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

Gudrun Meyer-Boehm
School of Economics, Griffith University, Nathan, Qld 4111, Australia.

ABSTRACT: This paper analyses multifactor productivity (MFP) dynamics within the Electronic and Electrical Equipment Industry across the States of the USA between 1982-1996. Studies on productivity growth trends have generally found that the discrepancies among the economies at the aggregate level, declined during the 1970s and 80s, yet results are not so clear cut at the industry level. The findings here reveal that MFP growth varies considerably across the States of the USA. States with above average growth rates in MFP appear to form a belt in the south-west of the country. Some of the outperforming states not only managed to catch up with high productivity states, but actually surged ahead, resulting in an increased dispersion of MFP. However, it is too early to predict whether the observed diverging trend will continue in the future.

1. INTRODUCTION

Studies on productivity growth 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). A convergence analysis investigates how economies develop relative to each other, that is whether they become more or less evenly distributed. While most of the existing contributions in the literature study labour productivity (LP) some authors also investigate trends in multifactor productivity (MFP). For example Dowrick and Nguyen (1989) find convergence in MFP across the OECD *countries*. Studies by Dollar and Wolff (1993) or Bernard and Jones (1996), 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 study will extend the above literature by focusing on the recent MFP trends but in a *state by state* (US states) analysis and within a specific *industry*, namely the Electronic and Electrical Equipment (EE) industry.

The aim of the paper 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 paper is structured as follows. The next section will give a brief review of existing studies on MFP growth. Sections 3 and 4 will discuss the theoretical framework and data used in the analysis while Sections 5 and 6 report the findings of the analysis of productivity dynamics and convergence patterns. Some concluding remarks are given in Section 7.

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.

Bernard and Jones (1996) 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 (1996) 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 although the countries of the EU become more similar in terms of LP, 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, North-South disparities continued to widen as countries in the South fell behind by utilising far less productive technology than the North.

Jorgenson and Stiroh (2000), Oliner and Sichel (2000) and Gordon (2000) take a slightly different view and investigate the contributions of MFP to growth in LP in for the US. Jorgenson and Stiroh and Oliner and Sichel 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% is sourced from 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 in particular that is responsible for most of the acceleration in the capital contribution.

Similarly Bosworth and Triplett (2000) investigate the link between MFP growth and the use of IT capital. They argue “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. This study 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.

3. THEORETICAL FRAMEWORK - GROWTH ACCOUNTING

A commonly applied framework in analysing economic growth is the Solow and Swan neo - classical growth model (Solow, 1957; Swan, 1956). The basic Solow growth model is based on a production function of the Cobb-Douglas type. This function provides the link between output (Y), capital (K), labour (L) and some multiplicative factor (A)

$$Y = A\,K^{\alpha}\,L^{\beta} \tag{1}$$

where alpha and beta are a number between zero and one. Under the assumption of constant returns to scale, both add up to one ($\alpha + \beta = 1$).

Solow (1957) interprets the factor (A) as a shift factor, which *"measures 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. Further, the technological progress factor (A) is assumed to be exogenous.

Rewriting (1) in growth rates results in

$$dlnY = dlnA + \alpha\ dlnK + \beta\ dlnL \tag{2}$$

where d = first difference with respect to time, ln = natural log, and solving for technical change (A) gives

$$dlnA = dlnY - \alpha\ dlnK - \beta\ dlnL \tag{3}$$

Technical change (dlnA) is here written as a residual. In other words, it contains the effects of all factors, which are not captured by capital or labour.

Consider the standard profit maximisation problem

max $Y = F(A,K,L)$
s.t.: $Y = rK + wL$

The first-order conditions from this are the familiar equations

$$(\delta Y/\delta K) = \alpha\ (Y/K) = r; \quad (\delta Y/\delta L) = \beta\ (Y/L) = w \tag{4}$$

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.

$$\alpha = r * (K/Y) \quad \beta = w * (L/Y) \tag{5}$$

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

While, the residual (A) is commonly interpreted as growth in MFP (Jones, 1997), in reality it incorporates the effects of all other factors that may determine output growth other than capital or labour changes. 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. But it could also arise from increases in another factor of production (eg. human capital) which is not yet captured in the model. Finally, it could reflect statistical errors, which arise in the estimation process. For all these reasons, the interpretation of changes in (A) over time as MFP growth need to be interpreted with care.

The neo - classical framework has been a benchmark in the growth literature, due to its simplicity and intuitions, but because of some shortcomings has not been entirely satisfactory. In particular, it failed to offer a persuasive explanation of the productivity slowdown during the 1970s and 1980s. Secondly, because of the assumption of diminishing returns to scale, it can only give an explanation of a temporary increase in per capita growth rather than a long term increase. That is, once countries have reached their steady state, where the marginal product of capital becomes zero, economic growth will not continue without technical progress. In particular, the last shortcoming induced a number of researchers to develop a range of models known as endogenous growth models. Yet these are not without limitations either. Most of these models include inputs such as human capital or are based on spill over effects arising from R&D activities (Romer, 1986; Lucas, 1988; Arrow, 1962). It is however difficult to find good proxies and measurements for those variables.

While both frameworks - exogenous and endogenous models - focus on different aspects, they *both contribute* to the understanding of the growth process. This study will proceed along the lines of the neo-classical growth model, while acknowledging that findings should be extended in future research.

4. DATA

4.1 Capital Stock

Provided that output (Y), capital (K) labour (L) and both input share parameters (α, β) are known, it is possible to calculate multifactor productivity (A) as a residual from Equation (3). However, generally only output and employment data are available, and capital stock data as well as the parameters alpha and beta must be estimated. In this subsection 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.

$$K_t = (1-\delta)*K_{t-1} + I_t \tag{6}$$

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

Investment data for the EE industry by state is taken from the Annual Survey of Manufacturers (ASM) as published by the Bureau of Economic Census (BEC, 1997). Investment data is 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, Economic Census 1997, Appendix A3)

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.

To check for sensitivity of the results with respect to this parameter, a COR of 3 was used, as according to the OECD most other countries seem to have a much higher aggregate 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 (Table 1), the differences do not affect the overall conclusion derived in this study; i.e. that MFP was the key contributor of growth in LP and that growth in MFP accelerated significantly during the last decade.

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 (Table 3).

Further, 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 alternative depreciation rates of 25% and 4% were used, but again did not change the results. Four percent was chosen as it is the rate for construction as provided by the PWT, whereas 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.

Table 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

For six states, investment data was 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 explained above will be subject to considerable sensitivity analysis, as outlined below.

4.2 Estimation of the Input Shares Alpha and Beta

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 to scale, it is conceivable that this assumption may not hold. Results from previous literature testing for constant returns are mixed. Hall (1990) demonstrated 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 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 in a country analysis (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 this 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 provides 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 (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.

without constant returns to scale

$$dlnY = = 0.08 + 0.59 \, dlnK + 0.71 \, dlnL \tag{7}$$

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

with constant returns to scale ($\alpha + \beta = 1$)

$$dlnY = 0.08 + 0.38 \, dlnK + 0.62 \, dlnL \tag{8}$$

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 Equation (7), alpha and beta add up to more than one, possibly indicating increasing returns to scale. But an alternative test, testing the null hypothesis that $\alpha = 0.4$ and/or $\beta = 0.6$, could not be rejected at the 1% significant level with a t-value of 2.39 ($t_{crit} = 2.42$). Imposing the restriction of $\alpha + \beta = 1$ (Equation 8), resulted in the expected value of a labour share of around 0.6 and a capital share of around 0.4. Despite this restriction the parameters remain significant 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 2. The variations in the estimates are very small and do not alter the overall conclusion. In addition, 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.

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.

Table 2. Sensitivity Analysis with respect to Alpha and Beta Coefficients: US Growth Rates of Labour Productivity (LP), Capital Intensity (KL) and MFP.

$\alpha = 0.4$ $\beta = 0.6$

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

$\alpha = 0.3$ $\beta = 0.7$

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

$\alpha = 0.6$ $\beta = 0.4$

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

5. 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 USA during 1982-1996. In the 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.

5.1 Decomposition of Labour Productivity

By transforming Equation (2), one can identify the sources of labour productivity (dlny). With constant returns to scale, Equation 2 can be written as

$$dlnY = dlnA + \alpha\, dlnK + (1-\alpha)\, dlnL \tag{9}$$

$$dlnY = dlnA + \alpha\, dlnK + dlnL - \alpha\, dlnL \tag{10}$$

Equation (10) can be expressed as 'per labour' by subtracting dlnL

$$dlny = dlnA + \alpha\, dlnk \tag{11}$$

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 (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 in 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% (Table 2). 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 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 and reveal 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 (BLS, 1997). All of these intermediate inputs experienced high growth rates during the 1990s. As MFP is calculated as a residual (Equation 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.

5.2 Cross - State Analysis of MFP

In addition to the above findings, the data also allows 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 grouped in the south-west of the USA such as Arizona, California, New Mexico, Oregon and Texas, a few also in the north-east such as Massachusetts, New Hampshire, or New York. The above indicates that all states experienced accelerated 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. 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 will be applied in the present section.

The literature on convergence distinguishes between two aspects of convergence, namely beta and sigma convergence (Sala-i-Martin, 1996). On the one hand, beta convergence is said to hold among a set of cross-section economies, when there is a negative relationship between the initial level of productivity (here MFP) and the rate of growth in MFP during the ensuing period. If beta convergence is evident, technological backward states will tend to grow more rapidly, enabling them to catch - up with technological leaders. On the other hand, sigma convergence exists when the cross sectional dispersion of productivity levels decline over time. If sigma convergence holds, then the disparities in productivity across the relevant economies will tend to diminish.

Table 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 both concepts are related, they are not identical. Sala-i-Martin (1996) showed that beta convergence is a necessary but not sufficient condition for sigma convergence to hold. For example relatively poorer economies may manage to catch - up with richer ones (beta convergence), but the dispersion in productivity could still increase (sigma-divergence), eg. cross-over scenario.

6.1 Beta Convergence

In a first step, it will be investigated whether the catch - up hypothesis for MFP holds in the EE industry across the US States. Beta convergence can be tested by regressing the trend growth rate of MFP ($mfp_{i,t}$) on a constant (α) and the initial value of $MFP_{i,0}$.

$$mfp_{i,t} = \alpha + \beta\, MFP_{i,0} \quad (12)$$

with i = state, t = time where a negative and statistically significant beta coefficient is taken as evidence for beta convergence to hold.

The regression results are reported in Table 3.

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 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.

6.2 Sigma Convergence

Sigma convergence looks into how the states develop relative to each other. There is evidence of sigma convergence if the coefficient of variation (CV), a measure of dispersion, of MFP declines over time.

where γ = constant; T= time trend; CV = coefficient of variation (=standard

$$CV_{MFP} = \gamma + \sigma\, T \quad (13)$$

deviation divided by the mean)

From Table 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 1 Panel C. In other words,

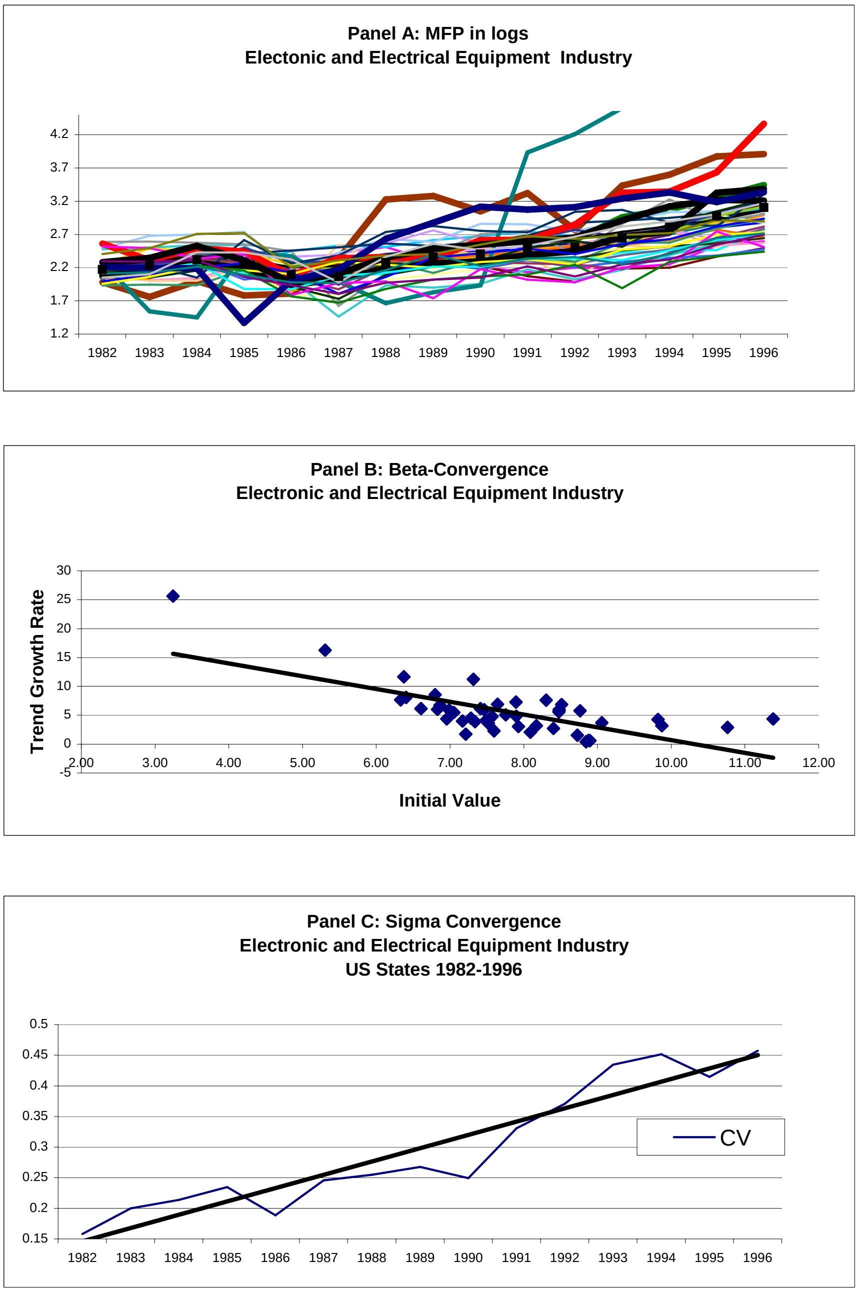

Figure 1. Electrical Equipment Industry.

Table 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%.

level although there is catch - up of the technologically backward oriented states, the dispersion of MFP between the states is increasing over time. One way of explaining the fact that beta convergence together with sigma divergence can occur at the same time, is through the cross-over case scenario. If initially low productivity states catch up with high productivity states due to relatively higher growth rates, the dispersion will decline over time resulting in beta and sigma convergence. If those states however continue to surge ahead and 'cross-over' high productivity states, the dispersion will start to increase again. In a last step it is therefore necessary to identify potential cross-over states.

The results of beta and sigma convergence were tested in a sensitivity analysis based on various combinations of different COR (1.5, 3) and depreciation rates (4, 15, 25). No matter what COR rate and depreciation rate was applied, there is clear evidence of beta convergence together with sigma divergence.

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.

7. CONCLUSION

Some of the earlier studies have analysed MFP trends, but due to limited data availability, only at the aggregate level. By contrast, in this study MFP trends are analysed in *Electronic and Electrical Equipment industry* based on constructed capital stock estimates for each *individual state.* 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.

REFERENCES

Baily, M., Hulten, C. and Campbell, D. (1992) Productivity Dynamics in Manufacturing Plants. *Brookings Papers Economic Activity: Microeconomics*, pp. 197-249.

Barro, R.J. and Sala-i-Martin X. (1991) Convergence across states and regions. *Brooking Papers on Economic Activity*, 1, pp. 107-158.

Barro, R.J. and Sala-i-Martin X., (1999) *Economic Growth*. MIT Press: Cambridge, MA.

Basu, S. and Fernald, J.G. (1997) Returns to scale in US production: Estimates and implications. *Journal of Political Economy*, 105(2), pp. 249-283.

Bernard A. and Jones C.I. (1996) Comparing apples to oranges: Productivity convergence and measurements across industries and countries. *The American Economic Review,* 86(5) pp. 1216-1238.

Bosworth, B.P. and Triplett J.E. (2000) *What’s New about the New Economy? IT, Economic Growth and Productivity.* Conference Paper Brookings Institute.

Bureau of Economic Census, (BEC) (1997) *Manufacturing*. Geographic Area Series, EC97M31A.

Bureau of Labour Statistics (BLS) (2000) *Productivity and Costs*. Third Quarter 2 November. USDL 00-319.

Bureau of Labour Statistics (BLS) (1997) *Handbook of Methods*. Bulletin 2490.

Dollar, D. and Wolf, E.N. (1993). *Competitiveness, Convergence, and International Spezialisation.* MIT Press: Cambridge.

Dowrick, S. and Nguyen D.T. (1989) OECD comparative economic growth 1950-85: Catch-up and convergence. *American Economic Review*, 79(5), pp. 1010-1030.

Gordon, R.J. (2000) Does the "new economy" measure up to the great inventions of the past? *Journal of Economic Perspectives*, 14(4), pp. 49-74.

Hall, R.E. (1990) Invariance properties of Solow's productivity residual. In P. Diamond (ed), *Growth, Productivity, Unemployment: Essays to Celebrate Bob Solow's Birthday*. MIT Press: Cambridge.

Jones, C.I. (1997) *Introduction to Economic Growth.* W.W. Norton: New York.

Jorgenson, D. and. Stiroh K.J. (2000) Raising the speed limits: US economic growth in the information age. *Brookings Papers on Economic Activity 1*, pp. 125-211.

Melachroinos, K.A. and Spence, N. (2001) Manufacturing productivity growth across European Union states: 1978-1994. *Environment and Planning*, 33(9), pp. 1681-1703.

OECD (1996) *Capital Output Ratio*. *Business Sector*.

Oliner S. and Sichel D. (2000) The resurgence of growth in the late 1990s. Is information technology the story? *Journal of Economic Perspectives*, 14(4), pp. 3-22.

Sala-I-Martin, X. (1996) Regional cohesion: evidence and theories of regional growth and convergence. *European Economic Review*, 40(6), pp. 1325-1352.

Sato, R. (1970) The estimation of biased technical progress and the production function. *International Economic Review*, 11, pp. 179-208.

Seater, J.J. (2000) *Technical Change and Factor Shares.* Research Paper, Economics Department: North Carolina State University.

Solow, R.M. (1957) Technical change and the aggregate production function. *Review of Economics and Statistics*, 39(3), pp. 312-320.

Swan, T.W. (1956) Economic growth and capital accumulation. *Economic Record*, 32(11), pp. 334-361.