase, rather than decrease, causing inequalities between regions to widen. Then states with similar economic conditions may not exhibit a tendency to converge.

Regional convergence has been tested for a number of countries. Table 2.2 summarises just a few of them. Extensive work was undertaken by Sala-i-Martin (1996). He conducts a study of income per capita and LP for the *States* of the US, Europe, and the prefectures of Japan during 1880-1988 and finds convergence to hold in all three cases.

> "... the empirical evidence on regional growth and convergence across the United States, Japan, and five European nations ... confirm[s] that the estimated speeds of convergence are surprisingly similar across data sets: regions tend to converge at a speed of approximately two percent per year. We also show that the interregional distribution of income in all countries has shrunk over time" (Sala-i-Martin, 1996: p. 1325).

Another regional convergence analysis was done by Persson (1995). He analyses per capita income for 24 Swedish counties during 1911-1993 and finds strong evidence on regional convergence. Similarly, Gundlach (1997) finds that convergence of labour productivity across the Chinese

provinces between 1979 and 1989 occurs at a rate of 2.2%. Funke and Strulik (1999) focus on GDP per capita for the 11 'Laender' in Germany during 1970-1994. They apply a cross - section and time- series analysis. The authors find support for convergence, yet the Laender do not share a common steady state and the disparities between rich and poorer Laender remain persistent.

Ferreira (2000) studies per capita incomes for 24 states in Brazil during 1970-1995. He finds evidence of convergence between 1970 and 1986. After 1986 the process of convergence slows down and almost comes to a halt, as a significant number of poor and very poor states appear to have reached their steady state. Similarly, Pekkala (2000) analyses convergence for the regions in Finland during 1960-1994. He finds convergence during 1960-1980 among the twelve regions; yet after 1980s the convergence trend has slowed down, although divergence is not reported.

Gumbau - Albert (2000) looks at the regions in Spain during 1964 and 1993 and reports evidence of convergence in labour productivity at the aggregate level due to faster growth of the capital - labour ratio and technical progress in the initially poorer regions. He also undertakes an industry analysis, yet support of convergence at the sectoral level is mixed.

Studies analysing the EU regions, that is the states of the EU member countries, include Abraham and Rompuy (1995), Armstrong (1995), Paci (1997) and Tondl (1999). Again, similar to Sala-i-Martin (1996) all find evidence of convergence, although at varying levels of significance and different speed of convergence.

In sum, as predicted by the conditional convergence hypothesis, most of the studies at the inter-regional level find support of the convergence hypothesis., although at different levels of significance, for different variables and over different time spans. Although some authors find that the convergence process has slowed down or even came to a halt during the mid 1980s, divergence was not reported.

The following chapters of this thesis will analyse productivity trends among the s*tates* of Australia and the US at an *industry level*. Earlier studies analysing economic and growth dynamics across the Australian states were undertaken by Harris and Harris (1992), Cashin (1995) and Neri (1998). All three studies are based on analyses of GSP per head of population. Harris and Harris (1992) analysing data for the Australian states between 1953/54-1990/91 find some evidence of convergence with deviations from the national mean of GSP per head in most of the Australian states tending to become smaller, except for Tasmania. Cashin (1995) looks at a longer time span (1861-1991) and also includes New Zealand and again finds that most of the convergence occurred during the 19th century, while during the following 90 years (1901-1990)

this trend has slowed down. Neri (1998) extends Cashin's study and emphasises that between the mid 1970s to early 1990s there was a clear rise in dispersion of the income gaps between the states.

Studies for the States of the USA at the aggregate level were done by Sala-i-Martin (1994), Crow and Wheat (1995), Mitchner and McLean (1999), Sum and Fogg (1999), to mention just a few. These studies analyse income per capita data and report convergence yet at different levels of significance.

Barro and Sala-i-Martin (1991) examine sigma convergence trends at the aggregate level and for eight industries within the USA during 1963 - 1986 in terms of income per capita, gross state product per capita, as well as labour productivity. They find beta convergence at the aggregate level and for each of the eight sectors, although at varying levels of significance. Yet, over different sub-periods beta convergence at the aggregate level shows substantial variation

Bernard and Jones (1996b) investigate productivity trends across the US states for specific industries using both a cross-section and a time- series approach. With cross - section analysis they find evidence of convergence at the aggregate level, but at the industry level the trends are mixed. The results of the time - series analysis confirm by and large their cross - section findings. In contrast, Carlino and Mills (1996) find evidence of cross -section convergence but divergence in a time -series

sense for income per capita data during 1929-1990. These studies will be discussed in more detail in Chapter Three for Australia and Chapter Four for the US.

2.4.   CONCLUSION

The exogenous growth model developed by Solow (1957) and Swan (1956) provides a framework to estimate and analyse the dynamics of growth rates of economies over time. Further, based on the assumption of diminishing returns to capital, it provides an explanation as to why some initially poorer countries tend to exhibit higher growth rates, enabling them to catch-up with relatively richer ones. This catch-up hypothesis has been subject to extensive empirical research.

The evidence on whether economies become more similar, as predicted by the neo - classical growth model, is mixed. Both convergence and divergence were found. Firstly, convergence depends on the *sample selected* and appears to hold for more homogeneous economies (conditional convergence) such as the OECD countries. *Secondly,* degree of convergence varies for different time periods. While convergence was much stronger during earlier decades, it appears to have ceased lately. *Thirdly,* convergence occurs less frequently in a time-series framework than with cross-section techniques and *last but not least*, evidence of convergence varies with the level of aggregation.

Endogenous growth models extend the neo - classical framework by determining long run growth *within* the model. In other words, technical change is assumed to be endogenous, and driven by spill-over benefits from new ideas resulting from R&D activities. While these two frameworks — exogenous and endogenous — focus on different aspects of growth and its dynamics they both contribute to an understanding of the growth process.

The following chapters will study productivity dynamics for the states of Australia and the US at an industry level. The analysis proceeds along the lines of the neo - classical model, while acknowledging that in future research the study should be extended further and incorporate features of the endogenous growth models, as data availability permits.

TABLE 2.1
EMPIRICAL STUDIES ON COUNTRY CONVERGENCE

AUTHOR	DATA	ECONOMIES	METHOD	FINDINGS
Abramovitz (1986)	LP GDP / HRSW 1870 - 1979	US + 16 countries	cross - section β and σ convergence	evidence of convergence as rank correlation between initial level and growth rate = -0.97 clear evidence of "catch-up", as CV declines from 0.5-0.15
Baumol (1986)	GDP/capita 1950-1980	72 countries	cross-section regression + graph	no evidence for GDP per capita
	LP 1870-1979	US + 6 countries		evidence for of convergence in LP suggests convergence clubs
Mankiw Romer & Weil (1992)	LP 1960-1985	- 98 countries - 75 countries - 22 OECD	growth accounting convergence	no evidence for convergence for first 2 samples, evidence of convergence for OECD sample
deLong (1988)	GDP/capita 1870-1979	23 countries	cross - section	no evidence of convergence due to falling behind countries, sample selection crucial for convergence
de la Fuente (1997)	GDP/capita 1960--1985	Europe, OECD, World	cross - section	industrialised countries converge, world dispersion increases conditional convergence, convergence. clubs
Baumol and Wolff (1988)	GDP/capita 1950-1970	19 European countries	cross - section	convergence 1950-70 convergence slowed during 1975-81
Quah (1993)	GDP/capita 1962-85	118 countries	ergodic distribution	thinning out of the middle-income incomes tend towards extremes at both high and low end positions convergence among high income and low incomes countries
Dowrick and Nguyen (1989)	GDP/capita, MFP 1950-1980	OECD	cross - section CV StDeviation	evidence of β for GDP per capita at various significant levels convergence in TFP
Oxley and Greasley (1995)	GDP/capita 1870-1992	AUS, UK USA	time- series unit root	evidence of convergence and catch-up
Linden (2002)	GDP/capita 1946-1997	15 OECD- US	time- series unit root	convergence for 10 countries not for AUS, Sweden, Switzerland, UK (some evidence of divergence in particular since 1980s)

TABLE 2.1 (continued)

AUTHOR	DATA	ECONOMIES	METHOD	FINDINGS
Freeman and Yerger (2000)	LP 1950-1998	8 OECD	cross-section and time- series	before 1970 cross-section convergence, but no time- series, states are in transition towards steady state after 1970s no cross-section but time- series convergence states have reached steady state
Bernard and Jones (1994)	MFP 1970-1987	14 OECD by industry	cross - section time- series	convergence for total aggregate TFP convergence for non-manufacturing industries divergence for Mfg
Dollar and Wolff(1993)	LP, MFP 1970-1987	14 OECD Mfg industries	cross - section	convergence at the aggregate level, results at the industry level vary
Caree, Klomp, Thurik (2000)	LP 1972-1992	18 OECD by industry	cross - section	convergence shows large inter-industry variations
Melachroinos and Spence (2001)	LP, MFP 1978-1994	13 EU Mfg industries	cross - section	convergence of LP at the aggregate and industry level no convergence of MFP at industry level

TABLE 2.2
EMPIRICAL STUDIES ON REGIONAL CONVERGENCE

AUTHOR	DATA/TIME SPAN	REGIONS	METHOD	FINDINGS
Sala-i-Martin (1996)	income/capita, LP 1880-1990	US, Canada, Europe, Japan	cross - section	convergence occurs within all four countries at 2%
Persson (1997)	income/capita 1911-1993	Sweden	cross - section	evidence of convergence
Gundlach (1997)	LP 1979-1989	China	Cross - section	evidence of convergence at 2.2.%
Funke & Strulik (1999)	GDP/capita 1970-1994	West Germany	cross - section, time- series (ADF)	evidence of convergence, but convergence clubs/clustering
Ferreira (2000)	income/capita 1970-1995	Brazil	cross - section	convergence between 1970- 1986, slowed down after 1986
Gumbau & Albert (2000)	LP and TFP 1964-1993	Spain	stochastic frontier approach	evidence of convergence also in MFP
Pekkala (2000)	LP 1988-1995	Finland	Markov -chain transition matrices	evidence of convergence
Abraham & Rompuy (1995)	income/capita 1985-1989	EU regions	cross - section time- series	overall convergence some divergence during 1975-1985
Armstrong (1995)	GSP/capita 1950-1980	EU regions	cross - section	convergence for 72 regions at 2% for 85 regions only 1 %, convergence speed peaked during 1960s; slowed down in later years.
Paci (1997)	income/capita; LP; 1980-1993	EU regions	cross - section	evidence of convergence for LP
Tondl (1999)	GSP/capita (1960-1994)	EU regions	cross - section	evidence of convergence

Note: LP is output divided by labour, where output is measured as income or GDP/GSP and labour measured as number of people employed, hours worked depending on the author.

CHAPTER THREE[1]

VARIATIONS IN ECONOMIC AND LABOUR PRODUCTIVITY

GROWTH AMONG THE STATES OF AUSTRALIA: 1984/85 - 1998/99

3.1. INTRODUCTION

As noted in Chapter Two, most of the earlier studies, have examined growth dynamics at a national level. Growth trends at a highly aggregated level however are likely to mask important underlying distribution dynamics and do not shed light on at least several questions. In particular, questions remain as to why some countries perform better than others. Is it because of specific sectors or industries that help a particular country to boost its economic growth rate or is it due to particular regions or states, or is it a combination of both? It is therefore interesting to study growth trends for specific industries and to carry out interstate comparisons.

This chapter examines differences in the economic and LP growth performances of the six states of Australia over the period 1984/85 to

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[1] An earlier version of this chapter was presented at the Conference of Economists of the Economic Society of Australia (Queensland) Inc., held at the Gold Coast, Brisbane on 3-6 July 2000. The paper was entitled "Variations in Economic and Labour Productivity Growth Among the States of Australia: 1984/85- 1998/99 and was co-authored by D.T. Nguyen, C. Smith and G. Meyer-Boehm,

1998/99. The analysis builds on and extends previous studies in this area in several ways. *First*, it examines LP as well as per capita income. In so doing, the results indicate that while considerable cross - state variations exist in the growth rates of gross state product (GSP) per capita, the rates of LP growth have been far more similar to one another. The discrepancy between these two pictures has been due mainly to demographic changes.

Second, the chapter investigates the industrial structure of each state, as well as the differences across states in terms of LP growth within each industry. The aim is to assess whether structural differences or differential growth rates have been the major cause of overall interstate variations in LP growth. The results suggest that the former factor has been dominant during the period studied.

Third, the analysis of most recently available data indicates that, contrary to international and historical experiences as discussed in Chapter Two, the levels of GSP per capita and LP in the various states of Australia have tended to diverge over the past fifteen years. When Mining is excluded, however, the pattern that emerges is one of neither convergence nor divergence — instead the growth paths are remarkably similar. This leads to a number of interesting policy implications, some of which may not have been immediately obvious before.

The chapter is organised as follows. Section 3.2 presents a brief review of previous studies and some background information. Section 3.3 describes the data used. Section 3.4 examines growth dynamics at the aggregate (all - industry) level for both GSP per capita and LP. Section 3.5 explains the cross - section analysis methodology and applies it to an *interstate* analysis at the aggregate as well as industry level. Section 3.6 takes a different approach to the problem: it examines differences in the national (all - state) rates of growth *across industries*. Section 3.7 contains a summary of the main results and draws out some policy implications.

3.2. PREVIOUS STUDIES AND BACKGROUND

Harris and Harris (1992) examined interstate differences in the rates of economic growth and levels of GSP per head of population of the states of Australia during the period 1953 - 54 to 1990 - 91. They found that real GSP per head for New South Wales (NSW) and Victoria (VIC) stayed above the national average throughout this period, while for Queensland (QLD), South Australia (SA) and Tasmania (TAS) it stayed below the national average. For Western Australia (WA) real GSP per capita went from below average to above. There was a general pattern of convergence, with deviations from the national mean of GSP per head in most states tending to become smaller, except for TAS. At the same time, states in the below - average group tended to experience higher rates of growth.

This type of cross - sectional convergence pattern has been the subject of much research and discussion in the comparative economic growth literature. For a very small sample of this literature, see Baumol (1986), Abramovitz (1986), Dowrick and Nguyen (1989), Barro and Sala-i-Martin (1992), Quah (1993), Sala-i-Martin (1996), and Bernard and Jones (1996b). For further details see Chapter Two. In contrast with the inter - country studies, where both convergence and divergence have been observed, interregional investigations have thus far tended to yield findings of convergence.

It may be that sub - national regions are more likely to share a common technological framework, a common culture, and common legal, social and other characteristics which would allow them to experience convergence in productivity more readily than is the case with different nations or groups of nations.

Cashin (1995) examined a much longer period than Harris and Harris, namely from 1861 to 1991, and subjected the data to formal statistical testing. (He also included New Zealand as a former Australasian colony). He found evidence of convergence in the per - capita income levels of the seven economies. However, most of the decline in cross - sectional dispersion had occurred in the 19th century, and during the subsequent 90 - year period (1901 - 1991) dispersion did not display a clear downward trend.

Neri's (1998) study was essentially a re - examination of Cashin's analysis, but with an alternative data set, and with the differences across sub - periods being examined more closely. Neri also included the Northern Territory (NT) and the Australian Capital Territory (ACT) as separate units of the cross section, and dropped New Zealand. While confirming Cashin's observations of convergence in the sub - periods prior to 1976, Neri emphasised that from the mid - 1970s to the early - 1990s, there was no clear evidence of catch - up, while the cross - sectional dispersion of income per capita increased significantly. He suggested that this widening of the income gaps between states has been due mainly to the ability of the more successful states to adapt to national and global changes through changes to their sectoral compositions.

The above studies were all based on analyses of data for GSP per head of population. Yet movements in population need not be identical to movements in labour force. If, for example, a state's population is being pushed up by a large inflow of retirees or other people of non - working age, its per - capita income level will tend to decline relative to other states, even if its LP is keeping pace with theirs. Similarly, if employment is rising less rapidly in a given state while its LP is growing at the same rate as the national average, its income per capita will tend to fall relative to the other states.

In what follows the analysis will consider both per - capita income and LP levels and will examine the differences in industrial structure across the states to determine whether and to what extent these differences affect their growth performance.

3.3. DATA

The data relate to the period 1984/85 to 1998/99, and come mainly from the Australian Bureau of Statistics (ABS) via the DX database.

There are two sets of real GSP data: one based on the SNA68 system and covering the years 1984/85 to 1996/97, the other based on SNA93 and covering the year 1990/91 to 1998/99. Here, the latter data set is adopted as the main source, and extended back to 1984/85 through simple backward splicing using the earlier data set. As for employment, both the number of persons employed and the total number of hours worked are considered; while the discussion below is based mostly on the latter measure, movements in the two were very similar and the main results are unaffected if the former measure is used instead. For the present purposes, NT and ACT are excluded, because the small sample sizes involved in the compilation of data relating to their individual industries render any analysis based on such data highly unreliable

3.4. GROWTH TREND AT THE AGGREGATE LEVEL (ALL INDUSTRIES): GDP PER CAPITA AND LABOUR PRODUCTIVITY

As a starting point, Table 3.1 presents an interstate comparison of rates of growth in real GSP. It is evident that WA and QLD outperformed the other states on this basis, registering trend growth rates of 4.7 and 4.5 percent per year, respectively, while NSW, VIC and SA were in the 2.2 to 2.9 percent range, and TAS recorded only 1.5 percent per year.

TABLE 3.1

Interstate Comparisons of Growth in Output, Population, Employment, and Labour Productivity
(1984/85 – 1998/99, per cent p.a.)

State	GSP	POP	EMPL	HRSW	GSP/ POP	GSP/ EMPL	GSP/ HRSW
NSW	2.9	1.1	1.5	1.5	1.8	1.4	1.4
VIC	2.5	0.9	1.1	1.1	1.6	1.4	1.4
QLD	4.5	2.3	3.1	3.0	2.2	1.4	1.5
SA	2.2	0.6	0.7	0.7	1.6	1.5	1.6
WA	4.7	1.8	2.5	2.4	2.9	2.3	2.3
TAS	1.5	0.5	0.6	0.4	1.0	0.9	1.1
All States	3.1	1.3	1.7	1.7	1.9	1.4	1.5

Notes: GSP is the chain - volume measure of gross state product, in million dollars, 1997/98 prices. Growth rates are obtained by fitting an exponential trend to the relevant series with a constant term.
Sources: ABS data via DX data base.

Figure 3.1A displays movements of real GSP per capita during this period, with the data being presented in logs to better illustrate growth trends. The growth paths can clearly be divided into two broad groups: the top group comprised NSW, VIC and WA, and the lower group consisted of QLD, SA and TAS. It can also be seen that WA moved from

the lower range of the top group to the upper range, having surpassed NSW and VIC in the early - 1990s. Over the same period, TAS failed to keep up and by 1998/99 could be thought of as being in a third group on its own.

Of course, much of these differences could be explained by variations in population growth (POP); data for this variable are also summarised in Table 3.1 WA and QLD again dominated, with 1.8 and 2.3 percent per year respectively, and again TAS recorded the lowest growth rate, 0.5 percent. Combining these movements, the results indicate that even in *per - capita* income terms, WA and QLD still registered the highest growth rates, and TAS the lowest, although the differentials across the states were now much smaller: 2.9 percent for WA vs. 1.0 percent for TAS (see the sixth column of Table 3.1).

Let us now turn to an analysis of employment growth. As Table 3.1 shows, the relative rankings of the states with respect to growth in the number of persons employed (EMPL), or in the total number of hours worked (HRSW), are largely unchanged from those obtained for growth in the total number of residents. However, the growth rate differentials between states with high population growth, such as QLD and WA, and those with low rates of population growth, such as TAS and SA, tend to be larger for the persons - employed and hours - worked measures than for the total - population measure. This suggests that the higher rates of population growth in QLD and WA were associated with inflows of

migrants who were more than proportionately of the working age and able to gain employment. Rather than having an adverse effect on per - capita income growth, therefore, population growth in these cases tended to lift income growth rates by raising the proportion of the overall population who are of working age.

The results thus far are consistent with the findings of previous studies, in terms of both the relative rankings of the states, and the absence of evidence in support of convergence during this recent period. Indeed, from Figure 3.1 Panel A (p. 58) and especially from the diverging paths of WA and TAS, one would be inclined to conclude that there may have been some divergence. In contrast, after adjusting GSP growth for employment — rather than population — growth, the interstate pattern displays a remarkably even performance in terms of LP growth. As the last two columns of Table 3.1 indicate, LP growth rates recorded by the various states were very similar to one another. Even though TAS's growth rates were still the lowest, the gaps between it and the other states were very small, especially when one considers statistical variations and errors. The only true exception was WA, which continued to register a substantially higher growth rate than all the others.

While the graph provides an illustration of how the states performed relative to each other in terms of GSP per capita growth, there is a need for a careful econometric analysis to gain a better understanding of the

underlying dynamics. Such an analysis will be undertaken in the next section.

3.5. INTERSTATE COMPARISON

3.5.1. Cross - Section Convergence Analysis: Methodology

In this literature, the term "convergence" is generally used to refer to the catch - up phenomenon, that is "backward" economies tend to grow faster than richer economies. In a cross section context, the term has also been used to refer to the tendency for differences in income or productivity between economies to decline over time. The convergence literature distinguishes between these two key aspects of the convergence phenomenon as beta - convergence and sigma - convergence (Sala-i-Martin, 1996). While beta - convergence relates to the catch - up phenomenon, sigma - convergence relates to the question of whether gaps between poorer and richer economies decline over time.

Formally, beta - convergence (or lack thereof) can be estimated by regressing the trend growth rate of LP on its initial level (and a constant).

(3.1) $$y_i = \alpha + \beta Y_{i,0} + \varepsilon_i$$

where y_i denotes the trend growth rate of LP in economy i over the sample period, α is a constant and $Y_{i,0}$ is LP in economy i in the initial year. Beta convergence implies that the slope coefficient beta is

negative[2]. This is interpreted as relatively poorer states having higher growth rates that enable them to catch - up with richer states.

The presence or absence of sigma convergence can be established through regressing the coefficient of variation (CV), a measure of dispersion, on a time trend and a constant. Formally:

$$(3.2) \qquad CV_t = a + \sigma t + \varepsilon_t$$

where CV_t denotes the coefficient of variation of GSP per capita or LP across all economies i, 'a' is a constant and 't' is a time variable. A negative and significant slope coefficient sigma is taken as evidence for sigma convergence, as a declining CV over time implies a narrowing of the dispersion of LP levels.

While these two concepts of convergence are related, they are not the same. In particular, beta - convergence is a necessary, but not sufficient, condition for sigma - convergence (Sala-i-Martin, 1996, p. 1328-9). One possible explanation illustrating this relationship is the "cross-over " scenario. For instance, initially poorer countries may not only manage to catch - up with richer ones, indicating beta - convergence, but they may

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[2] More precisely, a negative beta coefficient implies *conditional convergence*

also cross over and continue to surge ahead, causing a widening of the dispersion, which is evidence for sigma - divergence.

3.5.2. GDP per Capita and Labour Productivity Growth: Aggregate Level

Convergence trends for GSP per capita and LP across the Australian states are studied by firstly plotting the data and then applying them to the above described econometric framework. Figure 3.1 illustrates the trends for GSP per capita, Figure 3.2 those of LP.

Panel B of Figure 3.1 deals with beta - convergence, as it plots the trend growth rates experienced by the states against their initial levels of income. To reduce the risk of errors in measuring the latter variable, especially those due to short - term fluctuations, the actual values are replaced by the predicted values generated from the corresponding trend growth regressions. A sensitivity analysis is also carried out with an alternative method for specifying the initial levels, namely taking the average of the first few (say, three) years; the results from the two methods are quite similar. It can be seen from Figure 3.1B that the data did not support beta - convergence, nor beta - divergence. Regressing trend growth rate on predicted initial income level (and a constant term) confirms that there was neither a (statistically significant) negative nor a positive relationship between them, although reservations about the low

degrees of freedom and low R^2 must be kept in mind. The slope coefficient is 0.72, with t - statistic = 0.50, and R^2 = 0.06.

Panel C of Figure 3.1 shows movements over time of the cross - sectional standard deviation of the logs of per - capita incomes; this is essentially the coefficient of variation of per capita income. The figure indicates a rising trend, and a regression of the CV series against a linear time trend and a constant confirms that the positive trend is statistically significant with t - statistic = 10.88, and R^2 = 0.91.

Figure 3.2A illustrates the time paths of LP levels in the six states during the period of analysis. The relative rankings are consistent with historical trends and patterns: once again, WA joined the top group which previously had consisted of NSW and VIC; and again QLD, SA and TAS remained in the lower group. Compared with the pattern presented in Figure 3.1 for per - capita income, it would appear that the divergence tendency was far less pronounced here. As Figure 3.2B indicates, and a corresponding regression confirms (t - statistic = -0.04, adjusted R^2 = 0.00), there was no significant evidence of either beta - convergence or beta - divergence. Figure 3.2C shows, however, that there was still a tendency toward sigma - divergence; a regression confirms that this rising trend in the CV is significant at 5 percent (t - statistic = 2.70, adjusted R^2 = 0.38). Such divergence is in contrast with international and Australia's own historical experiences, where inter - regional incomes have tended to converge, especially over long periods of time. It is,

however, in keeping with Neri's (1996) results for the 1976 - 1991 subperiod, and can be seen as both confirmation and extension of those results to a subsequent decade.

The above analysis is undertaken at a highly aggregated level and so little can be said about the underlying dynamics and source of the observed diverging pattern in GSP per capita and LP. Therefore the analysis needs to be extended, to further pinpoint the driving forces of the growth patterns across the Australian states in terms of GSP/capita and LP.

3.5.3. Labour Productivity Growth: by Industry

With the results of a diverging trend at the aggregate level, there now arises the question, what has caused the widening in the dispersion of GSP/capita and LP? Is the observed divergence trend across the Australian states evident in each individual industry or only in some major sectors? Further, do the states perform similarly in individual industries or do the states' performances vary for the different sectors?

FIGURE 3.1: PER CAPITA INCOME

Panel A: Per capita income in logs

Panel B: Beta-convergence of per capita income

Panel C: Sigma-convergence of per capita income

FIGURE 3.2: GSP PER HOUR

Panel A: Labour Productivity in logs

Panel B: Beta-convergence of Labour Productivity

Panel C: Sigma-convergence of Labour Productivity
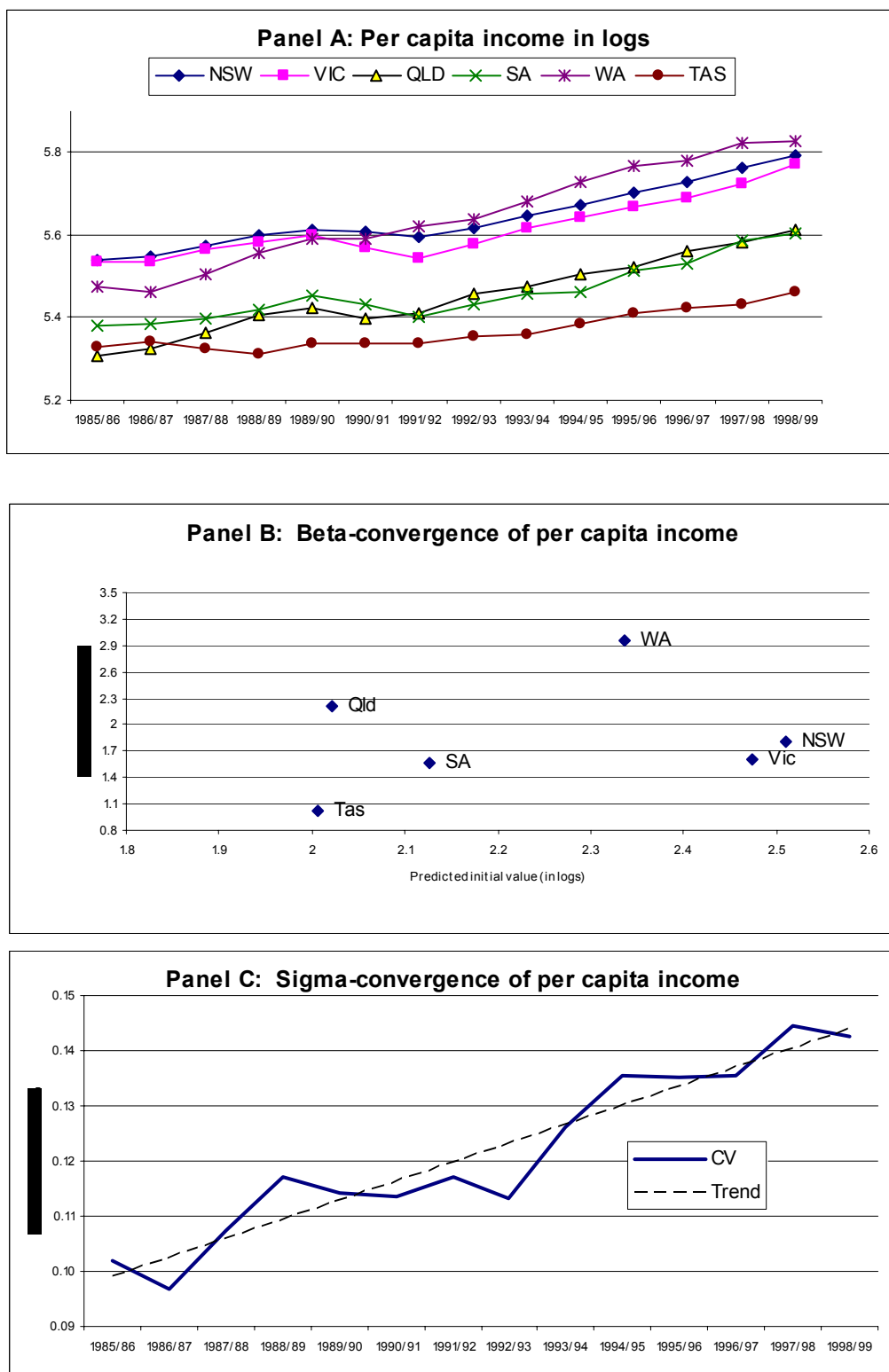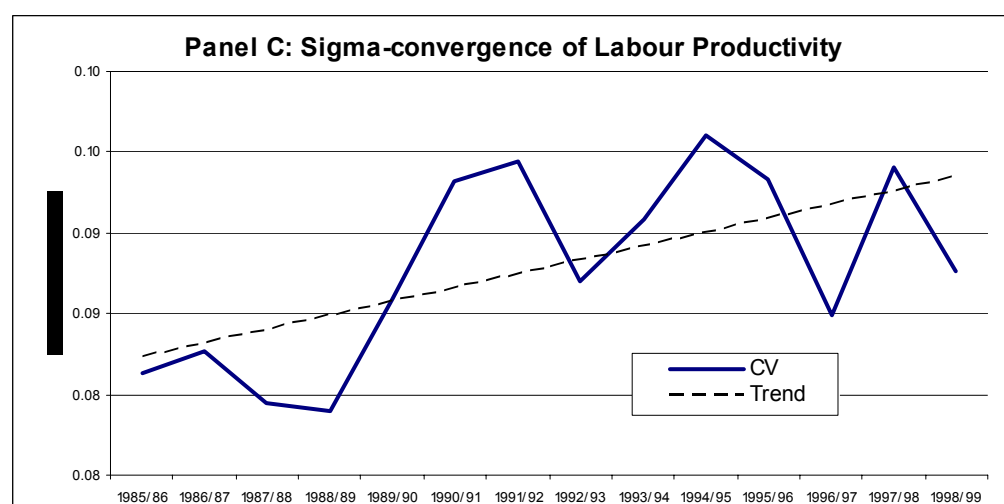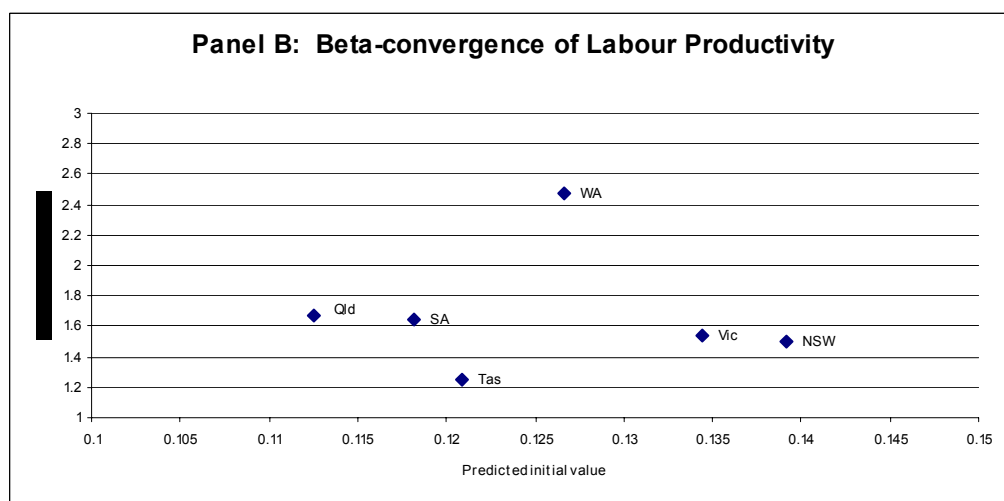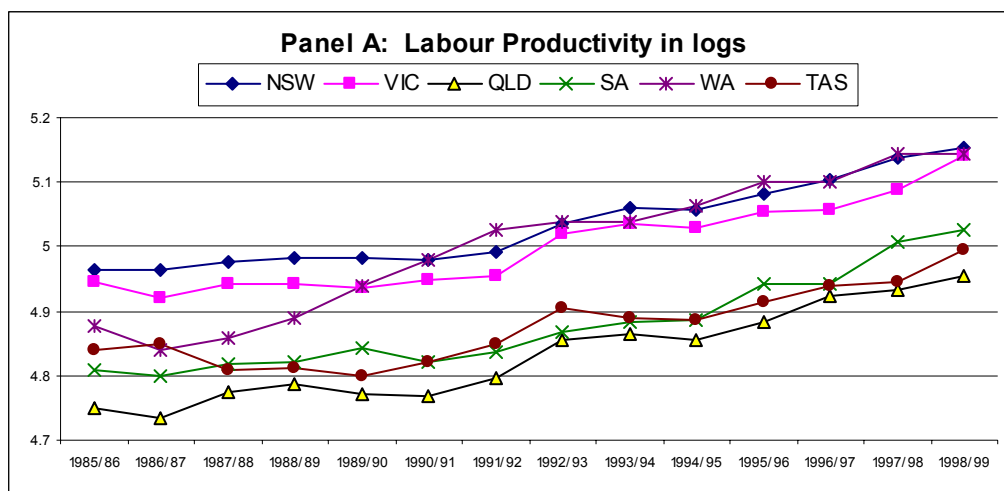
To answer those questions, the above analysis will now be replicated for a number of representative industries, including Agriculture, Forestry & Fishing; Mining; Manufacturing; Electricity, Gas & Water; Wholesale Trade; Finance & Insurance; Property & Business Sector; General Government; and Personal & Other Services. The findings of this analysis are reported in the following section and Figures 3.3 – 3.11 illustrate the findings graphically. Table 3.2 summarises the results. Again, Panel B of the figures plots the trend growth rates experienced by the states against their initial levels of income. Because of the small number of cross– sections (6 States), some of the plots appear to be outliers. However, the discussion below shows, that even if these states are removed the overall picture will not change. Further, if the outlier was to be removed, the degree of freedom is significantly reduced, in particular not just one specific state, but a different state within each industry.

Agriculture: Figures 3.3A, 3.3B and 3.3C present a summary view of LP growth in agriculture in the various states. It can be seen from Figure 3.3B that most states displayed a tendency toward beta - convergence. However, WA, which started out with a high LP level, continued to record a relatively high growth rate, thus tending to pull away from the other states. Partly as a result of this, the CV of state LP levels registered an upward trend which is significant at 10 percent. In short, the data indicate no beta - convergence (nor beta - divergence) but significant sigma - divergence. In Panel B, WA appears to be an outlier. Removing WA from the analysis will not effect the overall result, as beta-convergence

remains insignificant (t-value = -0.08), while sigma-divergence becomes significant at the 5 % level (t-value = 2.77).

Mining: As Figure 3.4A illustrates, VIC's LP level in Mining was consistently far above the levels in other states.   There is no strong evidence to support either beta - convergence or beta - divergence: as Figure 3.4B shows, WA, SA and QLD all started with very similar levels of initial LP, yet recorded considerably different growth rates.   Nor is there any sign of a significant secular trend in the dispersion of LP levels.   This picture does not change once VIC is removed, which appears to be an outlier in Panel B.

Manufacturing: This is the largest of all the "industries" listed.   As Figure 3.5A shows, QLD's LP level tends to remain substantially below the levels in other states.   From Figure 3.5B it can be seen that NSW, SA, WA and QLD all started from similar initial LP levels but then experienced divergent growth rates.   While there is no firm indication of either beta - convergence or beta - divergence, significant sigma - divergence is found at the 10 percent level.

Electricity: Figure 3.6A illustrates the strong growth of TAS's LP in this industry: after rising from the bottom position, the state caught up with, and then overtook, the leading states.   There are other examples of "cross - overs": these are consistent with the finding of significant beta -

convergence, as shown in Figure 3.6B, and at the same time sigma - divergence, as portrayed in Figure 3.6C.

Wholesale: As is evident from Figures 3.7A, 3.7B and 3.7C, the wholesale industry experienced both beta - and sigma - convergence. Note that some states recorded negative LP growth over several years. While this may accurately reflect some difficult times which were experienced by the industry, it also points to the inherent problems of measuring output in a service - oriented industry. Wholesale is the only industry, where the result for beta and sigma convergence changes from significant to in significant beta convergence (t-value = -1.91) and significant sigma – convergence (t-value = 0.01), once VIC is removed from the analysis as it appears to be an outlier in Panel B.

Finance: Figures 3.8A, 3.8B and 3.8C present perhaps the clearest example of convergence in both senses of the term. Note, however, that most of the sigma - convergence took place during the relatively short period of the latter half of the 1980s, and that during the entire following decade the CV or LP levels was fairly steady.

Property: Figure 3.9A displays a general pattern of falling LP levels. Apart from NSW, all states experienced considerable declines in LP. This divergent pattern resulted in an increase in cross - state dispersion; see Figure 3.9C. The rising trend is found to be significant at 5 percent.

Government Services: Figure 3.10A shows that QLD and VIC outperformed the other states in this industry: LP levels in these two states rose, enabling them to catch up and then surpass the others. By contrast, TAS generally remained below the other states. As a result, even though there is evidence of beta - convergence, the data also support a finding of sigma - divergence. This conclusion does not change once QLD, which lies outside the pattern of the other states, is removed from the analysis.

Personal Services: Figures 3.11A, 3.11B and 3.11C are of interest for at least two reasons. First, they relate to an industry which experienced negative LP growth, in common with several other service industries. Second, because of considerable swings in state LP levels, cross - sectional dispersion was not reduced significantly even though the growth rates did conform reasonably well to a beta - convergence pattern. Similar to Government Services, QLD appears as an outlier in Personal Services. Yet, even without QLD the result remains one of significant beta convergence (t-value = -3.72) together with insignificant sigma convergence (t-value = -1.01).

FIGURE 3.3: AGRICULTURE

Panel A: Labour Productivity in logs

Panel B: Beta-convergence of Labour Productivity

Panel C: Sigma-convergence of Labour Productivity

FIGURE 3.4 MINING

Panel A: Labour Productivity in logs

Panel B: Beta-convergence of Labour Productivity

Panel C: Sigma-convergence of Labour Productivity
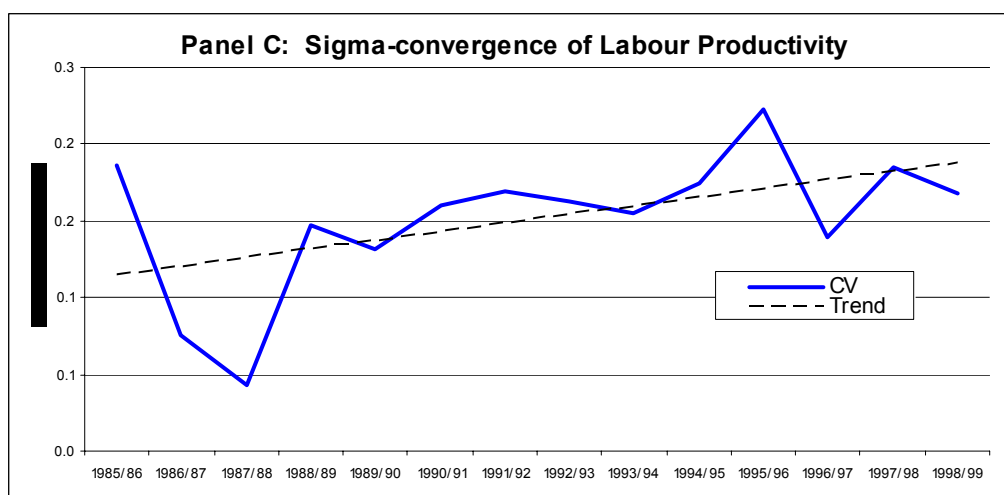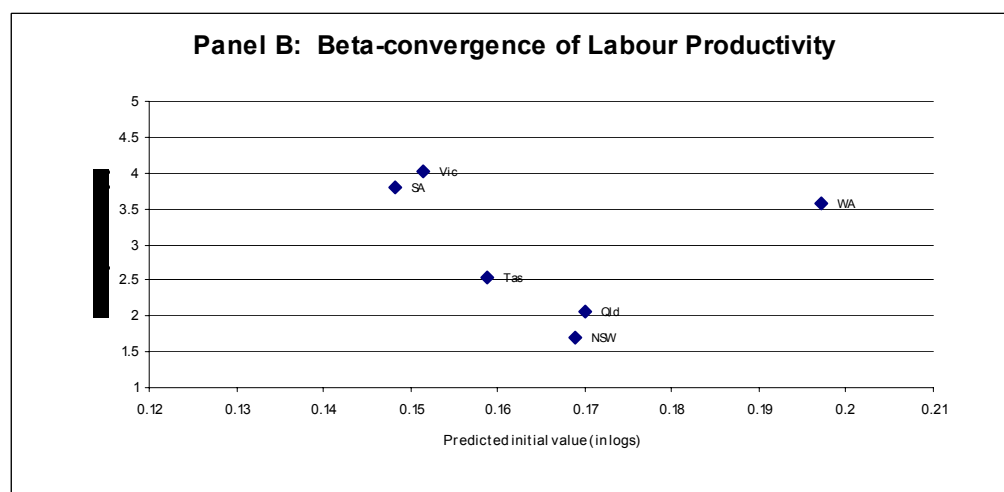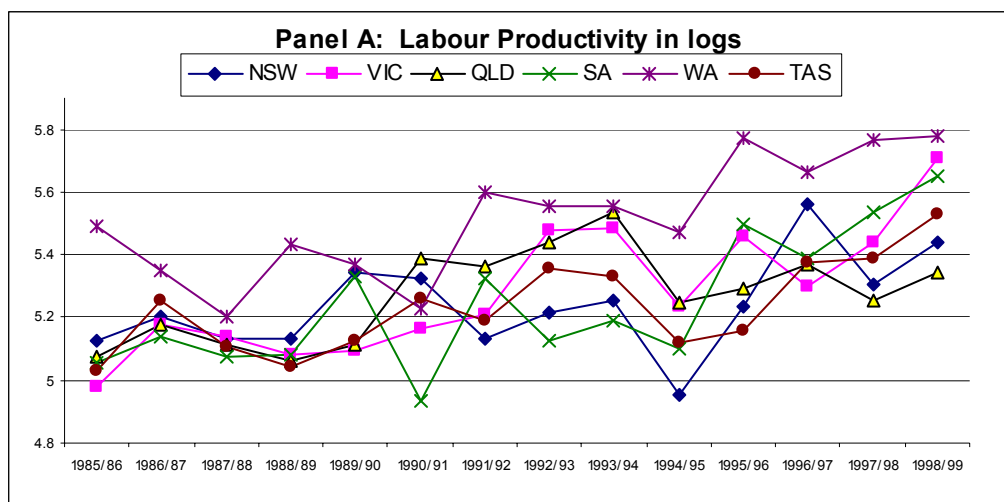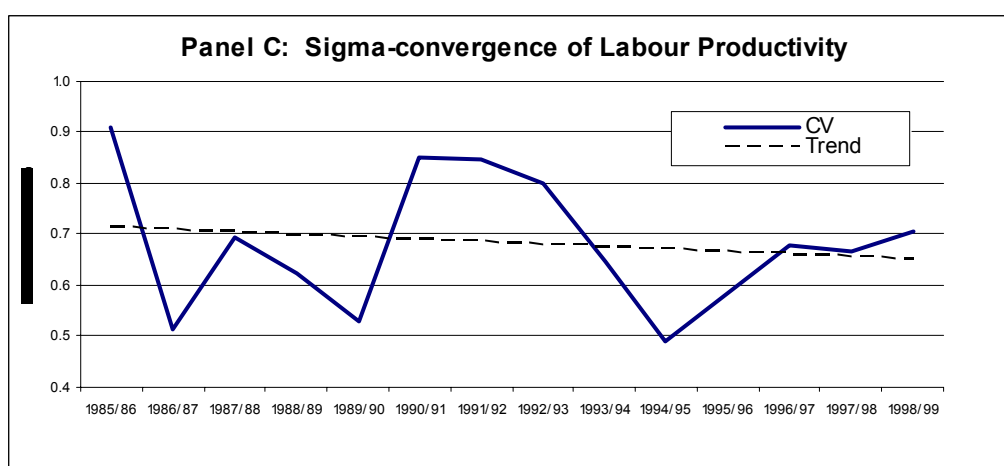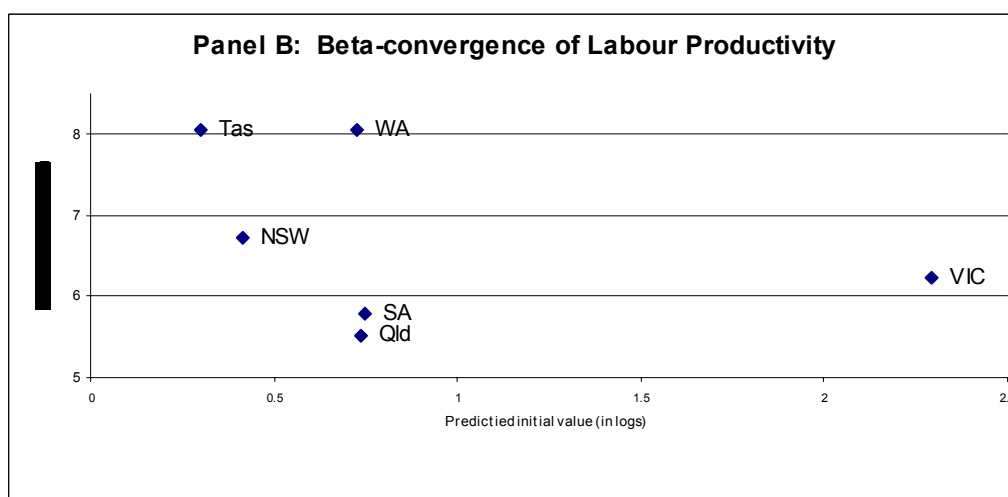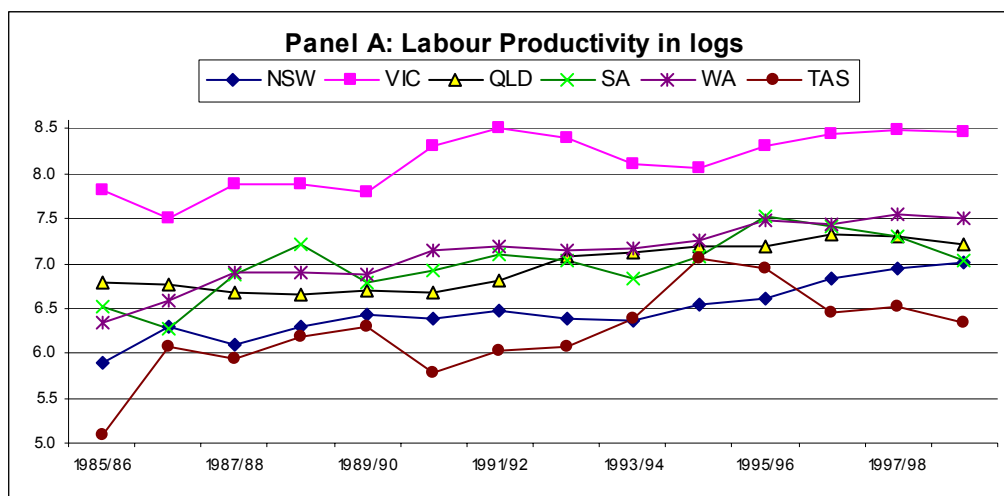
FIGURE 3.5: MANUFACTURING

Panel A: Labour Productivity in logs

Panel B: Beta-convergence of Labour Productivity

Panel C: Sigma-convergence of Labour Productivity

FIGURE 3.6: ELECTRICITY

Panel A: Labour Productivity in logs

Panel B: Beta-convergence of Labour Productivity

Panel C: Sigma-convergence of Labour Productivity

FIGURE 3.7: WHOLESALE

Panel A: Labour Productivity in logs

Panel B: Beta-convergence of Labour Productivity

Panel C: Sigma-convergence of Labour Productivity

FIGURE 3.8: FINANCE

Panel A: Labour Productivity in logs

Panel B: Beta-convergence of Labour Productivity

Panel C: Sigma-convergence of Labour Productivity

FIGURE 3.9: PROPERTY

Panel A: Labour Productivity in logs

Panel B: Beta-convergence of Labour Productivity

Panel C: Sigma-convergence of Labour Productivity

FIGURE 3.10: GOVERNMENT

Panel A: Labour Productivity in logs

Panel B: Beta-convergence of Labour Productivity

Panel C: Sigma-convergence of Labour Productivity

FIGURE 3.11: PERSONAL

Panel A: Labour Productivity in logs

Panel B: Beta-convergence of Labour Productivity

Panel C: Sigma-convergence of Labour Productivity
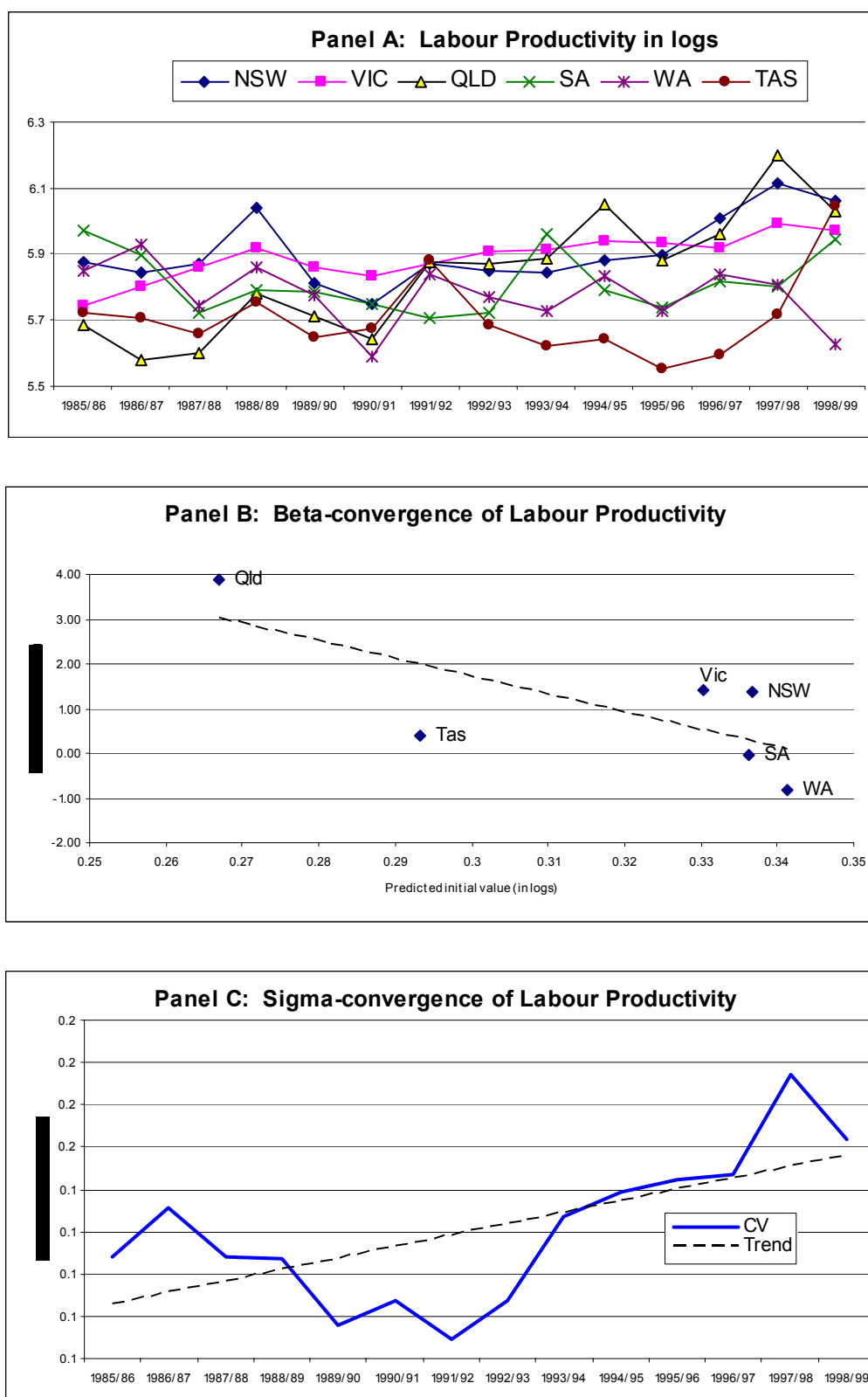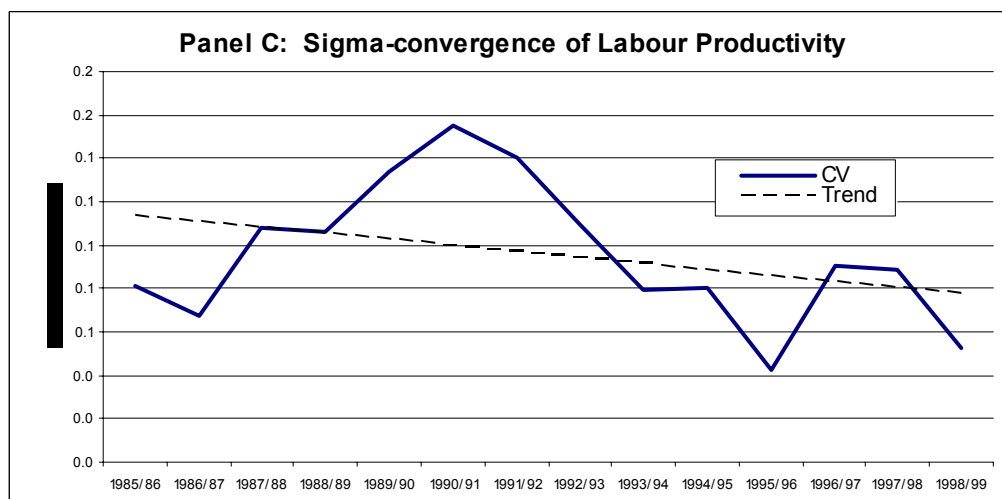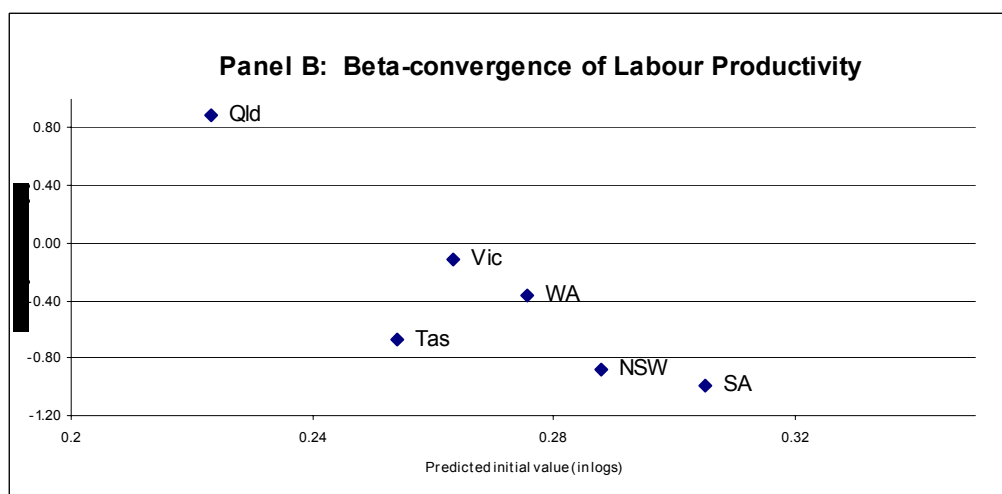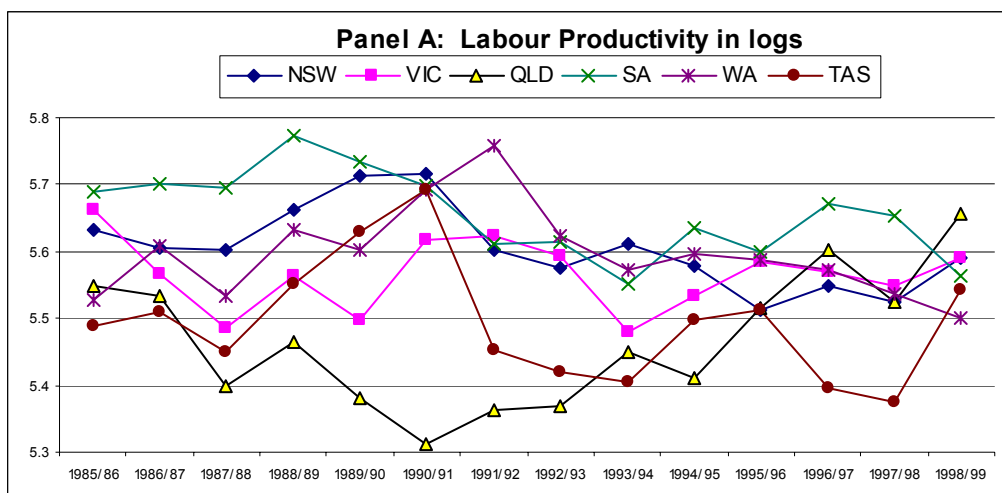
Summary: Table 3.2 (p.75) presents a summary of the evidence concerning cross - state convergence (or divergence) within each individual industry. It can be seen that LP levels within many industries displayed patterns which suggest, with varying degrees of confidence, beta - convergence, as indicated by the negative sign of most estimates of the slope coefficient in the regression of trend growth rate on initial income level. Yet the data for all industries combined do not indicate clearly either convergence or divergence. Why is this so? One possible reason is that the industries which show clear signs of convergence are not the largest industries. Another is that, as we have seen above, for different industries different sets of states were responsible for the converging behaviour, so that overall they did not converge (Simpson Paradox).

There are a number of industries (such as Electricity or Manufacturing), which exhibited either beta - convergence or no clear behaviour with respect to beta - convergence, yet clearly were subject to sigma - divergence. One possible explanation for this apparent discrepancy is that, for some industries, exogenous (e.g. technology - driven) shocks may have significantly affected the system, and these effects may have temporarily dominated the convergence tendency, which would eventually re - assert itself once the system settles down again, in the absence of major new shocks. Another possibility is the case of cross - overs where some states would come up from below the national average, catch up with the others (thus fulfilling the conditions of beta -

convergence) but then would just keep accelerating further, thus contributing to sigma - divergence.

Of the 17 industries studied, seven exhibited some significant tendency with respect to cross - sectional dispersion. Of these five showed sigma - divergence while two displayed sigma - convergence. Yet the overall picture, when all the sectors are combined, is unambiguously one of sigma - divergence, with the finding enjoying a higher degree of confidence than any of the specific - industry results (t - statistic = 5.27). In an earlier study Neri (1998) found that the convergence trends previously observed had apparently slowed down., The finding here both confirms and extends Neri's results. The above analysis indicates that the convergence process has not only continued to slow down but even changed to divergence.

One might attribute this to the fact that more industries exhibited divergence than convergence, and the divergence - displaying industries (such as manufacturing) tended to be more influential in terms of shares of both output and labour. But an alternative explanation is possible: it may be that, as Neri (1996) suggested, overall divergence has been caused mainly by differences in industrial structure and structural changes rather than by differentials in the underlying growth rates. This issue will be further examined in Section 3.6.

TABLE 3.2
Labour Productivity: Convergence Behaviour within Individual Industries
(1985/86 - 1998/99)

Industry	Regression of Trend Growth Rate on Predicted Initial Value				Regression of CV (SD of logs) on Time Trend			
	β -Coefficient	t-value		R^2	σ-Coefficient	t-value		R^2
Agriculture	-9.81	-0.36		0.03	0.56	2.11	*	0.27
Mining	-0.53	-0.74		0.12	-0.49	-0.55		0.02
Manufacturing	5.31	0.25		0.02	0.24	1.97	*	0.24
Electricity	-17.39	-2.90	**	0.68	0.63	2.48	**	0.34
Construction	-16.78	-0.49		0.06	0.24	1.61		0.18
Wholesale	-17.54	-4.94	**	0.86	-0.44	-3.74	**	0.54
Retail	-61.68	-2.67	*	0.64	-0.13	-1.05		0.08
Accommodation	-23.47	-0.96		0.19	-0.13	-0.71		0.04
Transport	-19.76	-1.06		0.22	0.26	0.97		0.07
Communication	-24.91	-2.89	**	0.68	-0.34	-1.01		0.08
Finance	-36.51	-4.60	**	0.84	-1.70	-3.50	**	0.51
Property	1.59	0.11		0.00	0.78	4.47	**	0.63
Government	-39.65	-2.17	*	0.54	0.54	2.88	**	0.41
Education	-13.42	-1.10		0.23	-0.13	-0.62		0.03
Health	-2.64	-0.23		0.01	0.12	0.99		0.08
Cultural	-9.31	-0.82		0.15	0.15	0.58		0.03
Personal	-21.40	-3.72	**	0.78	-0.28	-1.34		0.13
Total	2.67	0.27		0.02	0.17	5.27	**	0.70
Total *less* Mining	-0.00	-0.65		0.10	-0.00	-0.86		0.06

** Significant at 5 %   * Significant at 10 %

3.6. INTER INDUSTRY COMPARISON OF LABOUR PRODUCTIVITY GROWTH

Table 3.3 (p.77) presents summary data relating to the rates of LP growth in each industry for all states combined, as well as the industrial composition of employment in each state, measured as the average shares of that state's employment being devoted to the various industries. It is evident that the industries with the highest trend growth rates were Mining, Electricity, Communication, and Finance. This may have been due to rapid technological progress as well as changes in the labour - capital mix and industrial practices. The industries which recorded the slowest rates of LP growth (in some cases even negative rates of growth) were Property, Accommodation, Personal Services and other service - related industries such as Cultural Services, and Education. As pointed out above, this may well reflect fundamental problems with the measurement of output in a service industry.

The data presented in Table 3.3 can be used to answer the following question: Were some states assisted by the fact that their industrial structures were more conducive to high LP growth than others? Consider, for example, the hypothetical case of a state which is heavily oriented toward the service industries: given that these industries tend to record low rates of growth, the state is likely to be disadvantaged in any interstate comparisons of recorded LP growth.

TABLE 3.3
Labour Productivity Growth and Share of Total Labour: By Industry
(1985/86 - 1998/99, per cent)

Industry	Average Trend Growth Rate of LP*	Average Share of Total Labour in Each State						
		NSW	VIC	QLD	SA	WA	TAS	CV
Agriculture	2.79	5.52	6.05	8.27	8.75	7.66	10.03	22.72
Mining	6.69	1.07	0.33	1.75	0.90	4.59	1.56	86.71
Manufacturing	1.63	15.88	19.32	12.45	17.35	11.88	14.49	18.91
Electricity	7.55	1.41	1.30	1.06	1.37	1.26	1.80	17.29
Construction	0.74	7.57	6.86	8.78	6.34	8.65	6.74	13.59
Wholesale	1.36	7.37	6.87	6.49	6.28	6.39	5.47	9.98
Retail	1.32	12.66	13.01	14.11	13.19	13.28	14.10	4.40
Accommodation	-0.54	4.16	3.15	4.59	3.42	3.75	4.15	13.96
Transport	2.02	5.62	5.07	6.09	4.58	5.15	4.65	10.96
Communication	7.38	1.99	2.00	1.69	1.68	1.55	1.64	10.60
Finance	7.10	5.01	4.46	3.17	3.48	3.55	3.14	19.09
Property	-1.07	9.11	8.78	8.27	7.36	9.01	5.59	18.73
Government	1.45	3.66	3.95	3.91	3.58	3.72	5.88	18.63
Education	0.24	6.02	6.53	6.57	7.05	6.49	6.51	5.01
Health	0.93	7.68	7.30	7.63	9.26	7.64	8.77	9.40
Cultural	0.12	2.01	1.70	1.94	1.73	1.89	1.95	6.86
Personal	-0.36	3.27	3.33	3.24	3.66	3.54	3.53	4.99
Total	1.76	100.00	100.00	100.00	100.00	100.00	100.00	100.00

It turns out, however, that with one exception there was a fairly high degree of similarity across states with respect to the industry-specific shares of total labour used: in a majority of cases the coefficient of variation is less than 15 percent. It is true that variations in the share of Manufacturing, in particular, could be quite influential in view of the relatively large size of the industry: the labour - share of the industry in the most Manufacturing - intensive state (VIC) was 19.3 percent compared with only 11.9 percent in the least intensive state (WA). But by and large, variations in labour - shares across states tended to interact in an offsetting fashion with differentials in the LP growth rates achieved by the different states in each industry, so that they all ended up with similar aggregate LP growth rates.

As mentioned above, there was a very notable exception to this. Because the Mining industry's LP growth rate was so much higher than those of other industries, and because the industry accounted for such a large share of total employed labour in WA, this state's LP growth performance was substantially affected by it. To illustrate this point, the calculations have been replicated with Mining excluded from measures of both output and employed labour.

As shown in Table 3.4 (p.79), without Mining, WA's overall LP growth performance would have been slightly below average (1.5 percent per year, compared with the national average of 1.6). Moreover, as portrayed in Figure 3.12A, 3.12B and 3.12C, there would have been no strong

indication of sigma - divergence among the overall LP levels of the Australian states during the period of study. A regression confirms that there would have been neither sigma - convergence nor - divergence (t - statistic = - 0.86, adjusted R^2 = 0.06).

TABLE 3.4

Interstate Comparisons of Growth in

All - Industry Real GSP and Labour Productivity
(with and without Mining, percent p.a.)

State	Trend Growth Rate			
	GSP		GSP/HRSW	
	with Mining	without Mining	with Mining	without Mining
NSW	3.2	3.2	1.8	1.7
VIC	2.6	2.6	1.5	1.5
QLD	4.7	4.7	1.8	1.7
SA	2.3	2.4	1.8	1.8
WA	4.9	3.8	2.6	1.5
TAS	1.8	1.8	1.5	1.4
All States	3.4	3.2	1.8	1.6

FIGURE 3.12 ALL INDUSTRIES WITHOUT MINING

Panel A: Labour Productivity in logs

Legend: NSW — VIC — QLD — SA — WA — TAS

Panel B: Beta-convergence of Labour Productivity

SA, Qld, NSW, Vic, WA, Tas

Predicted initial value (in logs)

Panel C: Sigma-convergence of Labour Productivity

Legend: CV, Trend
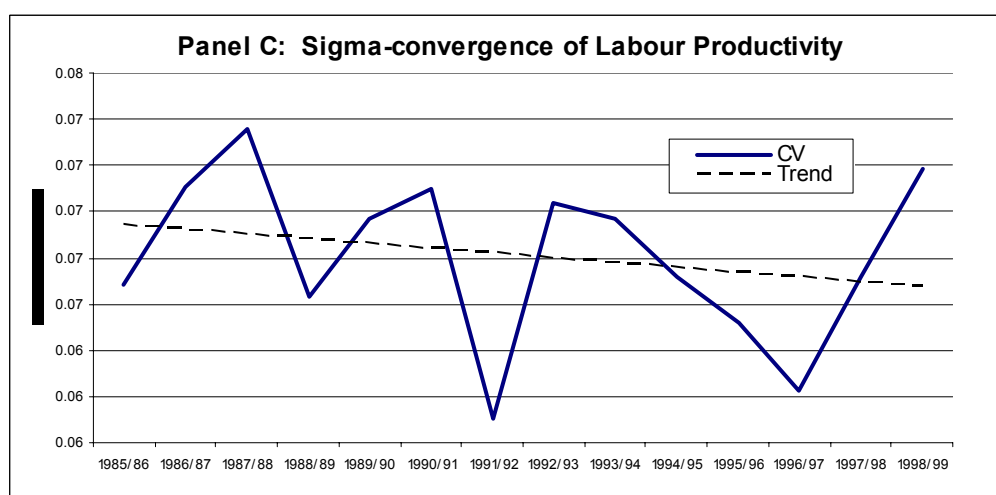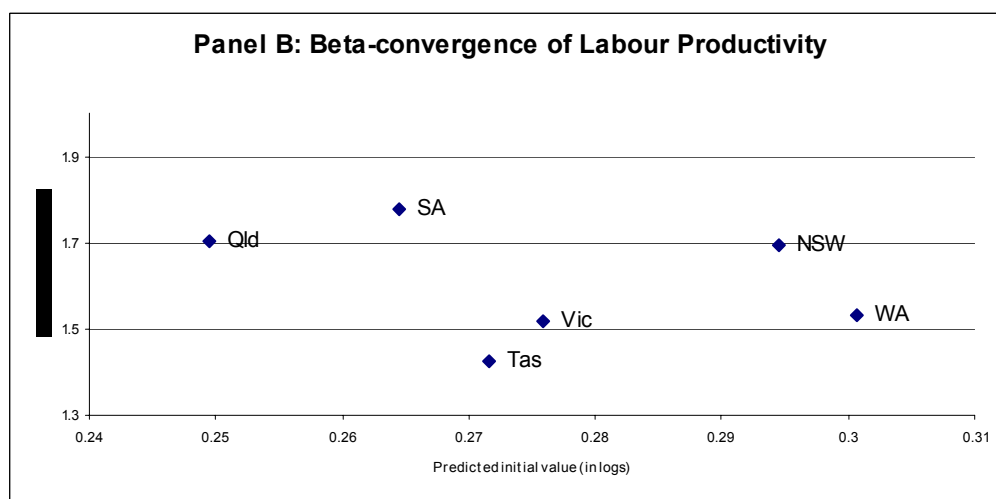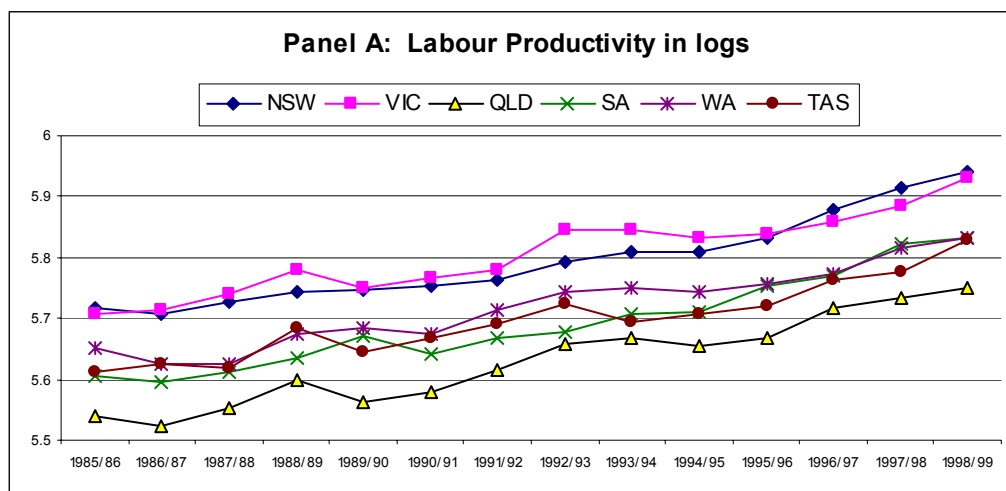
3.7. SUMMARY AND POLICY IMPLICATIONS

This chapter has examined differences across the states with regards to the levels and rates of growth in real GSP per capita and LP during the period 1984/85 - 1998/99. The findings suggest that some of the interstate variations in per - capita income growth rates could be attributed to variations in the rate of population growth, as states whose populations grew more rapidly tended to also receive larger inflows of working - age migrants who were then able to gain employment and raise the ratio of employed persons to total population.

Allowing for the effects of population growth, the differences in terms of LP growth performance across the states are very small, except for WA and, to a lesser extent, TAS. Even for WA, which enjoyed a markedly higher LP growth rate, the difference had largely disappeared by the early 1990s.

This is not to say that there were no interstate differences in industry - specific LP growth rates or in the industrial composition of the employed labour force. Indeed, the range of patterns of interstate and inter - industry variations is wide, and in some cases the variations were quite sizeable. It is rather remarkable, however, that such differences have tended to largely offset one another, leaving fairly small differences in the aggregate (all - industry) LP growth rates. Thus, while a given state may enjoy an advantage from having an industrial structure more conducive to high growth, it may at the same time be disadvantaged by lower LP

growth rates compared with the other states in a range of industries. By and large, the advantages and disadvantages across states have tended to cancel out each other. In particular, despite any differences which may have existed in the sets of policies adopted by the various state governments, the states have ended up with rather similar rates of LP growth.

This result is in contrast with the proposition (or concern) that states have differed substantially in their ability to adapt themselves to suit external conditions, and that this has resulted in substantial variations in LP growth rates. The results indicate that the only state with a clearly superior LP growth performance was WA, but even there the difference has largely disappeared and (while it lasted) was attributable mainly to a mining boom.

Neither the above finding, nor the fact that the interstate dispersion of LP in Australia has for decades been very low (around 10 percent) by international standards, can provide any grounds for complacency over the issue of income disparities across the states. *First*, policy - makers in slow - population - growth states (such as TAS and SA) still need to retain a focus on demographic changes, and work to avoid the situation where the state may end up being unable to attract and retain its fair share of dynamic, employable persons who would contribute to a rise in living standards for all residents.

Second, the historically and internationally prevalent tendency toward inter - regional convergence of LP appear to have been absent during the last 15 years (and, from Neri's 1998 results, during the preceding decade as well). For states which have remained in the lower - income group (such as QLD, SA and TAS), the convergence tendency should have given them an advantage over the top - group states. That this advantage has been offset by other factors only means that the lower - group states have some scope for identifying these disadvantages and working toward improving their LP growth performance.

Finally, all Australian states still need to remain vigilant about monitoring best practices among comparable economies overseas, and act to facilitate the adoption of these practices by organisations operating within their boundaries. After all, the international convergence tendency should present all of them with the opportunity to grow more rapidly than, and thereby catch up with, the most advanced economies in the world.

CHAPTER FOUR[1]

HAS CONVERGENCE BEEN REPLACED BY DIVERGENCE?

Labour Productivity in Specific Industries of the States of the USA,

1982 - 1998

4.1.   INTRODUCTION

While it would be useful to extend the analysis of the previous chapter to delve deeper into the dynamics and sources of economic growth in Australia, data availability limits further analysis. I now turn to the States of the USA, as for the States of the USA more data are available, especially at a highly dis-aggregated level. Moreover, it is not uncommon, that trends in the U tend to re-occur in other countries, including Australia, although delayed by a few years. Those trends can be of non-economic nature, such as music, movies or sport but can also include economic developments as Baily states: " *Both regions (*Europe and Japan*) lag the United States in the productive use of IT. The reasons for this are not new ones. Barriers to change …. discourages growth and productivity. (Baily 2002, p.42)".* In other words, one could expect that the observed LP trends in the US economy might be duplicated in Australia in a few years time.

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[1] An earlier version of this chapter was presented at the Econometric Society Australasian Standing Committee (ESASC) Inaugural Intensive Workshop for Young Scholars, University of Waikato, Hamilton, July 9-10, 2001 and the PhD Conference for Economics and Business, University of Western Australia, Perth, November 2001, where it won the award of the best presented paper.

The results from the previous chapter indicate that convergence trends among the Australian states have come to a halt in recent years and there now arises the question, how have the States of the US performed in terms of LP? Have they become more or less evenly distributed in terms of LP? It is questions like this that the current chapter will try to shed light on.

In particular, the following analysis has three aims. *Firstly*, by analysing more recent data it investigates whether the convergence trends — observed in the US before the 1990s observed — continued during the 1990s. *Secondly*, the analysis proceeds along a dis-aggregated line; in particular an industry analysis will be undertaken to identify the sectoral sources of the various trends. *Thirdly*, the performance of individual states is examined to identify those that may have had a major role in accounting for the observed trends. Last but not least, the analysis will apply both cross - section and time - series techniques.

The results indicate that beta convergence of LP, that is the catch-up tendency of relatively poorer economies to richer ones, has slowed down and disappeared entirely during the 1990s. Further, there is evidence of sigma divergence at the aggregate level and in most industries, where sigma divergence refers to the widening of the dispersion of LP over time. Both findings are in contrast with the conventional wisdom (as established prior to the 1990s; Chapter Two). During the 1990s most of

the divergence appears to have been caused by manufacturing industries. Prominent states that played a major part in this divergence pattern tend to be located in the North - Eastern and South - Western parts of the country.

Chapter Four is divided into the following sections. Section 4.2 reports findings of earlier studies on the US states. The data is described in section 4.3. Section 4.4 explains the methodology applied and Section 4.5 reports the findings of the cross - section analysis. Section 4.6 summarises the findings of the time-series analysis. Section 4.7 links and compares the findings for Australia (Chapter Three) and this chapter. Section 4.8 concludes.

4.2. BACKGROUND

Most of the earlier studies apply cross - section techniques to analyse convergence trends. Barro and Sala-i-Martin (1991) examine beta and sigma convergence trends at the aggregate level and for eight industries within the USA during 1963 - 1986 in terms of income per capita, gross state product per capita, as well as labour productivity. They find beta convergence at the aggregate level and for each of the eight sectors, although at varying levels of significance. Yet, over different sub-periods beta convergence at the aggregate level shows substantial variation and even divergence during the late 1970s, due to price shocks in the oil-

related industries. Further, they discover sigma convergence at the aggregate level, but the results at the sectoral level are mixed.

The majority of studies at the aggregate level, such as Crow and Wheat (1995), Mitchner and McLean (1999), Sum and Fogg (1999) to mention only a few, analyse income per capita data and report beta and sigma convergence yet at different levels of significance and speed of convergence. Interestingly, Vohra (1998) finds sigma divergence during the late 1980s once Mining states were removed.

Bernard and Jones (1996a) were among the first to apply time - series techniques to the analysis of LP data at the aggregate and industry level between 1963-1989 for the US. With cross - section analysis they find evidence of beta convergence at the aggregate level and for all industries. Sigma convergence occurs at the aggregate level but not in all industries. The results of the time - series analysis confirm by and large their cross - section findings.

Carlino and Mills (1996) test beta convergence via a cross - section but also apply a time - series analysis. They investigate income per capita data at the aggregate level for the States of the US between 1929 – 1990. Their main findings are that there seems evidence of beta convergence, which has, however, slowed down after 1964. In contrast, the majority of states exhibit a unit root, which is taken as time - series evidence for divergence. Again the divergence trend has partly reversed

after 1964. Also Strauss (2000) applies time - series techniques and tests income per capita data between 1929-1995 for the US. He reports divergence for the single time - series methodology, but convergence once panel data are applied.

In summary for the States of the US, earlier studies, applying primarily cross - section techniques, generally find evidence for beta and sigma convergence at the aggregate level. At the industry level the results indicate beta convergence but are mixed for sigma convergence measures. More recently, some studies applying time - series techniques report a tendency of divergence at the aggregate level. This Chapter extends the previous literature in three respects. *Firstly*, it focuses on more recent data. *Secondly*, it studies LP trends at the aggregate level as well as for 13 industries for the US states and *thirdly,* in a state analysis it studies how states perform relative to each other in terms of LP.

4.3. DATA

Labour productivity is measured as real Gross State Product (GSP) per employee. GSP is in chained 1996 dollars. The data are obtained from the Bureau of Economic Analysis (BEA) and the Bureau of Labor Statistics (BLS), covering a time span of 17 years between 1982 and 1998. The analysis also proceeds along the sectoral level and here 13 industries are considered. BEA publishes GSP data in 1992 and 1996 chained dollars, covering the periods between 1982 - 1997 and 1985 -

1998, respectively. The second data set was chosen as the main source as it provides more recent and more importantly revised data estimates. Through simple backward splicing based on the 1992 priced data, GSP data in 1996 chained dollars were obtained for the years between 1982-1998. The analysis focuses on the contiguous states only. Alaska was not included as it's industry structure is less diversified as the remaining states. In addition, data compilation at the industry level for Alaska, but also the DC and Hawaii, are likely to lack reliability, due to their small sample size. Thirdly, all three states were not regarded as representative of the bulk of the remaining states, due to their particular geographical and political characteristics.

4.4. METHODOLOGY:

CROSS - SECTION AND TIME - SERIES ANALYSIS

Similar to Chapter Three a cross - section analysis is applied to investigate growth dynamics across the States of the US. Again both concepts of convergence - beta and sigma - will be studied.

In addition, convergence is further analysed with time - series techniques. In particular, a panel unit root test is applied, as the investigated data set is available only for a relatively small time span. With such a limited number of years the power of a single unit root test is problematic and the results may be unreliable. While a panel unit root test does not fully resolve this problem, additional data from the cross - section dimension

will produce more reliable parameter estimates. In particular, for the case of the US with 48 states the addition of another dimension will increase the degrees of freedom significantly.

Recently, a number of panel unit root tests have been developed such Fisher (1932), Im, Pesaran and Shin (1997), Maddala and Wu (1999) or Hadri's Lagrange Multiplier test (1999). The test applied here is based on the work by Levin and Lin (1993)[2]. In particular, a model containing an intercept as well as a time trend in the dependent variable will be employed.

(4.1) $x_{i,t} = \rho\, x_{i,t-1} + \delta_0 + \delta_1 t + \varepsilon_{it}$

where $x_{i,t}$ is the difference between the natural log of LP of state i (y_{it}) and the cross-section mean ($\bar{y}_t$); i.e. ($x_{i,t} = y_{it} - \bar{y}_t$). Cross - section averages were subtracted from the observed data to correct for possible common time-specific fixed effects. Using cross -sectionally de-meaned ratios is further likely to mitigate possible cross-sectional dependency in the data and eliminates the influence of aggregate effects. δ_0 is the intercept and t the time trend. Under the null hypothesis of a unit root (H_0: $\rho_i = 1$), the data set is non - stationary. This is widely interpreted as evidence of rho - divergence, i.e. countries drift apart. Under the alternative hypothesis

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[2] The panel unit root results are calculated in GAUSS, based on a program by Chiang, M.-H. and C. Kao, (2000), *Non-stationary Panel Time-series Using NPT 1.2 - A User Guide*, Centre for Policy Research Syracuse University. T

(H_1: $\rho_i < 1$) the data set is stationary[3]. Stationarity of the data, in other words a rejection of the unit root null hypothesis is taken as evidence for rho-convergence. Then a shock to the system is regarded as only temporary. In the case of a unit root, the shock is permanent, deviations are not stationary and economies drift apart. Convergence does not hold.

However, it must be pointed out that the interpretation of "convergence" in cross - section and time - series analysis is rather different. According to Bernard and Durlauf (1996), cross - section analysis examines whether differences in LP levels narrow or widen over time. In other words, it assumes that states are in transition towards an equilibrium growth path. In contrast, time - series define convergence in terms of deviations from a common long run trend being only temporary. Time - series tests assume that economies are near their long run equilibrium and examine whether deviations from this equilibrium path are permanent (i.e. x_{it} is non-stationary) or transitory, that is mean reverting and therefore x_{it} is stationary. If the latter definition is satisfied, than convergence in a time series sense holds. In other words, if long-run technological progress contains a stochastic trend, or unit root, the convergence implies that the permanent components in output are the same across countries (Bernard and Durlauf (1995)). The time - series analysis, because of its distinct interpretation, is here treated as a third type of convergence. For

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[3] The Levin and Lin test tests a rather restrictive hypothesis. It is used here as I became aware of its limitations after the code has been secured. However, as this is just one piece of evidence, I have not tried a different method to replicate the results.

simplicity, I will refer to rho-convergence when time – series tests are applied.

4.5. CROSS - SECTION ANALYSIS

4.5.1. Interstate Comparison: Aggregate Level

Convergence trends are first analysed at the aggregate level, that is for the sum of all industries combined. Similar to Chapter Three, beta convergence is estimated by regressing the trend growth rate of LP on its initial level and a constant (α). Sigma - convergence can be established through regressing the coefficient of variation (CV), on a time trend and a constant.

The statistical results of sigma and beta convergence are summarised in the in Table 4.1 and 4.2 (p. 104, 105), respectively. There is no clear evidence for beta convergence (nor divergence) at the 5% critical value as the t-value is not statistically significant (t-value = 0.32). But there is clear sigma - divergence as indicated by the positive and significant slope coefficient (sigma = 0.18, t-value = 7.62) and trend line in Panel C of Figure 4.1.

Both findings, the lack of beta convergence and presence of sigma divergence, contrast with the results of most earlier studies. The majority of this literature, applying cross - section techniques, have found evidence of beta as well as sigma convergence for the States of the US,

although at different levels of significance. One possible explanation for the contrast is that most of these studies analyse data up to the late 1980s only. In contrast, this study focuses on the 1990s in particular.

It would be useful to divide the data set into two sub-periods to identify more precisely when the reported divergence trend during the 1990s set in. A careful analysis of Figure 4.1 provides a first indication that there may have been a change in the early 1990s. In particular, as can be observed from Panel A Figure 4.1, the individual states appear to drift more rapidly apart from 1991/1992 onwards. This can also be seen from Panel C Figure 4.1 where the CV curve has a kink. Therefore, the data set was divided into the two sub-periods, 1982-1991 and 1991-1998. This splits the time span into two periods of similar length.

For both sub-periods the results reported in Table 4.1 and 4.2 are robust in the sense that there is not only a lack of evidence supporting beta convergence, but also clear and significant evidence of sigma divergence. One would be inclined to conclude that, for the US States, convergence has been largely replaced by a tendency to divergence during the last two decades of the 20th century. Nevertheless, the Total of all industries is a highly complex variable as it aggregates industries of very different natures, and as such may conceal movements at a more dis-aggregated level. Hence, a careful analysis is necessary to reveal and pinpoint these dynamics.

4.5.2. Physical versus Services Industry

In a second step the data set is separated into two groups, the physical industries and the service industries. In 1998 output of the physical industries together (Agriculture, Mining, Construction, Manufacturing and Transport) was around 33% of total GDP, output of the remaining Service industries combined was 67% of total GDP. Here the term "output" rather than GSP is used, as it refers to the value added in each individual industry and not the aggregate of the sectors for a particular state.

Physical Industries: The sum of the physical industries alone exhibits significant beta convergence over the whole period (t-value = -3.69). Further, there is a clear and significant trend that the dispersion of LP levels declines (t-value = - 2.73). See the first major column in Tables 4.1 and 4.2 respectively. Thus, these industries appear to be a classical example of the catching-up scenario: Relatively poor states catch-up and additionally cause the dispersion of LP levels to decline. Yet a careful analysis of the picture emerging from plotting the LP levels (in logs) against time (Panel A Figure 4.2), indicates that the dispersion of LP levels declined only until the early 1990s, but started to increase afterwards. The results of sigma convergence for the two sub-periods confirm this observation: There is clear evidence of sigma convergence (t-value = -3.96) for the first period, but the result for the second and third major column in Tables 4.1, respectively are less clear cut.

Service Industries: The results for the service industries combined exhibit clear beta and sigma divergence, see Tables 4.1 and 4.2. Importantly, beta and sigma divergence occurs not only for the whole time span, but also for both sub - periods. Sigma divergence for the whole data set is significant at a t-value of 12.07. For the first and second sub-periods the slope coefficient is significant at a t-value of 11.49 and 14.33, respectively.

The findings so far indicate that the catch-up process has weakened during recent years. Although there is still some evidence of beta convergence in the physical industries, the service industries clearly diverge, leaving the overall result ambiguous. The observed results for sigma divergence for both groups of industries in the second sub-period further confirm the finding at the aggregate level. It appears that the diverging trend started with the service industries and was then followed by the physical industries during the 1990s. In view of this dichotomy, it may be useful to dis-aggregate the data further by analysing each *individual industry* separately.

4.5.3. Interstate Comparison: By Industry

In a third step, convergence trends in each individual industry are examined to identify which industry and which state within each industry may have caused the observed sigma divergence. From Table 4.1 and 4.2 (p.104) it can be seen that Agriculture, Mining and Construction

exhibit both beta and sigma convergence over the whole sample period. One could conclude that they appear to behave differently from the rest of the economy. However, in two industries this departure does not hold over both of the sub-periods, as will be explained below.

Agriculture: Within Agriculture there is evidence of beta and sigma convergence before 1991, but for the second period this trend does not continue. It weakens and becomes insignificant. This is consistent with the emerging overall conclusion that convergence was largely absent during the 1990s.

Mining: Similarly, Mining exhibits beta and sigma convergence during the first half of the data set. Yet again in the second period sigma convergence weakens and is not significant any more. This is in particular the result of some states surging ahead, primarily in the early 1990s, while a couple of others fell behind. Surging ahead states include Wyoming, New Mexico, Utah, Texas and Louisiana. Connecticut and Oregon started to fall off around 1993/94.

Construction: Construction appears to be one of the few exceptions which displayed both beta and sigma convergence not only over the whole data span but also for both sub-periods. A number of states managed to catch-up in the early 1990s contributing to beta convergence. Yet those states did not continue to surge ahead. Although three states, Vermont, Arkansas and Oklahoma, started to fall behind in the early 1990s

contributing to sigma divergence, the lack of surging states leaves the overall picture as one of sigma convergence. This is an example of the classic catch-up scenario and representative of the results established in the literature prior to the 1990s.

Overall, the convergence in Agriculture and Mining appears to have disappeared during the 1990s. Only in the Construction industry the convergence process has continued.

Manufacturing: Here the focus will not only be on the Manufacturing industry but also on two of its sub-industries at the 3 - digit - level as published by the Bureau of Economic Analysis, the Durable and Non-Durable industries. Firstly, these industries play an important role due to their relative size. For instance, in 1998 output in Manufacturing was around 20% of the overall GDP, and it was behind Services, the second largest industry. The shares of Durable and Non-Durable Manufacturing in GDP were quite substantial: roughly 12% and 8%, respectively. In comparison, output in Agriculture, Mining or Construction was each around 3 - 4% of GDP in 1998.

From Table 4.1 and 4.2 it can be seen that Manufacturing displays beta convergence (t-value = -5.80) but no evidence of sigma convergence or divergence, with a t-value of 0.27 (see also Figure 4.3). But this does not contradict the diverging pattern observed so far, as divergence is evident

during the second half of the period. Indeed, after 1991 sigma divergence clearly occurs with a t-value = 5.57.

One possible explanation for this result is the 'cross - over scenario'. In other words some of the poorer states were not only able to catch-up in the late 1980s, but 'crossed - over' (the national average) and continued to surge further ahead during the 1990s, causing the dispersion of LP to widen. To identify such cross - over cases, LP levels of each of the states were re-expressed relative to the average LP level of the US, with LP of the latter being normalised to 100. A state with an initial ratio below 100 growing above 100 can then be identified as a cross-over case. The following states 'crossed over': New Mexico (crossing over in 1991), Arizona (1994), Texas (1994), Idaho (1995), California (1996) and Oregon (1996), all of which are located in the West of the USA. There are also three states in the East, namely Connecticut (crossing over in 1990), Pennsylvania (1995) and New Hampshire (1996). In the sub-industries (Durable and Non-Durable) the results are similar.

Durable: For the Durable industry results are similar and reported in Table 4.1 and 4.2 and illustrated in Figure 4.4. Beta convergence is observed during the sample period as well as the two sub-periods. More importantly, there is again evidence of sigma divergence for the entire period: Sigma divergence is significant at a t-value of 2.80 for the whole data span combined. There is evidence of sigma convergence before 1991, but clear and significant divergence afterwards.

The switch from sigma convergence to divergence in the Durable industry appears to be partly the result of states not only crossing over, but further surging ahead. Cross over states are California (1990), New Mexico (1991), Arizona (1992), Oregon (1993), Texas (1994) and Montana (1995) in the West and Massachusetts (1987) and New Hampshire (1995) in the East. Out of those, New Mexico, Arizona, New Hampshire and Oregon continued to surge ahead. In addition, the increase in the dispersion of LP levels is also caused by a falling behind state, Wyoming. This is an example of the observation that beta convergence is a necessary but not a sufficient condition for sigma convergence to occur (see for example Barro and Sala-i-Martin (1991)). Although poorer states manage to catch-up, the dispersion of labour productivity is increasing over time, as they continue to surge ahead.

Non-Durable: In the Non-Durable industry beta convergence is insignificant for both sub-periods. But in terms of sigma convergence the sector displays evidence of divergence for the whole period as well as both sub-periods. As can be seen from Figure 4.5, the observed diverging pattern appears to have set in around 1985. This is in particular due to a surging ahead state – Louisiana – which started to surge from 1984 onwards. The divergence appears to further be revived during the 1990s, when states such as New Jersey, West Virginia, and Wyoming started to "take off", whereas a few others, eg. Vermont, South Dakota, Rhode Island, started to fall behind.

To summarise, trends in the Manufacturing sector reflect dynamics in the Durable and Non-Durable industries. In the latter, sigma divergence is observed for the entire period as well as the two sub-periods. In the Durable industry, cross over cases cause the dispersion of LP levels to increase from the early 1990s onwards. The observations suggest that there is a belt of states in the South-West of the country whose LP in the Durable industry grew faster than the national trend growth rate of LP, causing some of them not only to catch-up but to surge further ahead.

This finding is in line with an argument by Myrdal (1957) stating that "*The play of the forces in the market normally tend to increase, rather than decrease, the inequalities between regions (p.26)*". He shows that innovations and technical progress are not spread evenly throughout a regional system but will tend to perpetuate the agglomeration advantages of currently prosperous regions. Myrdal explains that the agglomeration of economic activities may have started originally due to access to certain resources or facilities and tends to become self-sustaining. While backward regions in a country fail to attract new activities that may generate autonomous economic growth.

The South-Western region is known as a mainstay of North America's semiconductor research, development and production. In particular Texas is one of the nation's leading chip producing state (SEMICON, 2000). Whether such diverging trends will continue or not cannot be predicted with any certainty. One possible scenario may be that, once

the process of technological change slows down, convergence in the system may be restored.

Transport & Utility: For the Transport & Utility industry, which accounts for about 4% of GDP in 1998, estimates reported in Table 4.1 and 4.2 indicate that beta convergence is significant at t-value = -2.28, but there is sigma divergence (t-value = 3.16), (see also Figure 4.6). Consistently, sigma divergence can further be found for both sub-periods. The widening of the dispersion of LP levels is by and large driven by a few surging ahead states: Wyoming, Rhode Island, California, Texas and New York, as well as a falling behind state – Tennessee. Some of them started to 'drift off' in the early 1980s, others started to surge ahead in the early 1990s, resulting consistently in divergence trends for both sub-periods. Once more three states, California, Texas and Wyoming are located in the West, whereas New York and Rhode Island are located in the eastern part of the country.

Electricity: Electricity exhibits beta convergence for the entire data span and also the second sub - period, but it displays significant sigma divergence at the 10% significant level (t- value = 1.86) over the whole sample period. The divergence trend is particularly strong during the first sub - period (t-value = 3.38). While it has started to weaken lately, there was still no evidence of convergence.

Wholesale: Similarly, Wholesale displays a sigma diverging trend during the 1980s, although this trend weakened in the 1990s. There is no evidence of beta convergence or divergence. In the 1980s New York and Connecticut started to surge ahead but this tendency did not continue, Idaho and South Dakota fell behind but managed to catch-up again during the 1990s.

Retail: The findings for Retail are also consistent with the observed diverging pattern, as it reports significant sigma divergence for the entire sample period as well as both sub-periods, and is insignificant in terms of beta convergence. The dispersion of LP widened as five states started to surge ahead from mid/late 1980s onwards, whereas another group of four states continued to fall off. The first group includes Nevada, New Jersey, New York, Connecticut and California, the second group are Montana Wyoming, Nebraska and North Dakota.

FIRE: The findings for the FIRE industry are similar to the above. Sigma divergence is consistently observed during all periods at the 5% significant level. Additionally, there is evidence of beta divergence. This is a good example of the falling behind scenario, which causes beta divergence and at the same time sigma divergence to occur. Falling behind states include Montana, New Jersey, New Hampshire, Massachusetts, California, Connecticut and Colorado. There are also two surging states, Delaware and New York.

Service: The pattern in the Service industry further confirms the divergence trend observed so far, as again sigma divergence is evident in all periods. And once more, it is New York and also New Jersey that surge ahead, while Wyoming, North and South Dakota and Iowa fall behind.

Government: The findings of the Government industry fit the above picture as well. Beta convergence is not significant and there is a clear sigma diverging trend during the 1990s. No predominant states can be identified that either surged ahead or fell behind. Rather all of the states drifted apart.

TABLE 4.1: Sigma-Convergence of Labour Productivity for Specific Industries of the USA:

Industry	SIGMA-CONVERGENCE 1982-1998				SIGMA-CONVERGENCE 1982-1991				SIGMA-CONVERGENCE 1991-1998			
	slope	t-value		R^2	slope	t-value		R^2	slope	t-value		R^2
Total	0.18	7.62	**	0.79	0.31	6.58	**	0.84	0.09	2.84	**	0.57
Physical Industries	-0.08	-2.73	**	0.50	-0.16	-3.96	**	0.66	0.17	2.48	**	0.51
Service Industries	0.55	12.07	**	0.91	0.82	11.49	**	0.94	0.23	14.33	**	0.97
Agriculture	-0.52	-1.73	*	0.15	-0.20	-2.92	**	0.52	0.23	0.49		0.04
Mining	-0.65	-6.29	**	0.71	-0.67	-2.95	**	0.52	-0.01	-0.02		0.00
Construction	-0.26	-3.23	**	0.40	-0.18	-0.87		0.09	-0.66	-3.76	**	0.70
Manufacturing	0.03	0.27		0.00	-0.09	-0.57		0.04	1.03	5.57	**	0.84
Durable	0.42	2.80	**	0.19	-0.51	-2.62	**	0.47	0.02	7.86	**	0.90
Non-Durable	0.17	2.34	**	0.15	0.36	2.61	**	0.37	0.38	2.55	**	0.52
Transport	0.11	3.16	**	0.65	0.27	4.31	**	4.31	0.23	2.38	**	0.49
Electricity	0.17	1.86	*	0.26	0.56	3.38	**	0.58	0.03	-0.21		0.01
Wholesale	0.14	5.45	**	0.67	0.20	4.11	**	0.68	0.00	-0.07		0.00
Retail	0.23	6.94	**	0.76	0.40	5.21	**	0.77	0.16	5.07	**	0.81
FIRE	0.66	11.5	**	0.90	0.46	3.61	**	0.62	0.94	8.66	**	0.93
Services	0.37	10.5	**	0.88	0.56	8.12	**	0.89	0.17	3.48	**	0.67
Government	0.04	3.62	**	0.51	0.02	0.68		0.68	0.10	4.86	**	0.80

** significant at 5 % level of confidence   (t-crit. = 2.11)   (t-crit. = 2.31)   (t-crit. = 2.37)
* significant at 10 % level of confidence   (t-crit. = 1.75)   (t-crit. = 1.86)   (t-crit. = 1.90)

TABLE 4.2: Beta-Convergence of Labour Productivity for Specific Industries of the USA:

INDUSTRY	BETA-CONVERGENCE 1982-1998				BETA-CONVERGENCE 1982-1991				BETA-CONVERGENCE 1991-1998			
	slope	t-value		R^2	slope	t-value		R^2	slope	t-value		R^2
Total	0.005	0.32		0.00	0.035	1.30		0.04	-0.019	-1.01		0.02
Physical Industries	-0.046	-3.69	**	0.23	-0.028	-1.54		0.05	-0.050	-2.43	**	0.11
Service Industries	0.083	3.48	**	0.21	0.129	3.03	**	0.17	0.024	1.76	*	0.21
Agriculture	-0.009	-2.47	**	0.12	-0.017	-4.86	**	0.34	0.002	0.65		0.01
Mining	-0.046	-3.40	**	0.21	-0.038	-1.87	*	0.07	-0.027	-1.82	*	0.07
Construction	-0.050	-2.94	**	0.16	-0.061	-1.78	*	0.03	-0.074	-4.15	**	0.40
Manufacturing	-0.131	-5.80	**	0.42	-0.043	-2.04	**	0.08	-0.153	-4.21	**	0.28
Durable	-0.164	-6.04	**	0.44	-0.099	-5.39	**	0.39	-0.169	-4.11	**	0.27
Non-Durable	-0.030	-2.02	**	0.08	0.002	0.09		0.00	-0.014	-0.66		0.01
Transport	-0.034	-2.28	**	0.10	-0.001	-0.04		0.00	-0.020	-0.90		0.02
Electricity	-0.036	-4.78	**	0.26	-0.007	-0.66		0.01	-0.029	-2.49	**	0.12
Wholesale	-0.029	-1.41		0.04	-0.027	-0.69		0.01	-0.034	-1.59		0.05
Retail	0.023	0.56		0.01	0.073	0.90		0.02	-0.008	-0.16		0.00
FIRE	0.021	2.05	**	0.08	0.009	0.53		0.01	0.038	2.57	**	0.13
Services	0.036	1.44		0.04	0.084	1.89	*	0.07	-0.027	-1.10		0.03
Government	-0.009	-0.98		0.02	-0.020	-0.83		0.01	0.001	0.05		0.00

** significant at 5 % level of confidence   (t-crit. = 2.02)
* significant at 10 % level of confidence (t-crit. = 1.68)

FIGURE 4.1: TOTAL OF ALL INDUSTRIES

Panel A: Labour Productivity in logs

Panel B: Beta Convergence of Labour Productivity

Panel C: Sigma Convergence of Labour Productivity
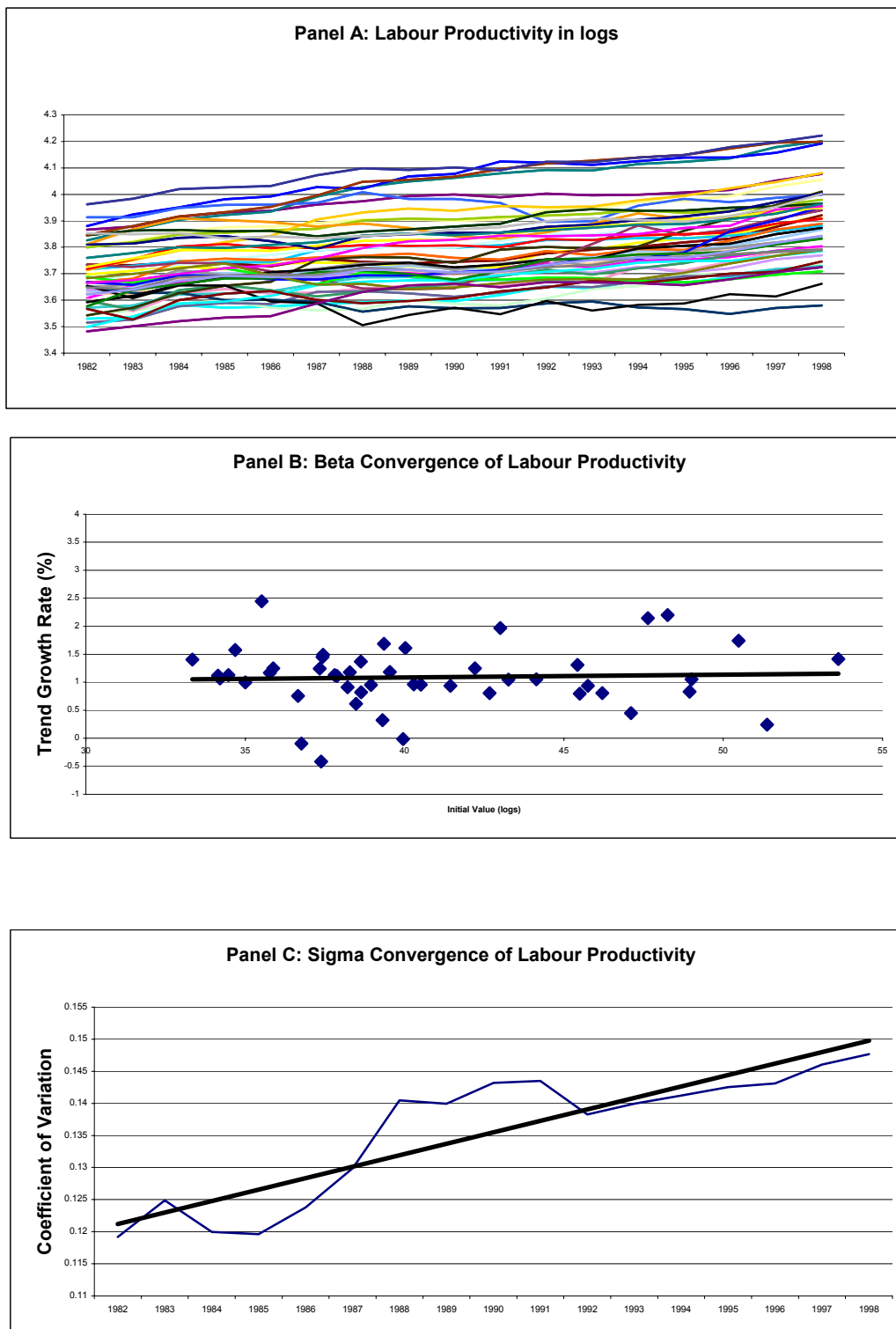
FIGURE 4.2: PHYSICAL INDUSTRIES

Panel A: Labour Productivity in logs

Panel B: Beta Convergence of Labour Productivity

Panel C: Sigma Convergence of Labour Productivity
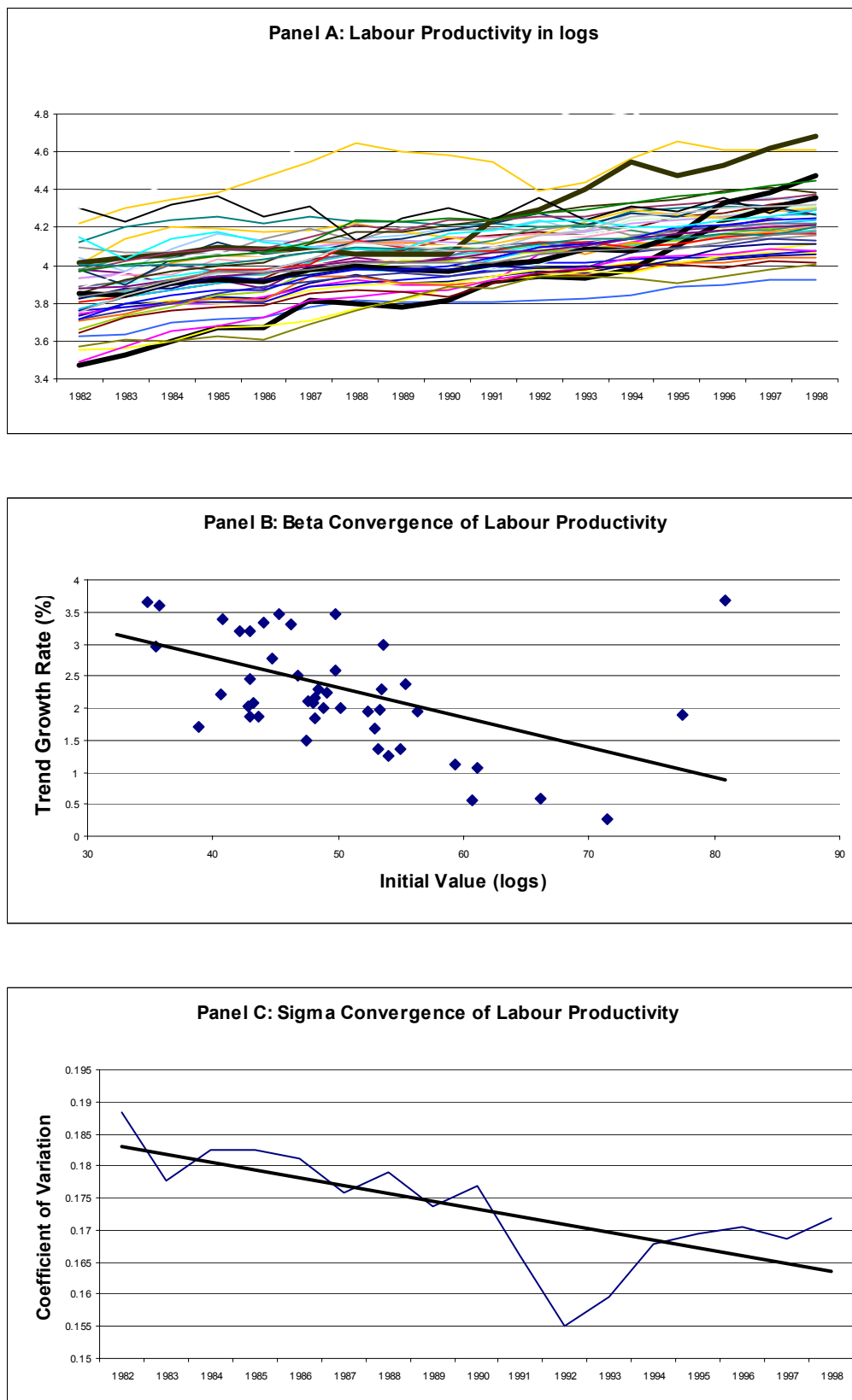
FIGURE 4.3: MANUFACTURING

Panel A: Labour Productivity in logs

Panel B: Beta Convergence of Labour Productivity

Panel C: Sigma Convergence of Labour Productivity

FIGURE 4.4: DURABLE

Panel A: Labour Productivity in logs

Panel B: Beta Convergence of Labour Productivity

Panel C: Sigma Convergence of Labour Productivity

FIGURE 4.5: NON DURABLE

Panel A: Labour Productivity in logs

Panel B: Beta Convergence of Labour Productivity

Panel C: Sigma Convergence of Labour Productivity

FIGURE 4.6: TRANSPORT

Panel A: Labour Productivity in logs

Panel B: Beta Convergence of Labour Productivity

Panel C: Sigma Convergence of Labour Productivity

4.5.4. Reconciliation with Previous Results

It would have been very useful to extend the analysis to LP data prior to 1982, for at least two reasons. Firstly, a longer time span makes the results more reliable, and secondly it helps to identify when the changes, in particular in the service industries started. Most of the service industries report sigma divergence during the 1980s, yet it would be interesting to analyse the trends prior to the 1980s. Unfortunately, GSP data for earlier years are no longer available from the BEA. Changes in their estimation methodology make earlier data estimates inconsistent with the current GSP series, which was used here. Therefore I will have to rely on the results as reported by Bernard and Jones (BJ) (1996a), who analyse an earlier set of data.

This section will try to relate the findings by BJ (1996a) to the results of this study. The results from BJ are comparable to this study for two reasons. Firstly, these authors also analyse labour productivity across the states of the US and secondly, both studies carry out a sectoral analysis. Yet the comparability is limited as BJ do not study as many sectors and include a slightly different set of states, that is all states except some mining states. Further, they only present trends in sigma convergence by plotting the standard deviation over time in a graph, without actually testing for its statistical significance. Last but not least ,their time span covers only the period up to 1990.

For the Total of all industries the plot of the standard deviation in BJ indicates some convergence, yet this trend slowed down from the late 1980s onwards. The results of this study — extending the time span — indicate that the convergence did not only come to a halt but reversed during the 1990s. For the Mining industry both studies report convergence. The results in the Construction sector are also consistent. Although the dispersion of LP increased prior to the 1980s, the diverging trend reversed during mid to late 1980s, and based on the result of this study continued to decline during the 1990s. For the Manufacturing sector BJ report a strong converging trend up to the mid 1980s. After the mid 1980s the trend of the standard deviation becomes nearly horizontal indicating that convergence has stopped. According to the results in this chapter, the dispersion of LP in the manufacturing sector did not only stop but started to increase during the following years. The results for the remaining service sectors, eg. Transport, Wholesale/Retail, FIRE and Other Service, are compatible as well. All show an increase in the dispersion of LP during the 1980s, which by and large appears to have continued during the 1990s.

4.5.5. Summary

In sum, although earlier data was not available from the BEA to reproduce previous findings, the results from BJ, for the overlapping years, are quite consistent with the trends in LP reported here. Both studies find that the majority of the services industries generally exhibits

significant sigma divergence during the 1980s and based on my findings this continued during the 1990s. In the Manufacturing industry BJ report that convergence slowed down. I extend the time span by also looking at the 1990s and find that the trend actually reversed in later years.

Further it appears that a few states in the North Eastern part of the country do to some extent drive the diverging trend in the service industries, in that they started out with high LP levels but continued to surge ahead, diverging from the national average. In the physical industries, in particular the Manufacturing sector, it is by and large a belt of states located in the West of the USA that drove this divergence trend.

4.6. TIME - SERIES ANALYSIS

So far the convergence hypothesis has been investigated in a cross - section approach. This section will extend the analysis by studying convergence trends via a time - series approach. In particular, a unit root test will be applied to test for stationarity of deviations between the LP of the state i and the average LP of all states. Time -series techniques do not only offer an additional econometric technique but also provide a slightly different interpretation of the convergence concept. To avoid misunderstandings time - series convergence will be referred to as rho-convergence.

As discussed in Section 4.4 the Levin and Lin (1992) panel unit root test is applied. The data are cross - sectionally de - meaned, by subtracting the national average of LP across all states from the log LP of each state to eliminate the influence of aggregate effects. Here the results for a model with intercept and time trend will be reported, as it seems reasonable to assume that both are evident in the underlying data. The statistical power of the unit root test will be significantly reduced, if a deterministic element is included but not evident in the underlying data. Therefore the model was also tested without any deterministic element as well as with an intercept only, but these variations yielded the same result and are therefore not reported.

The results of the panel root tests are reported in Table 4.3. Again, the test is applied to the whole data set as well as the two sub periods, 1982 - 1991 and 1991 - 1998 and to the individual sectors. 'T-rho' reports the t-statistics and 'rho' the unit root estimates. An asterisk indicates that, based on the reported critical probability, the statistic is not significant (in contrast to the conventional reporting practise). In other words, the null hypothesis of no-convergence (=unit root) cannot be rejected, and this is taken as evidence of rho-divergence.

TABLE 4.3: Rho-Convergence of Labour Productivity for Specific Industries of the USA; Panel Unit Root Results

Industry	Rho-Convergence 1982-1998			Rho-Convergence 1982-1991			Rho-Convergence 1991-1998		
	t-rho		rho	t-rho		rho	t-rho		rho
Total	-0.56	*	1.004	-0.23	*	0.998	-0.19	*	0.998
Physical Industries	-3.74		0.963	-4.04		0.947	-1.81		0.973
Service Industries	0.73	*	1.001	1.07	*	1.002	-0.30	*	0.999
Agriculture	-6.20		0.935	-6.08		0.906	-1.99		0.974
Mining	-4.08		0.960	-4.19		0.941	-1.87		0.075
Construction	-5.88		0.955	-4.73		0.946	-3.32		0.969
Manufacturing	-2.83		0.960	-5.03		0.910	-0.81	*	0.982
Durable	-1.76		0.971	-5.63		0.878	0.78	*	1.019
Non-Durable	-4.45		0.954	-3.84		0.942	-2.09		0.971
Transport	-3.84		0.957	-3.69		0.917	-2.17		0.963
Electricity	-3.83		0.932	-19.30		0.039	-18.18		0.100
Wholesale	0.38	*	1.008	-4.09		0.899	-0.14	*	0.996
Retail	-1.52	*	0.980	-5.12		0.905	1.32	*	1.024
FIRE	0.03	*	1.000	-0.54	*	0.993	0.40	*	1.005
Services	2.07	**	1.011	2.25	**	1.019	1.53	*	1.008
Government	-1.35	*	0.992	-1.98		0.981	0.49	*	1.003

*5% not significantly different from $\rho=1$
** 5% rho significantly greater than one

The panel unit root results broadly confirm the pattern of the cross - section analysis. Over the whole period (1982-1998) there appears to be evidence of rho-divergence for Total, Sum of all service industries, Wholesale, Retail, Services and Government. All of these industries have a rho coefficient very close to unity, indicating the existence of a unit root. In other words, divergence occurs primarily in the service industries, except Electricity. On the other hand rho - convergence is evident not only for the sum of all physical industries, but also for Agriculture, Mining, Construction, Manufacturing, and Transport. Also for the two sub-periods the results are quite consistent with the cross - section findings. During the first period (1980s) rho divergence is stronger in the service industries. During the second period (1990s) rho divergence in the service industries continues, and most of physical industries also report divergence. And again it is in particular the Manufacturing, Durable and Non-Durable sector, beside Agriculture and Transport, that report rho-divergence.

In sum, the findings from the time - series methodology are broadly consistent with the cross - section results. Divergence seems again to be much stronger during the 1990s and divergence trends during the 1980s are by and large reported for the service industries, whereas in most of the physical industries divergence started to set in during the 1990s. Here it is again the Manufacturing and in particular the Durable industry, which report significant rho divergence. Yet the results must be interpreted with care. Firstly, the findings lack direct comparison with the

cross - section results due to the different interpretation of the convergence concept. Secondly, although panel data techniques may be more powerful than 'pure' time - series regressions if applied to a data set with a relatively short time span, the number of periods is still very small, in particular for the sub-periods and may bias the results. Nevertheless, this section introduced another econometric technique and interpretation of convergence, which contributes to an overall understanding of what actually happened.

4.7. GROWTH TRENDS FOR THE STATES OF THE US VERSUS THE STATES OF AUSTRALIA

In this section the results from Australia (Chapter Three) and the US (this chapter) will be compared. Based on the analysis in Chapter Three and this chapter it can be concluded that the previously observed convergence trends for both economies came to a halt. In Australia this was accentuated by a mining boom in Western Australia. Once the mining sector was removed, the states' LP growth paths were more or less parallel, and there was neither evidence of convergence nor divergence. In the US the diverging trend appears to be sourced in the Services and Manufacturing sector. Clearly, some outperforming states in the South-West of the country continued to increase in the overall dispersion of LP. This trend is in particular strong during the 1990s.

While the previously observed convergence trend in Australia came to a halt, there is evidence of divergence across the US states. One might ask whether the developments in LP in the US economy are likely to occur in Australia as well, although with a lag. Or as DeLong (2000) states

> *"The forces that made for rapid growth in the US in the second half of the 1990s, ... seem poised to be duplicated elsewhere in the world economy" (p.10).*

In other words, one might expect that the current insignificance of convergence trends in Australia may turn into a clearly diverging trend. This question bears monitoring in the years ahead.

4.8.   CONCLUSION

Overall, the findings suggest that the convergence process observed in the literature prior to 1996 was no longer robust in recent years. At the aggregate level beta convergence of LP has slowed down or disappeared entirely during the 1990s for the United States. More importantly there is evidence of sigma divergence. This finding is broadly in line with the results for the Australian states. The dispersion of LP across the states in both countries widens because of different sources. While a mining boom in Western Australia was the main cause of the increased dispersion in Australia, it is turbulence in the Manufacturing sector in the US which contributed most to the increased dispersion there.

In the US divergence started during the 1980s when it was driven this trend was followed by the physical industries, and in particular by the Manufacturing and Transport & Utility industries. The time - series results broadly confirm the cross - section findings. Divergence in a time-series sense was evident in a couple of service industries during the 1980s, yet became stronger during the 1990s. Among the physical industries it was in particular the Manufacturing and Durable industry that contributed most to rho divergence in the second period of the data set.

The results suggest that we may be witnessing a period of turbulence with major changes in the relative rankings of states, caused perhaps by technological changes, particularly. Yet, divergence is not even across all states. Innovation and technical progress are not spread evenly throughout the states but perpetuate advantages of the regions which have adopted technological changes. There appears to be a belt of states in the Western, and also Eastern part of the country, which by and large seem to be responsible for the divergence trend. Some of them managed to not only cross over the national average, but to further surge ahead while at the same time a few other states fell behind.

The problem addressed is broad and complex. The next chapter will try to pinpoint further the sources of the reported LP trends and analyse the Manufacturing sector in more depth.

CHAPTER FIVE

LABOUR PRODUCTIVITY DYNAMICS FOR SUB - INDUSTRIES OF MANUFACTURING ACROSS THE STATES OF THE USA: 1982 - 1998.

5.1. INTRODUCTION

The previous chapter studied convergence trends of LP across the US states and three new results were found. Firstly, the results indicate that the convergence trend found prior to the 1990s, has slowed down. Furthermore, sigma convergence has not only stopped, but reversed to divergence and this widening in the dispersion of LP started in the early 1980s in the service industries followed by the physical industries in the 1990s. Secondly, the sectoral analysis revealed that sigma divergence during the 1990s was by and large driven by the services industries and Manufacturing sector. Thirdly, the widening in the dispersion of LP was the result of a belt of 'crossing over' states in the West and also a few in the North East of the country. Those states reported above average growth rates, which enabled them to surge further ahead during the 1990s contributing to sigma divergence.

The motivation of this chapter is to delve deeper into the sources and driving forces of the observed dynamics in the Manufacturing industry. The analysis will therefore proceed along an even more dis - aggregated level and examine the sub - industries within the Durable and Non -

Durable Industries. This analysis will help to sharpen the findings of Chapter Four, by pinpointing specific sub - industries within the Durable and Non - Durable industries, which may have caused the observed trends in the dispersion of LP.

The results of this chapter identify the Electronic and Electrical Equipment industry (EE - industry) as the main contributor to divergence in the Manufacturing sector. Some of the divergence also appears to be due to the Industrial Machinery and Equipment industry. In the Non - Durable sector it is the Chemicals and Allied Products industry which reports sigma divergence during the 1990s. Further, in the EE - industry the same belt of states in the South - West and North - East of the US could be identified as crossing - over or surging cases, causing the dispersion of LP to widen. The observed increase in the dispersion of LP in the EE - industry supports the argument that divergence during the 1990s appears to be the result of turbulences in the high - technology sector.

Section 5.2 will describe the data and sub - industries within the Durable and Non - Durable industry. Section 5.3 summarises the convergence trends within each sub - industry and undertakes an analysis of the growth performance of the states. Section 5.4 reports the convergence results from the time series analysis and Section 5.5 finishes with some concluding and summarising comments.

5.2. DATA

The Bureau of Economic Analysis (BEA) lists eleven sub - industries in the Durable industry and ten in the Non - Durable industry. Because of a lack of data three industries were left out of the analysis, namely the Furniture industry in the Durable and the Textile industry and the Tobacco industry in the Non - Durable industry. Further some industries are not included as they are regarded as too small and not representative for the Durable or Non - Durable sector. Those industries had less than 5 % of value added in 1998 of the Durable or Non - Durable sector. Among them are Miscellaneous Manufacturing Products (3%), Lumber (4.5%), Stone (4%) and Primary Metal (5%) in the Durable sector and Apparel (4.5%), Leather (0.8%) and Petroleum (4.5%) in the Non - Durable sector. This leaves a total of eleven industries with six in the Durable sector and five in the Non - Durable sector.

Within each industry the number of cross - sections analysed varies slightly, as BEA did not disclose output or employment data for a few of the states. Those states were left out, together with Alaska, DC and Hawaii, which were earlier identified as outliers and not representative for the majority of states. Last but not least, output data for the EE - industry and the Instruments and Related Products industry are only available for the years 1986 - 1998.

5.3.   CROSS SECTION ANALYSIS

5.3.1. The Durable Industry

Findings in Chapter Four indicate that the sigma divergence trend in the Manufacturing sector appears to be due mainly to the trends in the Durable industry and to a lesser extent by the Non - Durable industry. In 1998 output in the Durable industry accounted for around 60% of the Manufacturing industry and is with 20% of the overall GDP the second largest industry behind Services.

This section will now analyse the convergence trends of each sub - industry within the Durable sector. These industries are listed by their importance as measured by their relative size that is the industry's percentage of output within the Durable industry. Table 5.1 (p. 131) reports the results of the beta convergence analysis and Table 5.2 (p. 132) the sigma convergence results.

Electronic and Other Electrical Equipment: The EE - industry is not only the largest industry in the Durable sector, accounting for one quarter (25%) of its output, but also the largest industry within the whole Manufacturing sector (15%). Consequently, the industry's convergence trend has a large impact on the performance of LP in the Durable industry but also on the whole Manufacturing industry. As illustrated in Figure 5.1, and reported in Table 5.1 the slope coefficient has the correct sign and beta convergence is statistically significant (slope coefficient of − 0.37 with a t - value of −2.94). Although it appears from Figure 5.1 that the

catch - up process has weakened during the 1980s, it reverses to significant convergence during the 1990s with a t - value of -4.09. In contrast, and consistent with the findings in Chapter Four, there is evidence of significant sigma divergence over the whole period (slope coefficient = 1.28; t - value = 9.61) and also during the 1990s. Although divergence is not evident during the 1980s, the dispersion of LP clearly widens afterwards (slope coefficient = 11.92; t - value of 4.38). The upper dot in Panel B appears slightly outside the overall pattern of the remaining states. Even if this outlier is removed, both beta convergence and sigma divergence remain significant. The observed picture is very much in line with the trends in the Manufacturing industry reported in Chapter Four.

Beta convergence during the 1990s together with the observed sigma divergence is an indication of cross - over cases. Crossing over states are again identified by normalising the level of LP to one hundred and finding the year when the states' LP moves from below to above one hundred. The state analysis identifies the following states as crossing over cases: Arizona (crossing over in 1992), California (1988), Idaho (1993), New Mexico (1991), Texas (1988). Further Oregon, although not crossing over is a surging state with an average growth rate of 33%, compared to the national average of 15%. Consistently, these states are located in the West of the US with New Hampshire being the only crossing - over state in the East, crossing over in 1994. So far there is a clear similarity with the former observed pattern in the Manufacturing and

also Durable industry. The sectoral analysis pinpointed the EE - industry as one of the most important contributors to sigma divergence during the 1990s. This finding is quite remarkable, as it indicates that dynamics in the high - technology sector may be partly responsible for reversing the convergence trend observed prior to the 1990s.

Industrial Machinery and Equipment: This industry is with 21% of output the second largest of all the Durable Industries and with 13% the second largest within Manufacturing. Again, sigma divergence is evident for the whole period and also both sub - periods. Further, from Panel C Figure 5.2, it can be seen that the upwards sloping trend of the CV considerably resurges after 1993.

The state analysis revealed that during the 1990s, the widening in the dispersion of LP is mainly driven by surging states. Some of the initially richer states maintained higher growth rates relative to the national average of 9% and continued to grow. Consistently, those states are predominantly located in the West of the US and include California (12%), Idaho (15%), Oregon (11%), and Texas (14%). Some states are located in the East and consist of Georgia (11%), Massachusetts (10%), New Hampshire (17%) and also North Dakota (11%). This causes beta divergence and at the same time sigma divergence to occur. Further, Colorado and Connecticut cross over in 1992 and 1994, respectively. Overall, the Industrial Machinery industry appears to have contributed to sigma divergence as well. In particular, during the 1990s the widening in

the dispersion of LP increased rapidly. And in line with the findings in the Durable industry the divergence was driven by a group of surging states, most of which are located in the West of the US except for Georgia, Massachusetts and New Hampshire in the East.

Motor Vehicles and Equipment: Figure 5.3 illustrates the trends of the Motor Vehicles Equipment industry. This industry is with 12% of output the third largest industry but compared to the EE industry and the Industrial Machinery industry much smaller. It appears to be one of the few exceptions which displays both beta and sigma convergence. However, although sigma convergence is evident for the whole period and the 1980s, this trend started to slow down during the 1990s, as sigma convergence is not statistically significant any more. Interestingly, there are a few states which report negative growth rates during the 1980s, but above average growth rates during the 1990s. Their growth performance reverses during the 1990s to be three to four times higher than the national average of 4%. Among those states are California growing at –3% during the 1980s but 8% during the 1990s. Colorado (-14%, 12%) in the West, and also Minnesota (-2%, 10%),   Mississippi (-2%, 17%) and Wisconsin   (-5%, 10%). Again California and Colorado are states located in the West of the US.

Overall this industry is relatively small and although sigma divergence was not significant during the 1990s, neither was convergence.   Still, there is some consistency. A couple of states in the West of the US report above average LP performance in the 1990s.

Fabricated Metal Products: With 11% of output the Fabricated Metal Products industry is the fourth largest industry in the Durable sector. Beta convergence is evident in all three periods. Sigma divergence is significant for the whole period, but not for the 1990s. Yet, changes in LP trends are only minor and without any remarkable impact due to the size of the industry.

Other Transportation and Equipment: Output in the Other Transportation and Equipment industry amounts to only 6% of output within the Durable industry and the performance of LP trends does not show any major deviation. Beta convergence is evident for the whole period and during the 1980s at t - values of – 3.47 and – 4.31, respectively, yet slows down during the 1990s. Sigma convergence is significant for the whole period only, but could not be observed during either of the two sub - periods. The visual analysis of Panel C of Figure 5.4 indicates, that the dispersion in LP started to slightly widen from 1995 onwards, which is too late to be picked - up in the regression analysis. It will be interesting to see whether the trend will continue in the future. Overall, the performance of the individual states is rather steady without any major fluctuations and no dominant states in terms of LP performance can be identified.

Instruments and Related Products: This is the smallest of the selected industries with 5% of output. In the whole Manufacturing sector this industry ranks 12th with only 3% of output. Still, the industry's diverging

pattern is consistent with the overall picture, as sigma divergence is significant (t-value = 7.28) during the 1990s, after a period of convergence prior to 1991. The state analysis exhibits that the increase in the dispersion of LP is the result of falling behind states — New Mexico (-11), New York (-8), and Maine (-4). Overall the impact of this industry on developments in the Durable industry appears to be of less importance due to the relatively small size of the industry.

In summary, the above analysis sharpens the results of the previous chapter. The study analyses LP trends across the US States at a highly dis - aggregated sectoral level to further pinpoint the driving forces of the observed sigma divergence during the 1990s. So far Manufacturing, and here in particular the Durable sector, were identified as the main industries contributing to a widening in the dispersion of LP. The main sub - industries driving divergence appear to be the EE - industry and to some extent the Industrial Machinery industry. This is because both industries are quite important due to their relative size.

Further, the timing of the divergence in both industries is consistent, as the widening of the dispersion of LP was again observed to be strongest during the 1990s. Last but not least, the state analysis reveals that divergence is primarily driven by a group of crossing - over and surging states. Most of those states are located in the West of the US, in particular Arizona, California, Colorado, Idaho, New, Mexico, Oregon and

Texas and a few in the North East of the country — Massachusetts, New Hampshire, Georgia, Vermont — where they form a clear belt.

The EE - industry and to some extent the Industrial Machinery industry can be regarded as representative for the high - technology sector. This may be taken as evidence that the observed sigma divergence trend is to a large extent driven by the 'New Economy' phenomena. Further, it could be argued, that the formation of such a clear belt in the West is due to spill - over effects between those states, yet a more detailed analysis would be required to fully study any spatial distribution effects.

TABLE 5.1: Beta - Convergence of Labour Productivity across the States of the USA:

Durable Industry: 1982 - 1998, 1982 - 1991, 1991 - 1998

Industry	BETA - CONVERGENCE 1982 - 1998			BETA - CONVERGENCE 1982 – 1991			BETA - CONVERGENCE 1991 - 1998		
	slope	t-value	R^2	slope	t-value	R^2	slope	t-value	R^2
EE industry (1986-98)	-0.37	-2.94 **	0.16	--	--	--	-0.51	-4.09 **	0.27
Industrial machinery and equipment	-0.23	-4.41 **	0.30	-0.08	-0.84	0.02	0.07	0.69	0.01
Motor vehicles and equipment	-0.05	-4.86 **	0.36	-0.05	-2.32 **	0.11	-0.06	-3.02 **	0.18
Fabricated metal products	-0.07	-2.92 **	0.16	-0.10	-2.62 **	0.13	-0.09	-2.33 **	0.11
Other transportation equipment	-0.06	-3.47 **	0.22	-0.08	-4.31 **	0.30	-0.03	-0.85	0.02
Instruments and related products (1986-98)	-0.03	-2.13 **	0.10	--	--	--	-0.02	-0.84	0.02
Miscellaneous manufacturing industries	-0.08	-2.75 **	0.14	-0.00	-0.03	0.00	-0.17	-3.17 **	0.18

** significant at 5 % level of confidence   (t-crit. = 2.02)

TABLE 5.2: Sigma - Convergence of Labour Productivity across the States of the USA:

Non - Durable Industry: 1982 - 1998, 1982 - 1991, 1991 - 1998

Industry	SIGMA - CONVERGENCE 1982 - 1998			SIGMA - CONVERGENCE 1982 - 1991			SIGMA - CONVERGENCE 1991 - 1998		
	slope	t-value	R^2	slope	t-value	R^2	slope	t-value	R^2
EE-industry (1986-98)	1.28	9.61 **	0.89	--	--	--	11.92	4.38 **	0.76
Industrial machinery and equipment	0.12	6.69 **	0.75	0.11	5.46 **	0.79	0.22	3.21 **	0.63
Motor vehicles and equipment	-0.03	-4.48 **	0.57	-0.04	-2.23 **	0.38	-0.01	-0.66	0.07
Fabricated metal products	0.03	2.36 **	0.27	-0.03	-0.94	0.10	0.00	0.31	0.02
Other transportation equipment	-0.05	-2.81 **	0.34	-0.02	-1.04	0.12	-0.08	-1.01	0.14
Instruments and related products (1986-98)	-0.04	-0.82	0.06	--	--	--	0.16	7.28 **	0.90
Misc. manufacturing industries	0.02	1.73	0.17	0.09	3.95 **	0.66	-0.10	-3.31 **	0.65
** significant at 5 %	(t-crit. = 2.11)			2.31			2.37		

FIGURE 5.1 Electronic and Electrical Equipment

Panel A: Labour Productivity in logs

Panel B: Beta Convergence of Labour Productivity

Panel C: Sigma Convergence of Labour Productivity
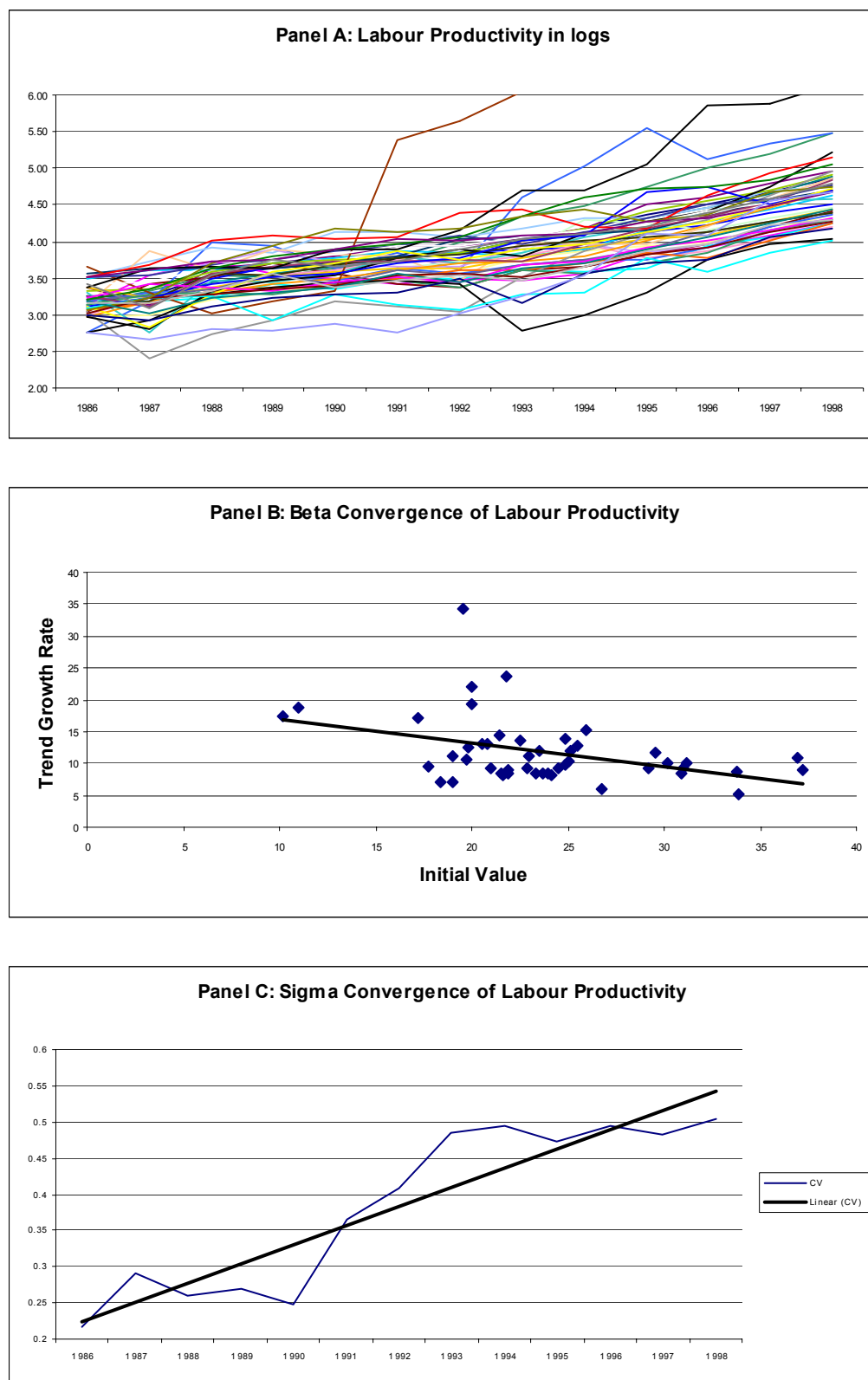
FIGURE 5.2: Industrial Machinery and Equipment

Panel A: Labour Productivity in logs

Panel B: Beta Convergence of Labour Productivity

Panel C: Sigma Convergence of Labour Productivity
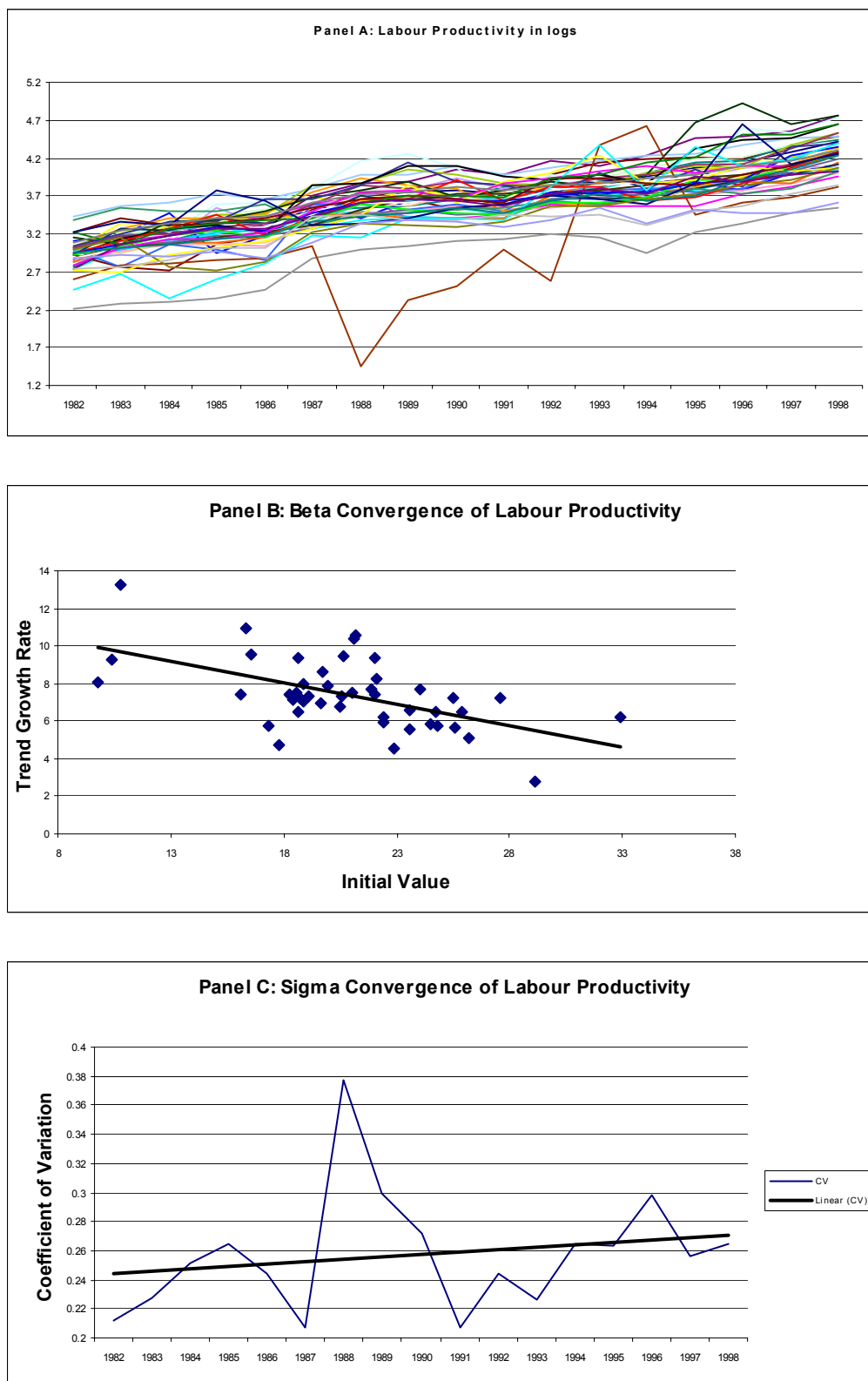
FIGURE 5.3: Motor Vehicles and Equipment

Panel A: Labour Productivity in logs

Panel B: Beta Convergence of Labour Productivity

Panel C: Sigma Convergence of Labour Productivity
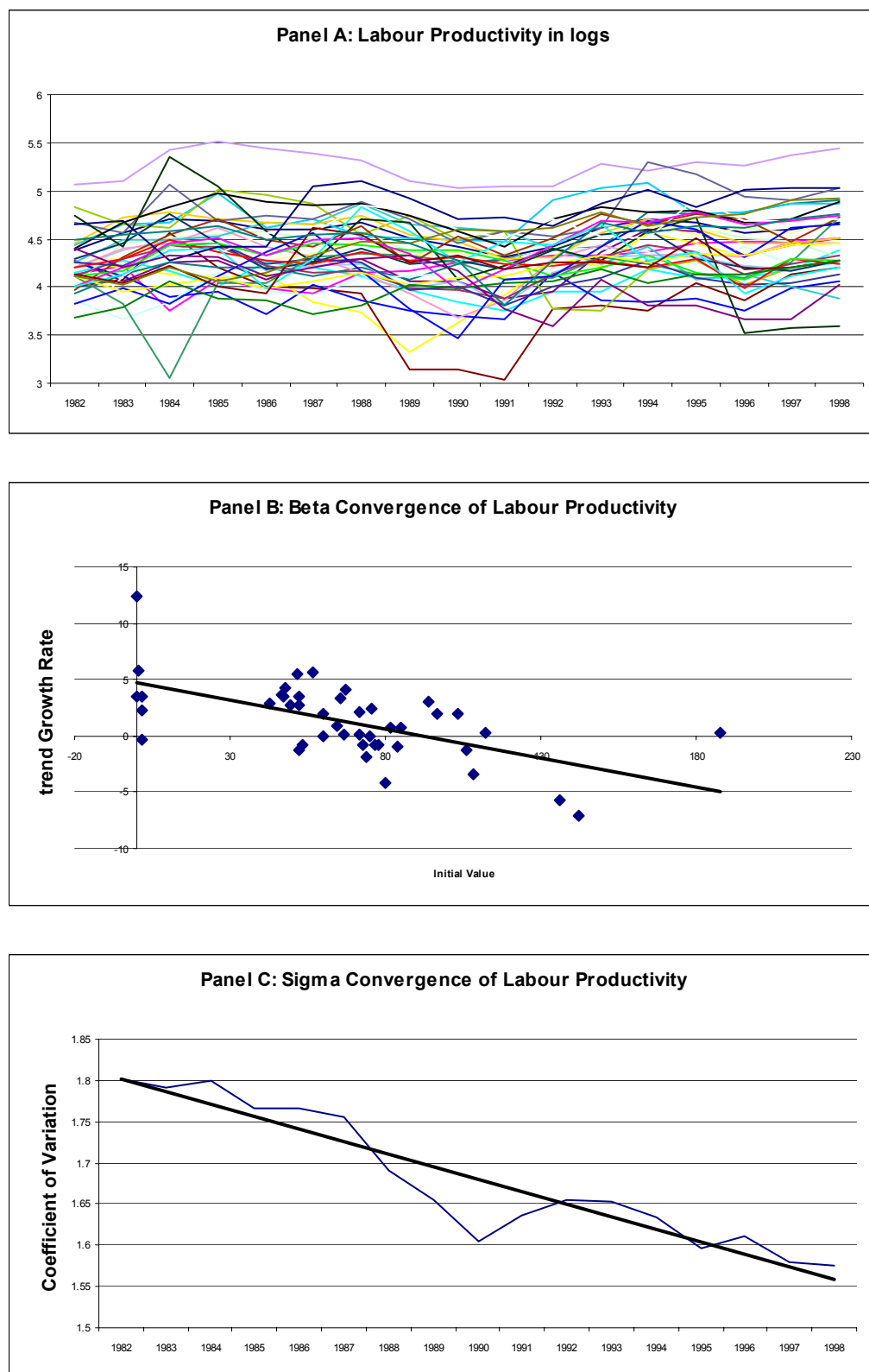
FIGURE 5.4: Other Transportation Equipment

Panel A: Labour Productivity in logs

Panel B: Beta Convergence of Labour Productivity

Panel C: Sigma Convergence of Labour Productivity
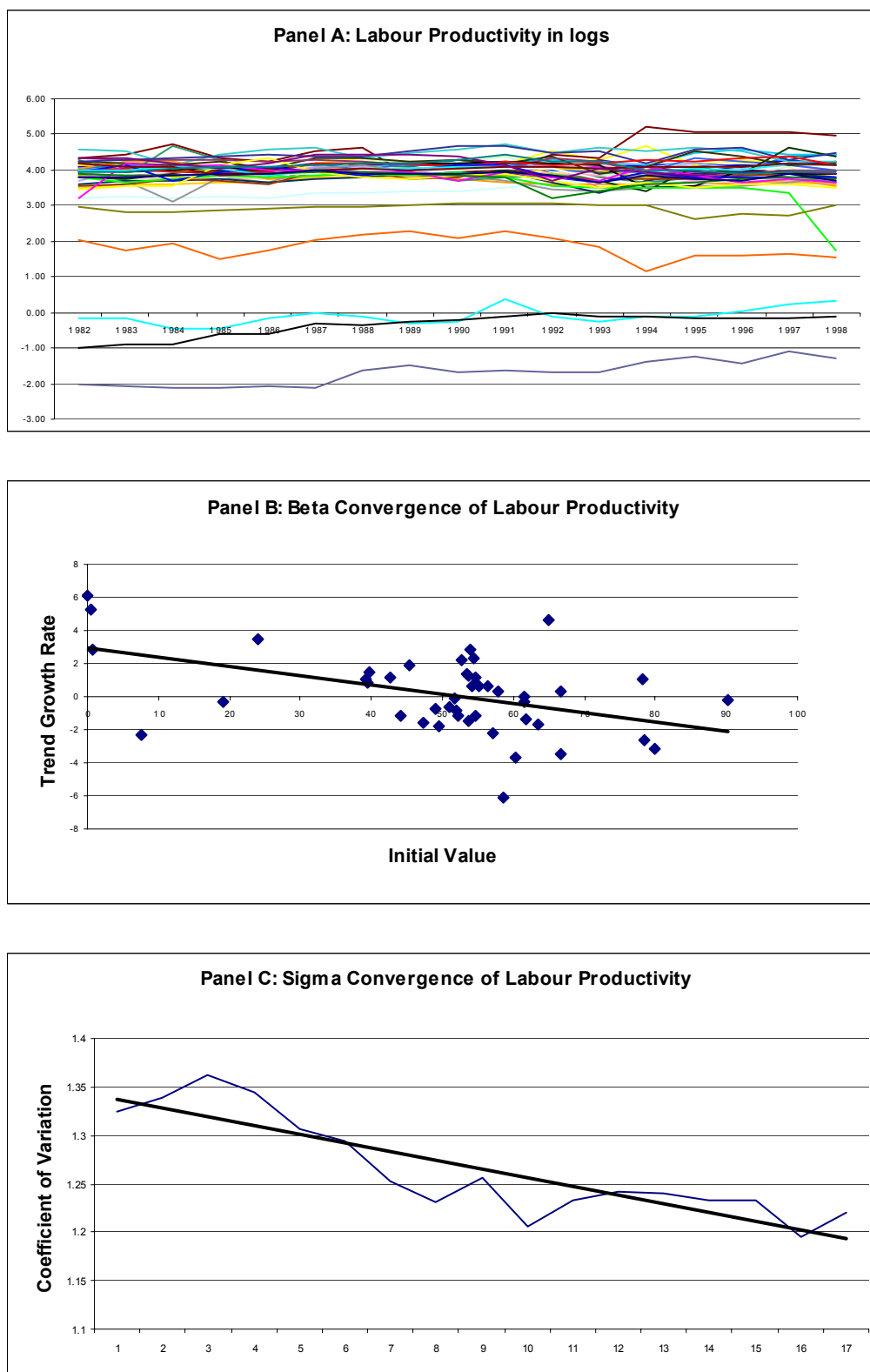
5.3.2. The Non - Durable Industry

The following section will focus on the sub - industries of the Non - Durable sector. Previous analysis of this sector revealed evidence of beta convergence over the whole period (1982 – 1998). However, for both sub - periods neither beta convergence nor divergence was observed. In contrast, and closely in line with trends in the Durable industry, there is evidence of sigma divergence for all three periods. This section will discuss the convergence trends of the sub - industries within the Non - Durable industry to explore which industries and which states may have caused the observed pattern. The results are reported in Table 5.3 and Table 5.4 (p.141, 142). Again, the industries will be listed according to their size, measured as the percentage of output in 1998 relative to the Non - Durable industry

Chemicals and Allied Products: The Chemical industry is the largest industry in the Non - Durable sector and its output amounts to around 27%. Further, it is behind the EE - industry and the Industrial Machinery industry the third largest in the whole Manufacturing sector, accounting for 10% of the output. Consistently, sigma divergence is evident over the whole period (t - value = 2.22), and also for both sub - periods with t - values of 2.76 and 2.72, respectively. As Figure 5.5 illustrates, this is because of surging states, while relatively poorer states do not manage to catch - up. Fast growing states, which report slightly higher growth rates in comparison to the national average of 4%, are Indiana, Iowa, Louisiana, Nebraska, and Oklahoma. By contrast New Mexico, North

Dakota and South Dakota start off relatively poor and continue to report negative growth rates during the 1980s. During the 1990s, they exhibit some convergence trend, yet have not managed to close the LP gap with the majority of the other states and sigma divergence remains evident during the 1990s. Within the Chemical industry it is again New Mexico, which shows an outstanding LP performance during the 1990s. It has a negative growth rate of -4% during the 1980s (national average = 4%), yet this reverses to the highest growth rate in the whole industry of 11% during the 1990s. Overall sigma divergence is evident and driven by some fast growing but also falling behind states.

Food and Kindred Products: This industry is the second largest industry in the Non - Durable sector with around 18% - 20% of output over the period of analysis. The dynamics in terms of growth of LP are rather stable and without any major changes. Correspondingly, neither beta convergence nor divergence is observed over the whole period. Although sigma divergence is reported for the whole period and the 1980s, with an average growth trend in LP of around 1%, this industry does not exhibit any remarkable growth performance.

Printing and Publishing: This industry is the third largest in the Non - Durable industry (15%) and beta as well as sigma divergence are reported for the whole period and the 1980s. Consistently, sigma divergence is further evident during the 1990s (t - value = 5.34). The widening in the dispersion of LP is in particular due to 'falling behind

states'. Still, Figure 5.6 illustrates that the overall state performance of LP growth remains relatively unchanged and does not report any significant fluctuations.

Paper and Allied Products: The industry ranks fourth in the Non - Durable industry with an output ratio of 10%. Dynamics in LP growth are again rather stable and there is no clear evidence of convergence or divergence over the whole period and the 1990s.

Rubber and Miscellaneous Plastics Products: Rubber ranks fifth of the selected industries with only 9.5 % of output in the Non - Durable industry. Rubber is the only exception within the Non - Durable industry, reporting sigma convergence over the whole period and during both sub - periods. It appears to be a classical example of the catch - up scenario. Most of the beta convergence occurs during the 1980s. Catching up states are Florida, New Hampshire, New Mexico, Vermont, West Virginia, Wyoming, and Montana. Yet the industry is quite small and of less importance.

In sum, previous findings of the Non - Durable industry reported significant sigma divergence for all three sub - periods. Beta convergence was statistically significant for the whole sample but not for either of the sub - periods. The findings of the sub - industries do confirm the previous results. The dispersion of LP is widening (sigma - divergence), although at different degrees of significance, except for the

Rubber industry. In particular, the Chemical industry, the largest industry in the Non - Durable sector has a similar convergence pattern. In contrast to the Durable industry, where sigma divergence occurs primarily during the 1990s, in the Non - Durable industries the diverging trend appears to be slightly stronger during the 1980s. In comparison to the Durable sector, the dynamics in the Non - Durable sector are of less magnitude and have less significance due to the relatively smaller size of the Non - Durable industry.

TABLE 5.3: Beta - Convergence of Labour Productivity across the States of the USA:

Non - Durable Industry: 1982 - 1998, 1982 - 1991, 1991 - 1998

Industry	BETA - CONVERGENCE 1982 - 1998			BETA - CONVERGENCE 1982 – 1991			BETA - CONVERGENCE 1991 - 1998		
	slope	t-value	R^2	slope	t-value	R^2	slope	t-value	R^2
Chemicals and allied products	0.01	0.59	0.01	0.02	1.19	0.03	-0.01	-0.35	0.00
Food and kindred products	-0.02	-1.62	0.06	0.75	0.44	0.00	-0.04	-2.01 **	0.08
Printing and publishing	0.03	2.12 **	0.09	0.04	2.08 **	0.08	-0.50	-0.18	0.00
Paper and allied products	-0.02	-1.47	0.05	0.04	1.99 **	0.09	-0.02	-0.71	0.01
Rubber and misc. plastics products	-0.20	-14.32 **	0.82	-0.21	-6.34 **	0.47	-0.13	-5.03 **	0.36

** significant at 5 % level of confidence   (t-crit. = 2.02)

TABLE 5.4: Sigma - Convergence of Labour Productivity across the States of the USA:

Non - Durable Industry: 1982 - 1998, 1982 - 1991, 1991 - 1998

Industry	SIGMA - CONVERGENCE 1982 - 1998				SIGMA - CONVERGENCE 1982 – 1991				SIGMA - CONVERGENCE 1991 - 1998			
	slope	t - value		R^2	slope	t - value		R^2	slope	t - value		R^2
Chemicals and allied products	0.07	2.02	**	0.21	0.22	2.76	**	0.49	0.12	2.72	**	0.55
Food and kindred products	0.03	2.42	**	0.28	0.10	7.26	**	0.87	-0.04	-1.68		0.32
Printing and publishing	0.08	6.35	**	0.73	0.11	3.37	**	0.59	0.11	5.34	**	0.83
Paper and allied products	0.05	1.06		0.07	0.27	3.59	**	0.62	0.01	0.12		0.00
Rubber and misc. plastics products	-0.01	-11.77	**	0.90	-0.02	-9.13	**	0.91	-0.01	-3.24	**	0.64

** significant at 5 %   (t-crit. = 2.11)   2.31   2.37

FIGURE 5.5: Chemicals and Allied Products

Panel A: Labour Productivity in logs

Panel B: Beta Convergence of Labour Productivity

Panel C: Sigma Convergence of Labour Productivity
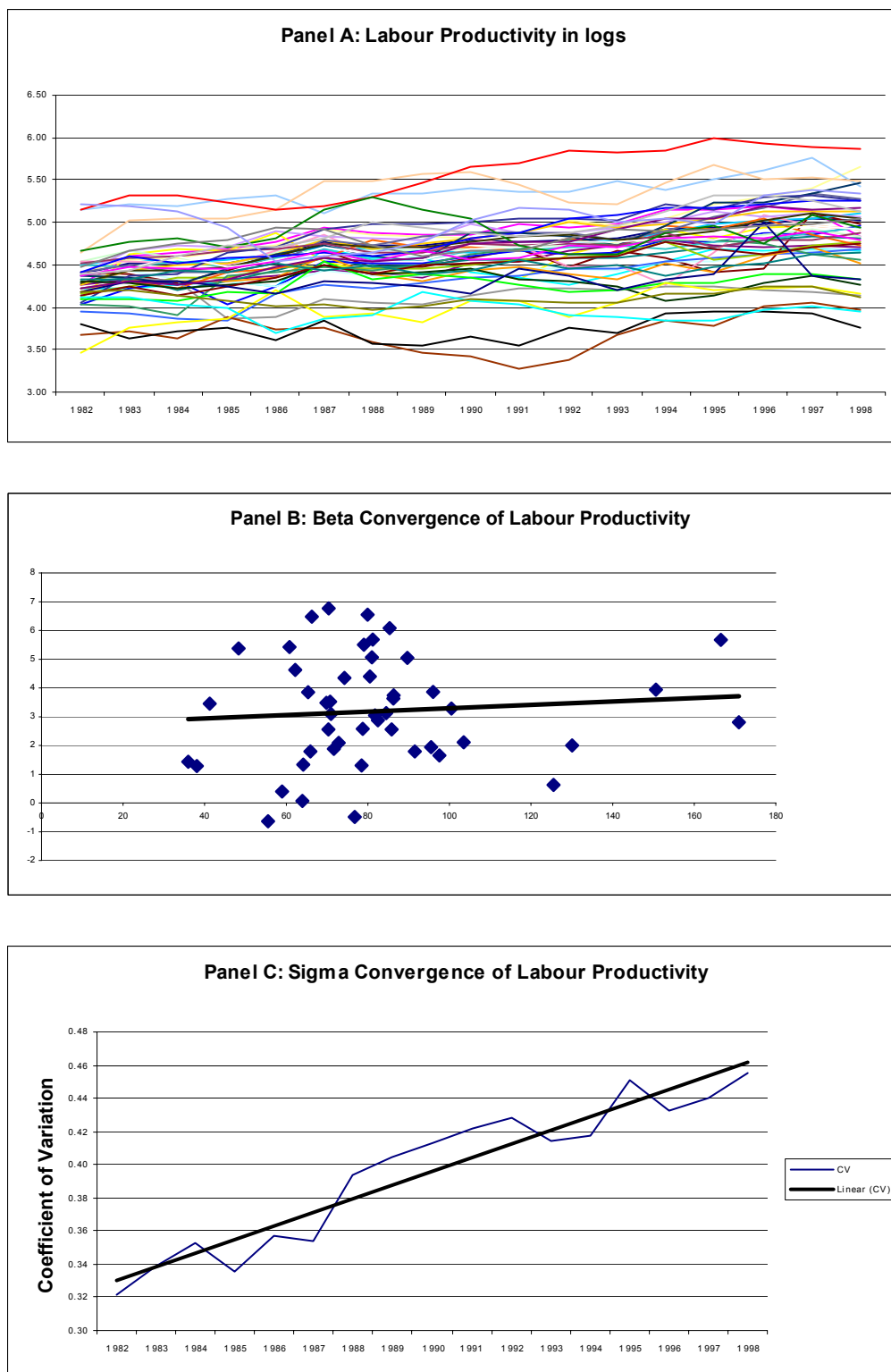
FIGURE 5.6: Printing and Publishing

Panel A: Labour Productivity in logs

Panel B: Beta Convergence of Labour Productivity

Panel C: Sigma Convergence of Labour Productivity
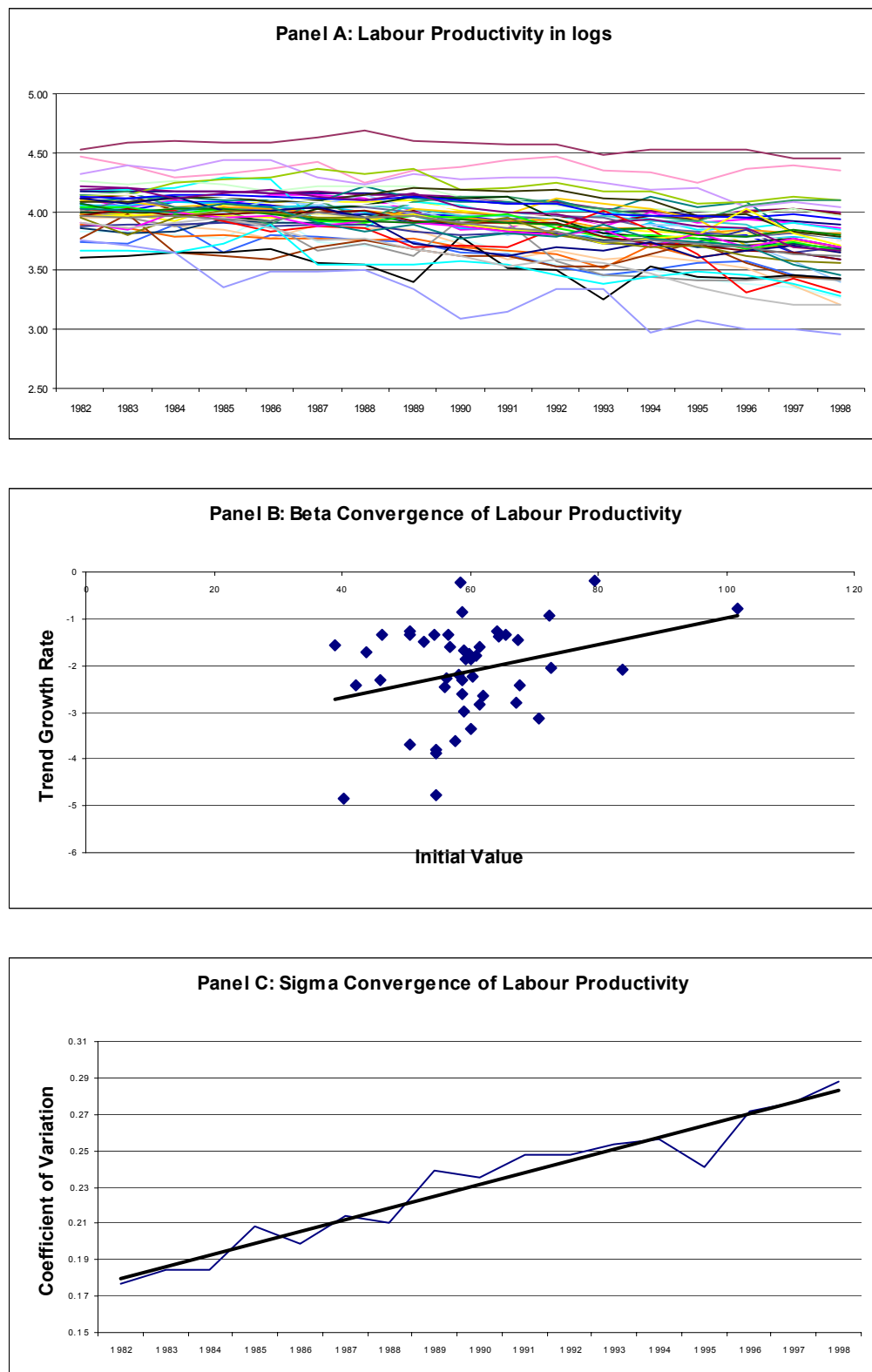
5.3.3. Summary

Most of the observed divergence trend in Manufacturing appears to be due to dynamics in the Durable industry, which is with 62% nearly twice as large as the Non-Durable sector (38%). Within the Durable industry this divergence trend is by and large driven by the EE - industry, which is not only the largest industry in the Durable industry, but also in the whole Manufacturing industry. The Industrial Machinery industry and the Instruments industry may also have caused some of the divergence. The widening of the dispersion in LP is to some extent driven by a belt of states in the West of the US and a few states in the East. Therefore, it is reasonable to argue that sigma divergence was caused by shocks in the high-technology sector, which also seem to have a contagious effects and spilled over to bordering states. To a lesser extent, sigma divergence is the outcome of turbulences in the Non-Durable industries.

5.4.   TIME SERIES ANALYSIS

Convergence trends in the sub - industries of the Durable and Non - Durable industry will now be examined using a time - series approach. As discussed in Chapter 4 the results of unit root panel data analysis based on a test by Levin and Lin (1992) are reported in Table 5.5 (p. 149,150) and confirm by and large the cross - section findings.

In the Durable sector the results of the time - series analysis confirm the observed divergence pattern from the cross - section analysis. For the

majority of industries, there is clear rho divergence during the 1990s. In other words, states are moving away from the national average. Industries reporting a unit root during the 1990s are the EE - industry, the Motor Vehicles, the Other Transportation Equipment and the Instruments and Related Products industries. Out of those, Motor Vehicles and Other Transportation Equipment also report rho - divergence for the whole period and the 1980s. Again and consistent with the cross section findings, the largest industry in the Durable sector, namely EE - industry, reports rho divergence. This is not surprising, as in particular in this industry the identified cross - over states clearly drift away from the national average.

Rho - divergence is not evident in the Fabricated Metal Product and the Industrial Machinery industry. In the first case this is still in line with the cross - section finding. For the Industrial and Machinery industry the results seem to contradict each other. Still, the emerging picture from the time series analysis is consistent with the overall pattern of divergence discussed previously. Again it is the EE - industry, which, besides others, reports divergence in a time - series sense, supporting the argument made earlier in this chapter that shocks in the high – technology sector may have driven a widening in the dispersion of LP.

In the Non - Durable sector the results are even more consistent with the cross - section findings. Consistently, rho divergence is reported for the majority of industries for both the 1980s and 1990s. These industries

include the Chemical and Allied products, the Food and Kindred industry and the Printing and Publishing industry. It can be observed that in all three industries some of the states are moving away from the national average or their steady state, causing not only a widening in the dispersion of LP (sigma divergence) but also rho divergence. The Paper and Allied Products industry and the Rubber and Miscellaneous Plastic product industry display no evidence of divergence in the time - series sense, yet this is in line with the cross section results. Further, both industries are relatively small and so have less influence on the aggregate results.

In sum, the panel unit root results broadly confirm our cross - section findings. In only a few cases do the results differ. In particular, the results of the time series analysis reinforce the important finding of the diverging trend in the Durable industry. Further, they highlight the argument that the widening of the dispersion of LP appears to be driven primarily by the EE - industry and support the overall picture of a technology driven divergence trend in the Manufacturing sector

5.5. CONCLUSION

The aim of this chapter was to delve deeper into the sources and driving forces of the observed divergence trends in the Manufacturing industry, by analysing labour productivity growth trends within each sub-industry of the Durable and Non-Durable industry.

The results support the findings in Chapter Four that changing growth patterns in the high – technology sector appear to have caused the reversal of the convergence trends found prior to the 1990s. In particular, the industry analysis reveals that trends in the EE - industry account for most of the divergence in the Durable sector, while some of the divergence also appears to be due to the Industrial Machinery and Equipment industry. In the Non - Durable sector the driving force is the Chemicals and Allied Products industry reporting sigma divergence during the 1990s. From the state analysis it emerges that in EE - industry the same belt of states in the West and North - East of the US could be identified as cross - over cases. It is the outperforming LP growth in these states that cause the dispersion of LP to widen.

**TABLE 5.5a: Rho - Convergence of Labour Productivity across the States of the USA
The Durable Industry: 1982 - 1998; Panel Unit Root Results**

Industry	Rho - Convergence 1982 - 1998		Rho - Convergence 1982 - 1991		Rho - Convergence 1991 - 1998	
	t-rho	rho	t-rho	rho	t-rho	rho
Fabricated metal products	-4.74	0.92	-4.01	0.90	-2.82	0.94
Industrial machinery and equipment	-8.9	0.80	-6.49	0.82	-6.14	0.77
EE-industry (1986-98)	-2.64	0.95	-4.07	0.79	-0.84 *	0.98*
Motor vehicles and equipment	-3.48	0.98*	-2.98	0.98*	-1.80	0.98*
Other transportation equipment	-2.91	0.98*	-2.88	0.98*	-1.34 *	0.99*
Instruments and related products (1986-98)	-3.76	0.94	-3.58	0.89	-1.41 *	0.98*

* 5% not significantly different from $\rho=1$

**TABLE 5.5b: Rho - Convergence of Labour Productivity across the States of the USA
The Non - Durable Industry: 1982 - 1998; Panel Unit Root Results**

Industry	Rho - Convergence 1982 - 1998		Rho - Convergence 1982 - 1991			Rho - Convergence 1991 - 1998		
	t-rho	rho	t-rho		rho	t-rho		rho
Food and kindred products	-3.00	0.97	-1.88	*	0.97*	-2.46		0.97*
Apparel and other textile products	-4.97	0.92	-3.93		0.92	-3.07		0.92
Paper and allied products	-5.10	0.92	-2.69		0.95	-4.60		0.88
Printing and publishing	-2.20	0.97	-1.75	*	0.96*	-1.38	*	0.98*
Chemicals and allied products	-2.14	0.97	-1.21	*	0.98*	-1.79	*	0.97*
Petroleum	-7.50	0.84	-5.75		0.83	-4.78		0.86

* 5% not significantly different from $\rho=1$

In summary, the EE - industry appears to have an important impact on the growth trends in LP in the Manufacturing industry during the 1990s. This is because it is one of the largest sub - industries within Manufacturing and it reports the most dramatic changes in LP growth over this period. Further, most high technology equipment, such as semi-conductors are produced within this industry. In other words, the analysis has not only pinpointed the 'drivers' of divergence during the 1990s, but also supports the argument, that divergence during the 1990s appears to be partly the result of shocks in the high - technology sector.

CHAPTER SIX:

COMPARISON OF MFP GROWTH IN THE ELECTRONIC AND ELECTRICAL EQUIPMENT INDUSTRY ACROSS THE STATES OF THE USA: 1982-1996[1]

6.1. INTRODUCTION

Studies on LP trends have generally found robust convergence during the 1970s and 80s for the US States at the aggregate level (Barro and Sala-i-Martin, 1991). By contrast the findings from Chapters Four and Five suggest that the convergence trend may have ceased during the last decade. This appears to have been driven to some extent by changes in the Electronic and Electrical Equipment Industry (EE industry), a sub-industry of the Durable Goods Sector.

As can be seen within the Solow growth accounting framework (as described in Chapter Two), LP can grow because of a higher capital intensity or because of technological change. The question naturally arises as to whether the recent productivity surge in the EE industry was the result of a higher capital per labour ratio or technological advance.

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[1] An earlier version of this Chapter was presented at the Australia and New Zealand Section of Regional Science Association International Inc. (ANZRSAI) 2002 conference held at the Gold Coast.

Most of the existing contributions in the literature studying multifactor productivity (MFP) trends focus on the *national* level that is, they perform *country by country* comparisons. For example Dowrick and Nguyen (1989) find convergence in MFP across the OECD countries. Studies by Dollar and Wolff (1993), Bernard and Jones (1996a), Melachroinos and Spence (2001) also undertake a country by country analysis, but at a dis-aggregated, *industry* level. These authors also find convergence of MFP at the aggregate level, but the results are not so clear cut at the industry level. This chapter will extend the above literature by focusing on MFP trends but in a *state by state* (US states) analysis and within a specific *industry* (EE-industry).

The aim of the chapter is threefold. *Firstly*, a capital stock series by state for the EE-industry will be constructed. *Secondly*, these estimates will then be used to analyse the contributions of MFP growth to LP growth in the EE-industry. The results so far indicate that technological change had a significant impact on growth in LP. *Thirdly*, a state by state comparison of MFP dynamics will be undertaken to analyse how the states perform relative to each other. It appears that MFP growth was not even across states, but that some states benefited more from technological advance than others.

The chapter is structured as follows. The next section will give a brief overview of existing studies on MFP growth. Sections 6.3 the data used while Sections 6.4 and 6.5 report the findings of the analysis of

productivity dynamics and convergence patterns. Some concluding remarks are given in Section 6.6.

6.2.   BACKGROUND

Before the mid 1990s the literature on MFP tended to focus mainly on the *aggregate* level in a *country by country* analysis. Dowrick and Nguyen (1989) for example examine productivity dynamics among the OECD countries between 1950-1980, and find that the countries become more similar as poorer countries catch-up with richer ones. This trend is in particular strong in MFP.

Other authors also study MFP trends on a country by country basis, but examine them at an *industry* level as well as *the aggregate level*. Dollar and Wolff (1993) compare productivity trends across the OECD countries during 1960-1985 for several industries. They find that convergence in LP holds at the aggregate as well as industry level. In contrast, convergence in MFP is only evident at the aggregate level but there is no clear pattern at the industry level. Most of the services industries experience a decline in the disparities of MFP, while for the majority of non-service sectors the disparities increased. Manufacturing remains largely unchanged (Dollar and Wolff, 1993).

Bernard and Jones (1996a) analyse MFP trends across 14 OECD countries for several industries, but for a later time span, 1970-1987.

Similar to Dollar and Wolff (1993) they find convergence at the aggregate level, but the results for each industry vary. Interestingly, while Dollar and Wolff (1993) do not find a change in the disparities in the manufacturing sector, during the 1970s and 1980s, Bernard and Jones (1996a) report a diverging trend in the manufacturing sector for the later years. Convergence still holds in the non-manufacturing industries.

Melachroinos and Spence (2001) study MFP trends in the Manufacturing sector among 13 member countries of the EU during 1978 and 1994. Their main finding indicates that the countries of the EU become more similar in terms of LP, however the catch-up trend is not evident in MFP growth. This is in line with the findings of Bernard and Jones (1996). In addition the trends are not equal among the countries. In particular, the North-South disparities continued to widen as countries in the South fell behind by utilising far less productive technology than the North.

A country by country analysis to study MFP dynamics during the 1990s was also undertaken by Daveri (2000) for the OECD countries. Daveri focuses on the aggregate level, but also looks at the *IT producing industry* — an industry very similar to the EE-industry — and its contributions to growth in productivity. They conclude that the contributions of TFP and the accumulation of IT capital accounted for most of the growth in the EU. Similar to Daveri (2000) they argue that the contributions were not equal across the EU states. Again, MFP growth

played a larger role in countries in the North of the EU such as Finland, Ireland, Norway and Sweden.

A very similar approach was applied by Jorgenson and Stiroh (2000) (JS), Oliner and Sichel (2000) (OS) and Gordon (2000), for the US. JS and OS and to a lesser extent Gordon show that during the 1990s contributions of MFP to growth in output was around 40 %, whereas the remaining 60 % are sourced in accelerating growth of all inputs. Gordon argues that some of the growth in output is attributable to a cyclical component. Further, around two thirds of the *acceleration* in LP during the 1990s come from more rapid growing MFP and only one third is due to capital deepening. Further, it is the IT capital that is responsible for most of the acceleration in the capital contribution.

Bosworth and Triplett (2000) investigate the link between MFP growth and the use of IT capital. Both argue that the recent improvements in MFP in the US cannot be attributed to the use of IT equipment, but acknowledge at the same time "*that there is room for disagreement about what is happening to MFP in the IT-using industries, and several potential reasons to believe that the contribution of IT to economic growth might be understated in the studies .... discussed so far*" (p.14).

In summary, at the aggregate level convergence in MFP across countries appears to hold. At the industry level the results are not as clear cut. In the US, growth in MFP was a key contributor to LP and output growth.

Further, this trend increased during the 1990s accounting for around two thirds of growth in LP.

The present chapter will now extend the above literature and analyse MFP dynamics in the *EE-industry* and at the same time also undertake a *state by state* comparison of MFP trends within this particular industry.

6.3. DATA

6.3.1. Capital Stock

The following analysis is based on the neoclassical growth. A detailed explanation of the methodological framework has been given in Chapter 2. Provided that output (Y), capital (K) labour (L) and both input share parameters (alpha, beta) are known it is possible to estimate technical change (dlnA) as a residual from equation (2.5). However, here only output and employment data are available. Data on capital stock need to be constructed and the parameters alpha and beta must be estimated. In this section the construction of the capital stock estimates is explained. The next section will describe the estimation of the parameters.

The Bureau of Labour Statistics (BLS) publishes output and employment data by state for the EE industry, where output is value added in 1996 prices. Capital stock for each state is calculated using the perpetual inventory method, which takes into account the continual additions of new

investment to, and subtractions of the capital depreciation from, the existing capital stock.

(6.1) $K_t = (1-\delta)*K_{t-1} + I_t$

where K= capital stock, t = time, I =investment and δ= depreciation ratio

Investment data for the EE industry by state are taken from the Annual Survey of Manufacturers as published by the US Department of Commerce, Bureau of the Census (BEC) (BEC, 1997). Investment data are available only for 1982 - 1996, as after 1996 the BEC changed its industry coding and definition which made the data no longer comparable. According to the BEC, investment is defined as

> "new and used expenditures for (1) permanent and additions and major alterations to MFG establishments and (2) machinery and equipment used for replacement and additions to plant capacity" (BEC, 1997).

To construct the capital stock series with the perpetual inventory method two more pieces of information are necessary. Firstly, the initial capital stock of the starting year 1982 (K_0) must be derived. It can be obtained by multiplying the output of each state in 1982 by a capital output ratio (COR). Here a COR of 1.5 was used. This ratio was calculated for the base year 1982 based on output and capital data published by the BLS

for the EE Industry for the whole US (The data is reported in Table 6.6 at the end of this chapter.

To check for sensitivity of the results with respect to this parameter, a COR of 3 was used, as except for the US with an *aggregate* COR of 1.9 most other countries seem to have a much higher COR; for example Australia (2.87), France (2.93), Germany (2.75), Japan (2.55), Norway (3.43), Switzerland (3.21) (OECD, 1996). While the obtained results do differ considerably (Table 6.1), they all are consistent with the overall conclusion derived in this chapter, that MFP was a key contributor of growth in LP and that growth in MFP accelerated significantly during the last decade.

TABLE 6.1
Sensitivity Analysis with respect to Capital Output Ratio (COR):
US Growth Rates of Labour Productivity (LP),
Capital Intensity (KL) and MFP

COR = 1.5	LP	KL	MFP
1982 - 1996	8.46	0.64	7.82
1982 - 1990	4.21	0.30	3.91
1990 - 1996	13.71	1.28	12.43

COR = 3	LP	KL	MFP
1982 - 1996	8.46	-1.01	9.47
1982 - 1990	4.21	-1.98	6.19
1990 - 1996	13.71	-0.01	13.72

It is necessary to assume that the COR was the same across the States of the USA in the initial year. This clearly was unlikely to be true. However the introduction of new capital (investment) flows over subsequent years reduces the extent of the bias over time. Furthermore, because the

analysis is based on growth rates and not actual levels, inaccuracies in the estimated initial level of capital stock are not likely to cause serious problems. Further, the results also remain robust in the state by state sensitivity analysis as will be discussed in Section 6.6 (Table 6.3).

Secondly, a geometric depreciation process at a rate of 15% is assumed. The number was taken from the Penn World Trade Tables (PWT, mark 5.6). PWT publishes depreciation rates for different countries and different types of capital. The depreciation rate for plant and equipment for the whole USA is 15%. This rate was used here as plant and equipment is closest to the investment definition used here. In the sensitivity analysis in section 6.6 alternative depreciation rates of 25 and 4 were used, but again did not change the results. Four was chosen as it is the rate for construction as provided by the PWT, whereas the rate of 25 was picked as a number higher than the assumed 15.

In summary, from the above calculations, labour and capital stock data for the EE industry for 45 of the States of the US for 1982-1996 have been derived. For six of the states investment data were either not or only partially available and therefore those states were omitted from the analysis. These states are Alaska, Delaware, DC, Hawaii, North Dakota, and Wyoming. Capital estimates are notoriously difficult to construct and the procedures outlined above will be subject to considerable sensitivity analysis, as I will outline below.

6.3.2.   Estimation of the Input Shares

As a last step, both input shares alpha and beta need to be estimated. While it has been standard in the literature to assume constant returns, it is conceivable that this assumption may not hold. Results from previous literature testing for constant returns are mixed.   Hall (1990) demonstrates that macroeconomic data in the USA are inconsistent with constant returns to scale, while Basu and Fernald (1997) report decreasing returns with similar data. Further studies, using plant level data (e.g. Baily, et. al., 1992) find constant returns to more or less hold. These conflicting findings need to be investigated further.

The estimation of both parameters can be done in two different ways. Firstly, under the assumption of perfect competition and profit maximisation firms will hire inputs until the marginal product of each input equals the price of each input (see equation 6.5). Then alpha and beta can be replaced by the income shares of labour and capital. Secondly, alpha and beta can be estimated in an econometric regression estimation.

Most of the earlier studies followed the first approach and estimated the labour and the capital share to be around 0.6 and 0.4, respectively (Solow, 1957, Barro and Sala-i-Martin, 1999, Jones 1997). With the same approach Sato (1970), Seater (2000), and Oliner and Sichel (2000), estimated labour and capital shares for the US and confirmed the above findings. The data used here are taken from the National Income and

Product Accounts as published by the BLS (BLS, NIPA Table 1.6) for the whole USA at the aggregate level. Based on these data an average labour share during 1982 - 1996 (the period used here) was estimated to be 61.3% or approximately 0.6 giving a capital share coefficient of 0.4.

While the data from the NIPA table only provide information at the aggregated level, the second approach allows estimation of alpha and beta for the EE industry in particular. This is done by applying an OLS regression to equation (6.3); in other words, the trend growth rate of output is regressed on a constant and the growth rates of labour as well as capital.

(6.2) without restriction

$$dlnY = 0.08 + 0.59 \, dlnk + 0.71 \, dlnL$$

t-values (13.56)   (4.66)   (3.37) $R^2 = 0.71$

(6.3) with restriction $\alpha + \beta = 1$

$$dlnY = 0.08 + 0.38 \, dlnK + 0.62 \, dlnL$$

t-values (13.30)   (2.87)   (4.75) $R^2 = 0.68$

From the regression statistics it can be seen that in both equations all coefficients are statistically significant at the 5% critical level. In the first equation (6.2), alpha and beta add up to more than one, possibly indicating increasing returns to scale. But as an alternative, if the restriction of $\alpha + \beta = 1$ (equation 6.3) is imposed, we would obtain an estimate of the labour share of around 0.6 and a capital share of around 0.4. Despite this restriction the parameters remain significant, that is both

the null hypotheses that $\alpha = 0$ and that $\beta = 0$ was rejected at the 5% critical value. The restriction of constant returns itself was tested and passed at the 5% significant level, in other words the null hypothesis $\alpha + \beta = 1$ cannot be rejected at F = 3.93, where the critical F-value is 4.08 (with 1;43 DF).

In summary, although there are some indications of slightly increasing returns to scale, the assumption of constant returns could not be rejected either. It is encouraging that the estimates based on this assumption are consistent with the results of the first approach based on the NIPA tables. A sensitivity analysis was conducted using capital shares of 0.3 as well as 0.6. The results of this analysis are reported in Table 6.2. The variations in the estimates are very small and do not alter the overall conclusion. In particular, the analysis focuses on growth rates rather than levels. The following analysis will proceed with a labour share of 0.6 and a capital share of 0.4.

TABLE 6.2

Sensitivity Analysis with respect to Alpha and Beta Coefficients:
US Growth Rates of Labour Productivity (LP),
Capital Intensity (KL) and MFP

α = 0.4 β = 0.6			
Year	LP	KL	MFP
1982 - 1996	8.46	0.64	7.82
1982 - 1990	4.21	0.30	3.91
1990 - 1996	13.71	1.28	12.43

α = 0.3 β = 0.7			
Year	LP	KL	MFP
1982 - 1996	8.46	0.48	7.98
1982 - 1990	4.21	0.03	4.18
1990 - 1996	13.71	0.97	12.74

α = 0.6 β = 0.4			
Year	LP	KL	MFP
1982 - 1996	8.46	0.80	7.66
1982 - 1990	4.21	-0.12	4.33
1990 - 1996	13.71	1.93	11.78

In summary, the parameters alpha and beta were estimated with two different approaches. With both methods the labour share was estimated to be around 0.6 while the capital share was estimated to be around 0.4, and the end results remained robust with respect to variations in the values used.

After extensive testing of the results for sensitivity, the preferred model is based on a COR of 1.5 and a depreciation ratio of 15%. The capital and labour share coefficients alpha and beta are assumed to be 0.4 and 0.6, respectively.

6.4. PRODUCTIVITY DYNAMICS

With the constructed data on hand, the present section will now analyse the productivity dynamics in the EE industry among the states of the US during 1982-1996. Findings in Chapter Four indicated a quite remarkable increase in the trend growth rates of labour productivity in this particular industry. However, labour productivity can change because of several factors. In a first step, LP in the EE industry will be decomposed into its main components to analyse their importance and dynamics over time. In a second step, a convergence analysis will be applied to study the trends and distribution dynamics of productivity growth in the EE industry across the States of the USA.

6.4.1. Decomposition of LP

By transforming Equation 6.2, one can identify the sources of growth labour productivity growth (dlny). With constant returns to scale, equation 6.2 can be written as

$$(6.4) \quad dlnY = dlnA + \alpha \, dlnK + (1-\alpha) \, dlnL$$

$$(6.5) \quad dlnY = dlnA + \alpha \, dlnK + dlnL - \alpha \, dlnL$$

equation 6.5 can be expressed as 'per labour' by subtracting dlnL

(6.6)   dlny = dlnA + α dlnk

where dlny = dlnY - dlnL and dlnk = dlnK - dlnL

Growth in labour productivity (dlny) depends on growth in technical change (dlnA) and capital deepening, expressed as the rate of change in capital per worker (dlnk).

Estimating equation (6.11) will help in answering three questions. Firstly, has the growth in labour productivity in the EE industry been due to an increase in the capital intensity or is it the result of stronger growth in technology? Secondly, how has each component evolved over time? Finally, has the observed growth pattern been even across the States of the USA?

The first main finding is that for the USA as a whole the contribution of MFP growth to labour productivity in the EE industry was much larger than the impact of an increase in the capital intensity. For example, with a COR of 1.5 and a depreciation rate of 15% LP for the USA as a whole the EE industry grew at a rate of around 8.5% during 1982-1996. This is primarily due to an increase in MFP of 7.82%, while capital intensity experienced a trend growth rate of only 0.64%. It appears that MFP had a major impact on LP growth. These findings are also consistent with the work by Oliner and Sichel (2000) as discussed in section 6.2. The time span was further divided into two sub-periods, 1982 - 1991 and 1991 -

1996 to analyse the most recent trends. The results reveal a second important finding that MFP growth was not constant over time, but increased during the 1990s, reaching rates of over 10%.

MFP growth rates of over 10% are quite remarkable. The validity of the findings was further compared with alternative results. Independent MFP estimates based on data from the BLS (BLS, 2000) are also quite high. The BLS uses value of shipment rather than value added data as the output variable. Capital is derived from capital services and not capital stock and the BLS uses hours worked rather than employment and includes other intermediate inputs such as energy, materials and purchased services. Despite those differences, growth rates from the BLS data revealed a similar picture to the findings in this study. Trend growth in MFP was much lower during the 1980s but started to increase considerably during the 1990s. It should be noted that the trend growth rates of MFP of this study seem to overestimate the trend growth during the 1990s relative to the findings of the BLS. For instance MFP trend growth between 1991-1996 is 7.10% according to the BLS measure, while the estimates reported here are 12.43%. These deviations can partially be explained by the fact that the BLS also takes intermediate inputs such as energy, non-energy materials and purchased services into account.[2] All of these intermediate inputs experienced high growth rates

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[2] Energy input is constructed using data on price and quantity of fuels purchased for use as heat or power; materials include all commodity inputs exclusive of fuels but of inclusive fuel-type inputs used as raw material in manufacturing; purchased services are Business services purchased by manufacturing industries from service industries. (BLS Handbook of Methods, 1997)

during the 1990s. As MFP is calculated as a residual (equation 6.3), the subtraction of the intermediates is likely to result in lower rates for MFP relative to the estimates found here. In any case, the important point is both data sets indicate that firstly, MFP growth played a more important role than an increase in capital intensity in determining LP growth during the 1990s. Secondly, trend growth of MFP accelerated considerably during the 1990s.

6.4.2.   Cross-Section Analysis of MFP

In addition to the above findings, the data also allow us to analyse variations of MFP trends across states. Overall, the pattern for each individual state is similar to the trends at the aggregated level that is the majority of states report significantly higher MFP trend growth rates during the 1990s than during the 1980s. However, MFP growth trends are not even across the state but vary. Over the whole period states such as Idaho, New Mexico, Oregon, Pennsylvania and Vermont report MFP trend growth rates of over 10%. During the 1990s this number increased to a total of 15 states. MFP growth rates for the remaining states averaged around only 4 %. Further, the standard variation of MFP growth, measuring the disparities across the states, increased from four percentage points during the 1980s to 6 percentage points during the 1990s.

States with outperforming MFP growth rates are by and large clustered in the South West of the USA such as Arizona, California, New Mexico, Oregon and Texas, but there appears to be another cluster in the North East such as Massachusetts, New Hampshire, or New York. The above indicates that all states experienced increased trend growth rates in MFP growth and that the increase was not even across the states. Some states appear to have benefited more from MFP or technological advance than others.

In summary, construction of capital stock is notoriously difficult, but the estimates passed an extensive sensitivity analysis. Firstly, the recent surge in labour productivity growth in the EE industry appears to be driven largely by technological advances. Secondly and consistent with earlier studies, growth in MFP was not constant over time, but accelerated significantly during the 1990s. Thirdly, MFP growth is not equal across the states, but some states appear to have benefited more from technological change than others. In particular, states reporting some of the highest MFP trend growth rates during the 1990s seem to be located in the South West and some also in the North East of the USA.

Although the estimated residual combines many possible influencing factors, technological change is one of its main contributors. The results may then suggest that technological advance has played a significant role in the growth of labour productivity in the EE industry. In addition, states

which appear to have benefited most from this surge, seem to be grouped in the South-West and also the North-East of the USA.

6.5.   CONVERGENCE ANALYSIS

The above analysis offers important insights into the trends of productivity growth over time and across states in the EE industry.   However, the behaviour of trend growth rates says little about the distribution dynamics of the entire cross - section. In other words, the question remains how the states perform relative to each other. Do they become more or less similar? Do states with relatively low initial MFP levels manage to catch-up to technologically more advanced states? To answer these questions a convergence analysis as discussed in Chapter 3 will be applied in the present section.

6.5.1.   Beta and Sigma Convergence

In a first step, the concept of beta convergence will be applied. The regression results are reported in Table 6.3.

TABLE 6.3
Beta - Convergence of MFP
US Electronic and Electrical Equipment Industry; 1982-1996

MFP	β - Coefficient	t-value		R^2
1982-1996	-1.78	-5.86	*	0.44
1982-1991	-0.52	-1.00	*	0.02
1991-1996	-2.20	-4.18	*	0.29

* significant at the 5% level

While beta convergence is not statistically significant during the 1980s, there is clear catch - up behaviour during the 1990s. Overall, as can be seen from Figure 6.1 Panel B, the trend line slopes downwards, illustrating a negative relationship between the initial value and subsequent trend growth rate of MFP. Although the time span is relatively short for both sub-periods, which may limit the reliability of the results, degrees of freedom from the cross-section are still quite large with 46. States with initially low levels of MFP appear to catch - up with the technological leaders.

The results for sigma convergence are summarised in Table6.4.

TABLE 6.4
Sigma - Convergence of MFP
US Electronic Equipment Industry; 1982-1996

MFP	σ -Coefficient	t-value		R^2
1982-1996	1.90	13.19	*	0.93
1982-1991	1.58	4.86	*	0.77
1991-1996	2.12	4.21	*	0.78

* significant at 5%

From Table 6.4 it can be seen that there is clear sigma divergence (positive and statistically significant σ- coefficient) during all three periods. This is also visible from the upwards sloping trend line in Figure 6.1 Panel C. In other words, although there is catch - up of the technologically backward oriented states, the dispersion of MFP between the states is increasing over time. As illustrated in Chapter Three, one way of explaining the fact that beta convergence and sigma divergence can occur at the same time, is the cross-over case scenario.

FIGURE 6.1: ELECTRICAL EQUIPMENT INDUSTRY

Panel A: MFP in logs
Electonic and Electrical Equipment Industry

Panel B: Beta-Convergence
Electronic and Electrical Equipment Industry

Panel C: Sigma Convergence
Electronic and Electrical Equipment Industry
US States 1982-1996
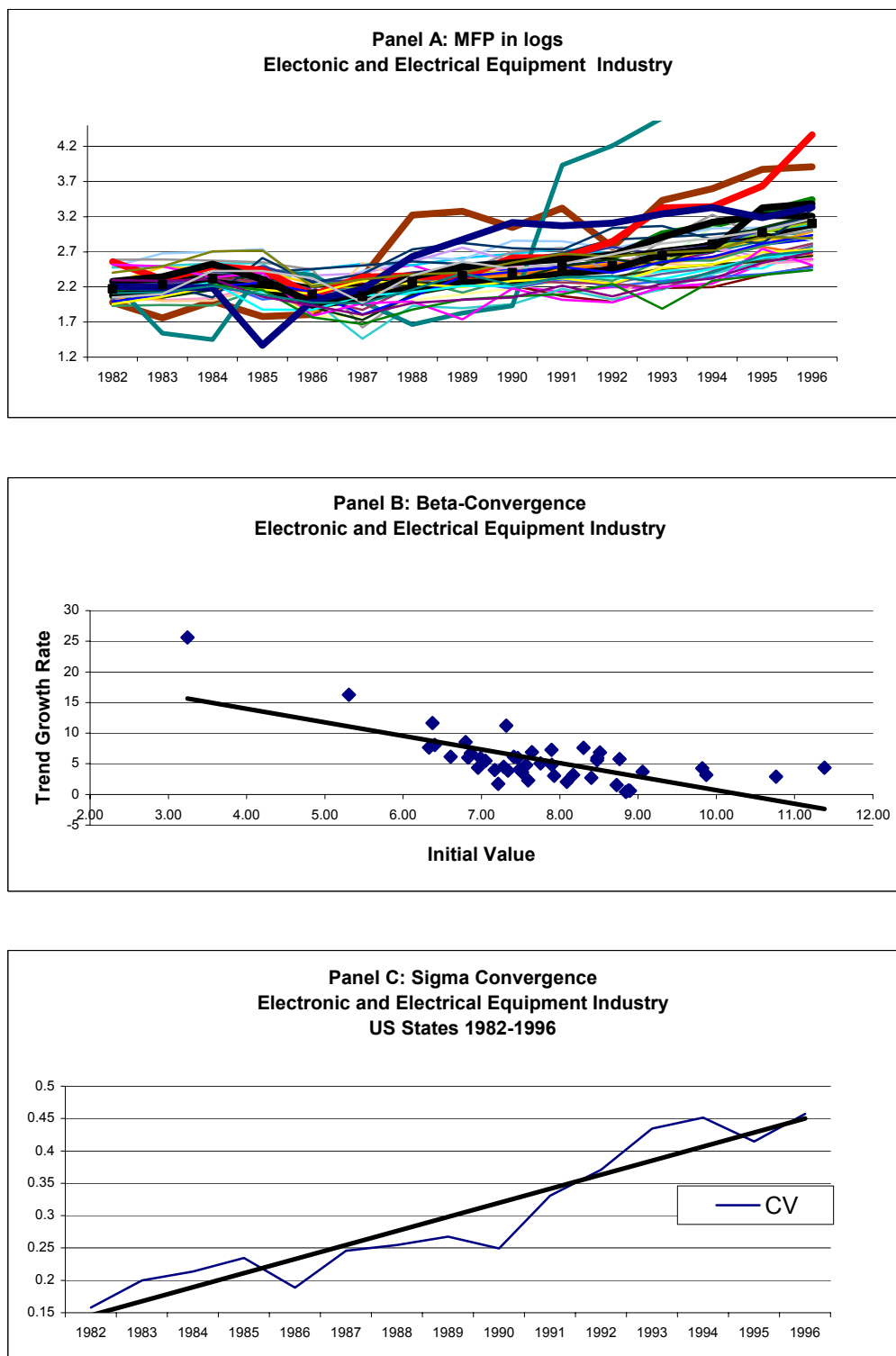
The results of beta and sigma convergence were tested in a sensitivity analysis (Table 6.5). No matter what COR rate and depreciation rate was applied, there is clear evidence of beta convergence together with sigma divergence.

TABLE 6.5

Sensitivity Analysis with respect to Beta and Sigma Convergence;
EE-industry; US states: 1982-1996

	β	t-value	R^2	σ	t-value	R^2
COR = 1.5; δ = 4	-2.03	-6.37 *	0.49	2.09	11.28*	0.91
COR = 1.5; δ = 15	-1.78	-5.86 *	0.44	1.90	13.19*	0.93
COR = 1.5; δ = 25	-1.24	-6.13 *	0.47	1.29	4.58 *	0.62
COR = 3; δ = 4	-2.69	-6.68 *	0.51	2.14	9.12 *	0.86
COR = 3; δ = 15	-2.33	-6.76 *	0.52	1.30	4.20 *	0.58
COR = 3; δ = 25	-3.13	-7.69 *	0.58	2.55	5.51 *	0.71

* significant at the 5% level

The analysis of the trend growth rates already indicated that growth rates of MFP vary not only *over time*, but more importantly also *across states*, with a group of states in the North-East and South West reporting above average growth rates. In addition, from Panel A it can be seen that there is a number of states which started out with relatively low MFP levels but manage to grow more rapidly than the national average. They continued to surge ahead to become the new technological leaders causing a widening in the dispersion during the 1990s. Formally, these cross-over states were identified by using the national MFP level as a benchmark by normalising it to 100.

Cross-over states can then be identified as states starting off with levels below 100 and ending with levels above 100. These states are in the North East of the USA, with Massachusetts crossing over in 1986, Vermont (1987), Connecticut (1991), New Hampshire (1991), Pennsylvania (1992) but also in the South West with Idaho crossing over in 1987, Nevada (1990), New Mexico (1991), Arizona (1992) and Oregon (1992). Those states appear to have benefited more from technological advances than the remaining states

6.6. CONCLUSION

The findings in Chapter Four and Five indicated that the convergence trends in LP appear to have ceased. This appears to be by and large due to turbulences in the Durable Industry, a sub-sector of Manufacturing, and in particular in the Electronic and Electrical Equipment Industry. However LP can grow as a result of a number of factors - such as technological progress - and there arises the need to also investigate the key factors contributing to this cessation in convergence in LP.

Some of the earlier studies have analysed MFP trends, but only at the aggregate level due to limited data availability. By contrast, in this chapter capital stock data for the EE-industry for each individual state was constructed. While capital stock estimates are notoriously difficult to derive the estimates are the best available based on the given data and the robustness of the results was checked in several sensitivity analyses.

There are three main findings arising out of the analysis. Firstly, and consistent with earlier studies, MFP appears to be the main contributor to LP growth and its growth accelerated significantly during the 1990s. Secondly, and more importantly, the inter - state analysis revealed that growth of MFP is not equal across the US states, but some states appear to have benefited more from technological progress than the others. There emerges a belt of states in the South - West and one in the North - East with above average growth performance. Thirdly, those states did not only manage to catch - up with technologically more advanced ones, but continued to surge further ahead resulting in a widening of the dispersion of MFP during the mid to late 1990s.

The findings suggest that we are witnessing a period of particularly rapid changes in the high technology area. Some South Western and North Eastern states may have gained more from this "New Economy" phenomenon, thereby accounting for much of the divergence trend. Nevertheless, the whole situation is a broad and complex question and this study can only highlight some of the more important elements. Further research will be required to fully explain the observed pattern and predict whether it will continue in future years.

Table 6.6 Capital Stock Data US States 1982-1996

YEAR	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Alabama	880	821	771	730	685	641	717	794	796	801	810	800	806	835	876
Arizona	1204	1323	1457	1557	1659	1670	1743	1851	1895	1874	1894	1961	2290	3387	4856
Arkansas	784	729	695	686	646	613	575	536	509	501	503	471	463	486	485
California	15009	14412	14775	15105	14779	14113	13672	13180	13049	12588	12292	12182	12326	13615	15629
Colorado	672	676	708	744	778	743	702	711	754	723	716	882	1128	1285	1390
Connecticut	2304	2106	1998	1961	1851	1676	1502	1359	1227	1109	1040	977	955	1404	1340
Florida	2380	2379	2546	2606	2528	2382	2310	2239	2211	2217	2174	2168	2222	2344	2629
Georgia	824	772	776	771	786	821	834	826	845	831	843	835	862	908	985
Idaho	85	72	62	52	45	38	32	27	23	20	112	344	763	1664	2683
Illinois	4870	4446	4230	4029	3740	3549	3497	3594	3639	3539	3505	3545	3456	3711	3967
Indiana	3355	3133	3064	3091	3161	3020	2781	2683	2560	2387	2293	2237	2176	2074	2003
Iowa	1436	1272	1167	1101	1030	955	899	837	789	766	731	709	692	715	740
Kansas	315	295	277	260	270	254	250	243	227	214	206	224	291	337	379
Kentucky	1143	1051	979	912	895	858	836	798	756	749	749	724	696	769	805
Louisiana	374	361	373	389	393	378	351	332	351	313	288	260	233	221	204
Maine	245	267	290	308	303	305	346	388	356	334	316	315	346	368	444
Maryland	2224	2081	2002	1912	1803	1577	1391	1233	1100	972	868	779	719	660	622
Massachusetts	4235	3997	3902	3908	3531	3416	3248	3084	2940	2835	2797	2690	2635	2684	2843
Michigan	1382	1301	1220	1163	1091	994	923	847	781	748	715	709	726	749	749
Minnesota	871	839	881	878	844	813	805	800	809	840	890	930	972	1048	1103
Mississippi	615	574	541	514	489	465	456	449	435	427	419	426	475	481	527
Missouri	1473	1372	1445	1496	1398	1278	1189	1117	1098	1094	1081	1053	1012	1061	1226

Table 6.6 continued

YEAR	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Montana	4	4	7	6	5	5	4	4	3	3	4	3	3	15	20
Nebraska	321	293	271	258	241	244	238	237	229	222	216	219	230	238	243
Nevada	75	64	58	54	50	42	36	31	26	22	22	24	27	28	32
New Hampshire	710	649	654	653	628	574	541	505	466	442	444	419	407	421	452
New Jersey	3910	3559	3348	3148	2974	2680	2422	2186	2005	1835	1689	1522	1431	1341	1250
New Mexico	207	181	197	223	237	258	321	364	440	536	622	703	773	840	902
New York	6203	6034	6067	6190	6243	5875	5806	5921	5891	5742	5632	5263	4934	4647	4407
North Carolina	2210	2254	2361	2568	2528	2351	2317	2295	2350	2199	2165	2154	2181	2208	2270
Ohio	4206	3819	3566	3419	3290	3155	3025	2898	2799	2662	2568	2517	2517	2665	2827
Oklahoma	427	447	458	448	431	413	415	409	389	397	379	390	398	401	394
Oregon	777	738	671	627	596	607	634	656	718	740	844	1123	1300	1967	3029
Pennsylvania	3894	3819	3766	3746	3536	3292	3122	3030	2985	2873	2879	2850	2705	2733	2928
Rhode Island	312	316	294	283	274	254	232	214	194	186	178	170	182	190	189
South Carolina	625	648	651	681	662	683	685	674	681	666	698	733	763	861	958
South Dakota	182	155	136	121	108	91	78	66	56	48	50	53	58	60	60
Tennessee	1443	1310	1255	1215	1165	1119	1083	1068	1041	1050	1065	1070	1080	1120	1143
Texas	4803	4644	4779	4888	4890	4663	4595	4820	5060	5071	5158	5740	7456	9140	10936
Utah	330	320	351	369	374	352	351	337	321	291	268	241	231	243	272
Vermont	536	455	387	329	280	238	202	172	146	124	105	104	89	75	64
Virginia	2135	1976	2025	2031	2010	1804	1615	1452	1340	1225	1154	1111	1085	1079	1360
Washington	526	541	569	575	566	516	477	459	490	524	515	526	614	693	829
West Virginia	129	118	111	98	91	78	66	56	48	41	38	37	36	39	49
Wisconsin	1651	1510	1451	1410	1345	1261	1175	1142	1152	1143	1145	1147	1160	1246	1281

CHAPTER SEVEN

SUMMARY, POLICY IMPLICATIONS and FUTURE RESEARCH

This study analyses economic and productivity dynamics among the states of Australia and the USA and sets out to address the following specific questions:

1. Has the convergence trend observed for the Australian and US States during the 20th century continued or reversed into a diverging pattern?

2. Can the causes of any observed patterns be traced back to particular state(s), industr(ies), or periods of time?

3. Is the observed pattern the same for the variables used – income per capita, labour productivity and multi factor productivity – or is there convergence in one but divergence in the other?

4. Do the findings depend on the methodology applied? Or is the analysis robust with respect to whether cross-section or time-series techniques are applied?

For Australia (Chapter Three) three major results were found. To answer the first question, the convergence trend among the states of Australia has slowed down and there is even evidence of divergence during recent years in GSP per capita and LP. The analysis of the second question revealed that this increase in dispersion was due to a Mining boom in Western Australia allowing the state to grow faster than the national

average. Once the Mining Industry was excluded the levels of GSP per capita and LP in the various states of Australia were found to have neither converged nor diverged.

The results for the US can be summarised as follows. The analysis of question (1) indicates that the convergence trend among the US States observed prior to the 1990s has not only slowed down but reversed into divergence. The answer to question (2) is that the divergence in LP started during the 1980s in the service industries and was followed by the Manufacturing Industry (and here in particular in the Electronic and Electrical Equipment Industry) during the 1990s. Further, there appears to be a belt of states in the West and a few states in the North-East which report above average growth rates in LP. Those states do not only catch-up but surge further ahead resulting in a widening in the dispersion in labour productivity. This divergence pattern is also evident for multi factor productivity. Last but not least, addressing the fourth question, the results remain robust whether cross-section or time-series techniques are applied.

While the previously observed convergence trend in Australia came to a halt, there is evidence of divergence across the US States. It is not unreasonable to surmise that the developments in LP in the US economy might be duplicated in Australia, although with a lag. In other words, one might expect that the current insignificance of convergence trends in Australia may soon turn into a clearly diverging trend. However, it is too

early to tell one way or the other. The question bears monitoring in the years ahead.

What do the findings imply for policy makers especially those in the non-leading states? What policies would they need to develop to allow their states to catch-up again? In general, the productivity agenda for all states is about developing policies which will lead to an increase in the rate of productivity growth. This can be brought about in several ways. Firstly, the above analysis indicates that policies need to promote an industry structure that is conducive to higher growth rates. Authorities should consider encouraging industries with higher growth rates, such as the Information and Communication Technology (ICT) industries.

Secondly, policies need to take into account demographic issues. As the analysis of the Australian states highlighted, to increase output per person states need to attract not necessarily more people, but more importantly more employable persons, who in turn can contribute to production and consequently a rise in living standards for all residents. Thirdly, to increase labour productivity states need to enhance the efficiency and productivity of the labour force. One way of achieving this is through investment in human capital and the provision of training and education opportunities to improve existing skills and promote the acquisition of new ones. In addition, policies fostering better utilisation of labour and creating incentives for employer and employees to become

more productive will also have a positive impact on labour productivity growth.

Fourthly and most importantly, the study of the US States highlighted the importance of innovation through technological progress for productivity improvements. Innovation enhances productivity through new products which create more value from given inputs and through new technologies, which make people more productive. Policies need to create an environment in which productivity enhancing innovation can be sustained. States need to engage in research and development activities to ensure the invention and adoption of new technologies.

Future research will be necessary to monitor the observed trends in productivity. For Australia further analysis will be needed with respect to trends of multifactor productivity. Therefore capital stock data, for each state and for the individual industries, needs to be constructed. For both Australia and the USA the analysis should delve deeper into the growth dynamics of the service industries. Such an analysis will need to address the question of how best to measure output in these industries. Last but not least, the role of human capital, research and development and other variables highlighted by endogenous growth theories should be incorporated into the analysis. The issues raised here are broad and complex and this study can only cover some of the main aspects, while acknowledging that further research needs to be done to fully address the remaining questions.

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