Establishing a Cointegrating Relationship Between the Exchange Rate and Relative Efficiency

Submitted By:

Louis Tuttle BBS. Dip. Econ. Sc.

A thesis submitted in candidacy for the degree of Master of Business Studies

Dublin City University

Business School

Supervisor: William Kelly

August 1997

DECLARATION

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Master of Business Studies is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

Signed:______________________________ Date: ___________________

Table of Contents

Chapter 6 Non-Stationary Time Series

Chapter 7 Cointegration

Chapter 8 Data Set and Variables Chosen

Chapter 9 Model

List of Appendices

List of Tables

Acknowledgements:

I would like to gratefully acknowledge the assistance of my Supervisor, Mr. Billy Kelly. I wish to thank him for his patience and guidance in the completion of this work. His knowledge and intuitive understanding of the subject area and his help in operationalising the empirical aspects of this work have been indispensable

Abstract

The intention of this work is to examine whether the real or nominal exchange rate of an nation reflects information regarding the relative efficiency of the economy. This research reviews work carried out in the area of economic convergence, economic development and the exchange rate.

A basic model for income is presented and residuals are analysed for further information on relative performance. These residuals are interpreted as a total factor productivity or Solow residual type measure coupled with information contained from the labour side of the economy. The sample covers the G7 countries and Australia, for the period 1950 to 1990.

The model is estimated using the Johansen Maximum Likelihood Procedure (reduced rank condition) and not the residual based method associated with normal cointegrating analysis. The latter method has a number of drawbacks. The unit roots present in the time series are identified using an Augmented Dickey Fuller. Results imply the existence of unit roots, but the author cautions that this conclusion is limited by low power of unit root tests in general. Non-stationarity may be a temporary post-war phenomenon, and the conclusion of a unit root is dependent on the sample period chosen.

The hypothesis is supported for six of the eight economies for the sample period 1960 to 1990. In some cases a statistical relationship exists between relative efficiency measures and the real exchange rate. This relationship is strongest in the 1950 to 1970 period. For the second half of the sample, results are less promising. A moving average is required to reduce the variability of the exchange rate measures. This produces results which are much more consistent and support the hypothesis.

The residuals generated by the model are imperfect is various ways. Nevertheless, the work supports a relative efficiency argument. The estimation procedure is also noteworthy. It examines relative efficiency by combining the information contained within the labour side of the economy with possible Solow residuals, while establishing a link between real and monetary phenomena.

CHAPTER ONE

INTRODUCTION

Chapter 1.0

Hypothesis

The intention of this work is to show that the exchange rate or the real exchange rate of an economy is in some way related to the economic fundamentals at play within the economy. It is posited that the real exchange rate contains information regarding the economy and that changes in what is referred to as the productive capacity, alter the real exchange rate value.

$$R_t = f\,(X_t) \quad [1.0.1]$$

where R_t is the exchange rate (real or nominal) and X_t is the data set that contains information from past shocks and potential innovations in the future.

It is intended in the course of the work following, to show that the relationship between the productive capacity and the real exchange rate runs from productive capacity to the real exchange rate. It is also hoped that in outlining the methodology, that it will appear logical to conclude that the real exchange rate of the economy should reflect the relative efficiency of that economy relative to one or more economies.

Chapter 1.1

The Real Exchange Rate

The real exchange rate of an economy may be defined as the relative value of the money in one economy compared to the value of money in a second or more economies. Since money is itself only a proxy for wealth, the real exchange rate is some reflection of the purchasing power of one economy's output relative to that of one or more nations.

Wealth is defined as the ability of a country to increase consumption paths over time. It is assumed that the purpose of economic development and economic activity is to increase consumption. Deflating the nominal exchange rate by changes in relative prices provides a better insight into the relative purchasing power of an economy. Thus the real exchange rate is defined as

$$RXR_t = XR_t * (P_t^f / P_t) \qquad [1.1.1]$$

Where RXR_t is the real exchange rate and XR_t is the nominal exchange rate. P_t^f is the foreign price level and P_t is the domestic price level.

There are a number of questions to be answered in this work. What forces are believed to alter the real exchange rate and hence determine the relative currency value? What decides the path taken by the real exchange rate in the long run?

Chapter 1.2

Nature of the Real Exchange Rate

What kind of patterns do we see in the real exchange rate of an economy over time? Do real exchange rates change in value or is there some mean reverting tendency associated with both exchange rates and real exchange rates for the World as a whole?

The above forms one of the basic starting points of this paper and the answer to this question leads on to the methodology employed.

Couching the question in terms used in the literature: Does the real exchange rate contain a unit root, or does it display a mean reverting tendency? This inquiry has typically been formulated in terms of whether the Purchasing Power Parity (PPP) held or not. That is, whether or not RXR_t and X_t as defined in [1.1.1] were cointegrated or not?

Chapter 1.2.1

Stationary Series or PPP

While it is not intended to examine the validity of PPP, it is noteworthy in that it has occupied the literature pertaining to both the exchange rate and the real exchange rate since exchange rate values entered the realm of economic and trade theory. If PPP does in fact hold, it implies that the real exchange rate may be a stationary series.

PPP claims that the nominal exchange rate changes so as to nullify any variations that may have occurred between the domestic and the foreign price levels. In its absolute form, the theory requires that the exchange rate changes so that an increase in the domestic price level of one percent leads to a change in the nominal exchange rate of the same amount. If an economy is experiencing inflation, an exchange rate depreciation ensues and hence a loss of purchasing power. In its less rigid form, relative PPP predicts the direction of movement of the exchange rate but not the magnitude. (Although relative PPP does allow for non-stationarity in the nominal exchange rate).

As a result, the exchange rate is seen as some kind of equilibrating mechanism. It maintains the relative value of monies. If PPP holds, then the real exchange rate is stationary over time and it returns to its original value after some shock. The real exchange rate should only move as a result of some real change in one economy relative to another.

$$R_t = \rho_t . P_t^* / P_t \qquad [1.2.1]$$

Where R_t is the real exchange rate; ρ_t is the nominal exchange rate, P_t^* is the foreign price level and P_t is the domestic price level. ρ_t moves so as to maintain R_t.

Is R_t stationary or non-stationary? If a shock occurs to either the domestic or foreign economy, what effect is observed in the real exchange rate ? If we deal in terms of the less restrictive version of PPP, (Relative PPP) R_t may deviate from some long run value while we wait for variables to react to a shock and move to their new value. If R_t is itself a mean reverting series (or trend reverting), then PPP would tend to hold in the long run. If this is not the case and PPP fails to hold even in the long run, one would have to conclude that the real exchange rate is itself non-stationary.

Despite the controversy revolving around this issue, from extant literature, I conclude that the nominal exchange rate itself does contain a unit root and is hence regarded as non-stationary. Conclusions regarding the real exchange rate are less precise. It is noted that the real exchange rate is highly persistent and that it may indeed contain a unit root. It is therefore accepted that PPP does not itself appear to hold in the short to medium term. More recent studies, which have used longer data samples, seem to support PPP. (Abauf and Jorion, 1990). Whitt's (1992) analysis finds support for PPP. In his case this result is independent of the deflator used, i.e. the Wholesale Price index (WPI) or the Consumer Price index (CPI). Recent improvements in the power of unit root tests again contradict the hypothesis that the real exchange rate does contain a unit root. (MacDonald, 1996). However if we accept that the real exchange rate is non-stationary, what impact does this have on estimation procedures and conclusions regarding explanatory variables?

Chapter 1.2.2

Non-Stationary Series

If the real exchange rate contains a unit root, it is referred to as being non-stationary. A series is referred to as being a (trend) stationary process if it returns to some original value (path) over time. It is referred to as a difference stationary process if it does not return to its value before the shock occurred. A shock to the real exchange rate is therefore permanent. The real exchange rate does not return to its previous value but now moves to a new rate or path.

If the real exchange rate could be modelled as an ***Autoregressive process*** of order one, AR(1), then the presence of a unit root may be depicted as follows

$$R_t = \delta R_{t-1} + \varepsilon_t \qquad [1.2.2.1]$$

where subscript t refers to the time period from which the real exchange rate is taken and ε_t is an error term. If a unit root is present then $\delta = 1$. This representation forms the basis of the Dickey-Fuller test, discussed later. The hypothesis tested is whether $\delta < 1$ or not.

Such a representation claims that only the last period's value explains the real exchange rate. The series is said to be integrated of order one (I(1)). This is a rather simplistic assumption. It is more likely that the series is in fact I(d), where d is the number of times that the series must be differenced in order to make it stationary. It is necessary to first identify whether the series is non-stationary or not. From there, successive differencing can make the series stationary and estimation may proceed using normal regression methods. Unfortunately this is not always the case.

From [1.2.2.1], last year's value of the real exchange rate predicts this year's value. A shock in last year's real exchange rate carries on into period t, without diminishing. If this is the case, the changes in the real exchange rate value are a function of past shocks.

These shocks may be either positive or negative. What is relevant is that the effect of these shocks does not diminish over time, and so a change in the forces that drive the real exchange rate lead to a permanent change in the real exchange rate.

Chapter 1.3

Real Exchange Rate Determinants

$$R_t = f(X_{t-s}) + \varepsilon_t \qquad [1.3.1]$$

Let X_t be an information set. This set contains information regarding productive capacity and relative efficiency measures. Let the error term ε_t account for the random component that may exist within this specification.

The concern then is what forces are contained in the X_t term and what is the relationship between R_t and X_t?

Should X_t embody factors that affect the real exchange rate then would they be likely to account for the non-stationarity that is observed in the real exchange rate? At the very least, would they account for the high degree of persistence that is associated with the real exchange rate?

Therefore the X_t terms ought to have a large permanent component. Shocks that have a transitory nature would not be expected to affect the real exchange rate for any period of time and should therefore be disregarded. Only factors that are non-stationary in nature would be relevant to an analysis of the real exchange rate. Determinants of the real exchange rate should hence be non-stationary and therefore real. Monetary phenomena are transitory. They would not be expected to have a long term impact. This expectation is supported in the data. (Amano and Van Norden, 1995).

Chapter 1.4

Objective and Research Outline:

From the above, I propose to examine those factors that are likely to be contained within X_t, the state variables. From there I will attempt to examine the relationship between X_t and the exchange rate.

The overall methodology is outlined as follows. It is proposed to examine whether the relative efficiency of one economy can be calculated and then compared to that of other economies. It is believed that superior efficiency eventually leads to an increase in the wealth of the economy and hence an appreciation in the real exchange rate of that economy.

This hypothesis is further justified from an examination of the literature on convergence, examined in Chapter 3. That is, laggard economies do catch-up with leader economies in terms of income and productivity. Since this is the case, do we see changes in the real exchange rate to reflect increased efficiency or increases in wealth producing ability? The fact that convergence can occur also implies that the characteristics of some economies are changing and allow laggard economies to converge to leader economies? The question is whether we can identify or isolate those factors responsible for convergence and hence for changes to the real exchange rate.

Two factors are believed to contribute to the phenomenon of convergence. They are the backlog of technology that exists in the first world economies, and the ability of some economies to alter their social capability in order to avail of this technological backlog. The latter cause is believed to be the reason why some economies converge and others do not. This is based on the assumption that technology is internationally tradable and therefore behaves as if it were a public good. This work should therefore incorporate the fact that some economies can alter their social capability, adopt new technology and from there increase their relative wealth.

In an attempt to identify this relative performance measure, we examine the literature surrounding Solow's residual growth term and total factor productivity (TFP). These measures are designed or exist to examine growth not accounted for by conventional inputs. It is assumed that technology is a public good and that capital is internationally tradable. Therefore capital goods should not be the reason for sustained differences in growth or efficiency. We are thus left with examining that growth not accounted for by capital. In an attempt to further isolate this relative efficiency measure, we limit ourselves to examining economies in the same stage of development. This is done so as to remove the contributions that structural change may make to the residual term due to the changes that occur as economies move from one stage of development to another.

Conventional inputs are examined so as to gauge their contribution to growth. By correctly estimating their contribution, we further isolate the increase from residual terms. This should enhance the ability of the residual growth term to serve as a relative efficiency measure. This relative efficiency is chosen so as to reflect the efficiency of one economy's specific characteristics relative to another nation. To this end it seems likely that this measure will incorporate some non-traded input. This composite measure is expected to include a residual measure (a Solow type measure) plus some country specific factor.

The United States is set as the base economy and all economies are compared to it. This is a reasonable assumption since the United States was (and probably still is) the principal leader economy. Following Summers and Heston (1991), although the analysis is sensitive to the base economy used, data available from the Penn World Tables has been created with this caveat in mind. It hence provides the most accurate data available for international comparisons given this drawback.

The final testable hypothesis is expected to take the form of a bivariate analysis, using a bilateral exchange rate (both real and nominal) in conjunction with a relative efficiency measure. Due to the problem of using normal estimation procedures on non-stationary time series and rather than attempting to difference the data, it is decided to adopt a cointegrating approach. The cointegrating methodology lends itself to long run analysis. By avoiding differencing of the data to achieve stationarity, valuable long run information is retained within the data series. The two terms are examined using Johansen's Maximum Likelihood estimation procedure which is believed to be superior to a residual based approach originally suggested. This procedure is based on an *error correction model*. Some equilibrating force ensures that the two non-stationary series remain together over time. This equilibrating force is believed to be the link between the relative performance of one economy versus another.

If the results indicate that there is a cointegrating relationship between the real exchange rate and the relative efficiency measure, it would imply that the real exchange rate does in fact reflect superior national efficiency. Therefore, if one economy performs consistently better than another, this fact should be contained within the real exchange rate and nominal exchange rate measures.

CHAPTER TWO

PRODUCTIVE CAPACITY

Chapter 2.0

Productive Capacity

The productive capacity of an economy is the ability of the economy to produce output in this and future time periods.

Income is often used as a proxy for relative performance of economies over time. Income is only a reflection of productive capacity. Changes in productive capacity lead to changes in income. Therefore productive capacity might be represented by the sum of all income streams within the economy.

Increases in the productive capacity of the economy should lead to an increase in income. The increase in income facilitates increases in consumption and investment. However, the efficiency with which inputs are used allows higher consumption paths for the commitment of a limited amount of resources. How do we measure increases in efficiency?

What is needed is a measure of relative performance over time. This can then be compared to the real exchange rate. The evaluation of the relative performance or efficiency measures that exist is the goal of this chapter.

The intention is to identify the determinants underlying growth in income and in productivity. To this end the productive capacity of an economy is analysed in the following way. We focus here on various efficiency or residual measure designed to capture growth not accounted by conventional inputs.

Subsequently the contributions from conventional inputs to growth are examined in the remaining chapters. By identifying the characteristics of growth that are common to economies we can then attempt to construct a relative performance measure.

The crux of this examination is to further identify the innovations in productive capacity that are permanent. Such innovations provide the impetus for convergence. Permanent changes in productive capacity brought about by conventional input growth or residual growth should be linked to changes in the real exchange rate.

Chapter 2.1

Total Factor Productivity

Tinbergen (1959), suggested that the production function could be written as

$$Y = A \cdot F(K,L) \qquad [2.1.1]$$

where A is seen as an input to the production process. A is a TFP measure and F is a well behaved neo-classical production function, concave and homogenous of degree one.

If production is defined in a general form let it be represented by the following equation:

$$Y = Af(K, L). \qquad [2.1.2]$$

Where A is technology, f is some function, and K and L are the factor inputs, that is capital and labour respectively. From this equation increases in income should come from increases in factor inputs and/or changes in technology. Assume inputs enter in a multiplicative fashion. More specifically, if we adopt a Cobb-Douglas production function which includes marginal products, but without specifying the production function further, we obtain

$$Y = Af(K^{\beta} L^{\alpha}) \qquad [2.1.3]$$

Let A=1 for convenience. K is the capital stock, L is the labour force, β is the marginal product of capital and α is the marginal product of labour. The advantage of the Cobb-Douglas is two fold. It allows catch-up to occur, something prohibited if we assumes an increasing returns to scale production function. Secondly it permits the use of use linear estimation procedures.

Taking logs we obtain

$$\Rightarrow \ln Y^* = \beta \ln K + \alpha \ln L \qquad [2.1.4]$$

This form is adopted because of its simplicity and not with the belief that development is linear. However it does allow the question of development to be examined simply. If there is some increase in output that is not accounted for by these factor inputs, (Y-Y*) it must be due to some residual term (Ψ).

$$Y - Y^* = \Psi \qquad [2.1.5]$$

Where Y* is the growth predicted from using conventional inputs

$$Y^* = A f(K^{\beta}, L^{\alpha}) \quad [2.1.6]$$

or

$$\ln Y^* = \ln A + \beta \ln K + \alpha \ln L \, . \qquad [2.1.7]$$

Let A=1, therefore LnA = 0. Let the residual term (Ψ) be called total factor productivity (TFP). That is, the difference between the predicted income generated from conventional inputs (Y*) and that actually experienced in the economy.

$$\Rightarrow \ln Y = \alpha \ln L + \beta \ln K + \ln TFP \qquad [2.1.8]$$

Therefore changes in income are due to factor inputs, factor productivity or a residual term.

The procedure above is common in the literature including Denison and Chung (1976), Kendrick (1991) and Morrison (1992). Residual growth is that income growth not accounted for by conventional inputs. Using the TFP definition or the residual term depends on the interpretation of the production function.

The ability to correctly attribute growth to factor inputs reduces the size of the residual term, which in some ways serves as a 'catch for all' term. However, in econometric terminology the TFP expression is the unexplained term. (It serves the function of some kind of error term). The more significant the error term, the more changes in income are accounted for by unexplained factors. If we can accurately measure the roles for capital and labour in the growth process it should become easier to identify whether a residual term exists which explains convergence.

The use of a TFP measure is attractive in a number of ways. Attempts to explain development begin by identifying those characteristics that are common to all growth processes. If all economies possess capital and labour inputs in their production function, how can one differentiate between them? Since capital tends to be regarded as an internationally mobile factor of production, it would not be expected to continually explain differential growth rates. This is highly arguable. If capital growth is related to savings, which is some function of the economy's time preference of money, which is itself a symptom of their planning for their future consumption, higher savings may be a contributory factor to differential growth patterns. This is the contention of King and Rebelo (1993). Some other factor must account for differences in an economy's consumption path relative to other nations.

I believe that capital is not the reason for differential growth for the following reason. Higher returns from capital in one area would imply a movement of factors to the more productive sectors within a nation or to more efficient economies. Over time, higher demand for capital would increase the price of capital hence driving down its marginal return. We tend to see interest rates being equalised across economies that allow international capital mobility. (The above argument implies a fixed amount of savings).

Baxter and Crucini (1993) note that national savings and investment tend to be highly correlated so that this would imply that there is little international movement of funds? I believe that it is reasonable to assume that supply and demand rules apply to the flow of funds. Higher returns within one economy encourage the movement of funds in the short to medium term? If the current account of an economy tends to return to equilibrium then this implies that changes in the flows of capital resources is a temporary phenomenon I believe that this is the case and that superior returns in one economy lead to the flow of capital to that economy.

Higher returns in one area would indicate that one economy is more efficient than another. If this is the case then how would this be measured? Would it be seen in the higher TFP measure? If the price of capital is equalised across economies (the β value in the above equations), then superior performance would enter into the TFP measure anyway.

A similar argument may apply in the case of labour and the wage rate. Does the wage rate of an economy reflect the contributions of labour in growth? Since labour mobility is less likely than capital mobility, there may be a tendency for differences in wage rates to persist. According to Hooper and Larin (1989), labour is the most important nontraded input in the manufacturing process. Labour mobility within the economy tends to equalise wage rates, as does the fact that changes in price levels tend to be highly correlated within economies. (Marston, 1990). The national price level would be likely to impact on the wage level perhaps more so than changes in labour productivity. We cannot depend on the wage rate to reflect the 'true' marginal product of labour. Different changes in the national price levels further reduce the ability to depend on the wage rate as a reasonable measure of the marginal product of labour. We must therefore look to another method of comparison between economies.

All the above leads to a possible conclusion that the TFP may provide a way to identify economies that are more efficient than others. This result depends on correctly applying the determinants of growth to the various factors within the economy. Otherwise the TFP measure becomes less accurate in international comparisons.

Chapter 2.1.1

Capacity Utilisation and Economies of Scale

There are criticisms in using TFP as a means of measuring relative efficiency. Ohkawa (1993) for his part believes that it is an inappropriate measure for developing countries. This is based on the fact the price levels and wages are far less likely to truly reflect labour's contribution to growth in income. Apart from the failure to measure inputs correctly, the residual measure may fail to be as comparable as one would think. Successfully measuring the inputs correctly in one country may render the index incomparable with a country that has failed to correctly calculate factor input contributions. If we assume initially that this is not the case, then what other problems are there?

It is claimed by Morrison (1992), that the TFP measure is sensitive *to capacity utilisation*, *economies of scale*, and *mark-up* effects. Morrison (1992) believes that there is a large amount of secular and cyclical changes in the productivity measure and that these are attributable to production characteristics other than technical change. *Scale effects* were found to be particularly important. Morrison (1992) shows that the cost elasticity of output can be expressed as a combined effect of long run scale economies and the capacity utilisation rate. The long run scale economies is a measure along the long run average cost curve while the capacity utilisation rate is a measure along the short run average cost curve. The empirical results of Morrison's model conclude that:

- Mark-ups, defined as price over marginal cost (P/MC) are taken as an indication of the level of market imperfection. It is noted that there is a negative correlation between TFP and mark-ups.
- The cost elasticity of output (the inverse of the short run scale economies), is related to the capacity utilisation arising from the short run fixity of more fundamental factors underlying the u-shaped long run average cost curve.

- It is believed that traditional TFP measures are biased upwards due to the fact that they are computed on the basis of long run costs and structures (as represented by the long run average cost curve), instead of taking into account the fact that there exists short run factors which push costs upwards.

According to Morrison (1992) the traditional TFP measure is Solow's residual. A *generalised* TFP measure also exists which takes into consideration the fact that there are observed cost reductions (productivity increases), which have been erroneously attributed to technological change rather than to scale economies or capacity utilisation effects. The traditional measure is also believed to confuse capacity utilisation with TFP change. It confuses the dichotomy between a shift in the production function (reflecting changes in productivity), and movements along the production function reflecting a change in capacity utilisation. This is not true with the generalised TFP measure, at least in principle. It is intended to measure disembodied technological change. The overall thrust of this exposition is that the TFP growth is much smaller than had previously been thought. On the basis of the traditional TFP concept, residual growth is exaggerated.

As far as the popular view on productivity slowdown in industrial economies is concerned, Flaig and Steiner (1993) and Park and Kwon (1995) reject the belief in such a slowdown and attribute the misconception to mismeasurement of the traditional TFP measure. Their results show that the generalised TFP (which has been adjusted for scale economies and capacity utilisation effects) is smoother than that based on the traditional measures. Cyclical fluctuations practically disappear from the residual using this generalised TFP measure. Unfortunately, it is observed that there is a distinct possibility that many of the changes in technology are embodied in the quantities and prices of factor inputs, thus leaving little for the residuals representing disembodied change to measure.

Park and Kwon (1995) note that P. Romer (1986, 1990), Lucas (1988, 1990) and Grossman and Helpman (1990) all stress the importance of scale economies with regard to TFP measures. It seems a mistake therefore to ignore such aspects when making cross country comparisons.

Chapter 2.2

Evidence regarding TFP's Ability to Measure Growth

Wolff (1991) observes that in the period 1870-1979, convergence was evident, although it was slower in the periods before 1938 and after 1950. K/L ratios converged over the period although the convergence was much slower post 1960. As noted earlier, TFP is found to be positively correlated with K/L growth and is strongest when capital intensity is growing rapidly.

Dowrick and Nguyen (1989) in their examination of the hypothesis of convergence, find that what has occurred is a systematic process of catching up in levels of TFP. They concern themselves with examining whether convergence was due to factor intensity or changes in TFP. TFP growth implies a tendency for income levels to converge, but such a tendency may be masked or exaggerated if factor intensity varies systematically with income. Dowrick and Nguyen (1989) define convergence in terms of income levels, in which case TFP is the correct proxy. If convergence is related to income dependent consumption patterns then we should define catch-up in terms of relative per capita Gross Domestic Product (GDP). The regression model suggested is such that the growth of GDP depends on the rate of growth of factor inputs, the common rate of exogenous technological change, and the initial level of output per employed worker relative to the leading country. There is evidence to conclude that convergence has been due, not to higher rates of investment, but to more rapid rises in labour participation rates in poorer countries. Results indicate that income convergence has been somewhat slower than the underlying rate of TFP catch-up, presumably because capital and/or labour intensities have been growing at a slower rate in the poorer countries. It is recognised that although convergence may not have occurred for larger samples of countries, *TFP catch-up has occurred for all but the poorest countries.* Income convergence, where it has transpired, has been the result of a systematic tendency of catching up in TFP terms. This conclusion is re-echoed in a 1992 paper by Dowrick. Dowrick in this paper concludes that there is likely to be a strong relationship between physical investment and human and social capital. This is further noted in Brander and Dowrick (1990).

Young (1994) documents the fundamental role played by factor accumulation in explaining the extraordinary post World War II growth for a number of newly industrialised countries. It is found that TFP is not as important in explaining growth when factor accumulation in terms of participation rates, educational levels and investment rates are included. In Young's (1994) approach, a translog index of TFP growth is used which provides a measure of the amount of output that would have increased had all inputs remained constant between two discrete periods. In essence, the translog production function provides a theoretical justification for the use of average factor shares and log differences as a means of extending the continuous Divisia analysis.

From this we may question whether the TFP measure is the appropriate measure when comparing economies over time. There are inherent risks in using the measure which preclude it. Difficulties in isolating the measure correctly and correcting it for differences in economies of scale are widespread. Therefore some other measure must be found that allows both cross country and time series comparisons.

The point of the discussion in this section is to acknowledge the possibility that TFP may not be the correct measure to use when making international comparisons. It is also noted that factor density may have been mismeasured. This would have encouraged a mistaken preoccupation with a TFP or some residual measure to account for growth in income while retaining some simple Cobb-Douglas production function. Young's (1994) work is noted because he feels that this is exactly what has happened. Some mismeasurement of factor inputs has indeed occurred. This is especially true of the labour measure. It is also true of capital and the problem of accounting for increases in the quality of capital over time due to technological progress.

These two issues are examined separately. The correct measurement of factor inputs is examined under various headings. In the case of labour, an attempt is made to calculate an effective labour measure to account for increases in skills over time and to account for explicit investment in labour. This links into the idea of human capital and social capability. Again difficulties are encountered in correctly measuring labour's contribution to productive capacity.

The correct measurement of capital and the identification of its true contribution to income over time is considered when we talk of embodied technology. However capital is a traded good. It seems unlikely that capital could account for persistent differences in income. This argument is supported in the examination of convergence. While one economy may be technological superior to another, capital's mobility encourages catch up under certain circumstances.

If I can correctly measure the contributions from factor inputs, both in terms of factor intensity and quality, it becomes easier to isolate the contribution from a residual term. This residual would hopefully represent an economy's efficiency. Therefore I have not discounted the use of TFP entirely. For now I note the criticisms of some authors and shall return to them later.

Chapter 2.3

Residual Growth, Development and Indicators

Ohkawa (1993) contends that it is impossible to measure TFP for all developing countries in such a way that the measures are internationally comparable. Ohkawa's (1993) conclusions appear to be based on the assumption that it is possible to equate prices of inputs with their respective marginal products. By fixing the wage and interest rates across economies, it may be an attempt to make cross sectional comparisons more meaningful. However as noted earlier in the case of wages, there appears to be a high correlation between wages and domestic price levels. He suggests that another residual (Ψ) be used in place of TFP.

$$\Delta\Psi = \Delta Y - \Delta Y^* \qquad [2.3.1]$$

$$\Delta Y^* = r.\Delta K + w.\Delta L \qquad [2.3.2]$$

$$\Delta Y/I = \Delta\Psi/I + r.\Delta K/I + w.\Delta L/I \qquad [2.3.3]$$

Where r is the return on capital and w is the wage rate. I is investment and L is the labour input. Ψ is the residual term and Y* is the predicted income level from [2.3.2]. Δ is the first difference operator.

Ohkawa (1993) offers three approaches to measure development - an output approach, an investment approach, or a growth ratio approach. (The approaches can be altered by changing the denominator value). A relationship exists between the investment and the output approaches.

$$\Delta\Psi = \Delta Y - (r.\Delta K + w\Delta L) \qquad [2.3.4]$$

$$\Delta\Psi/Y = \Delta Y/Y - (r.\Delta K + w.\Delta L)(1/Y) \quad [2.3.5]$$

$$\Delta\Psi/I = \Delta Y/I - (r.\Delta K + w.\Delta L)(1/I) \qquad [2.3.6]$$

The difference between the two residual terms emanates from the magnitude of I/Y. If it is believed that investment is more applicable in explaining growth patterns than income growth, then [2.3.6] is the correct equation to use.

Countries are split into five development categories ranging from the least developed (category I) to the most advance economies (V). A general increase in *product per worker* for all groups (I-V) is observed as measured by the difference between the growth in income and the growth in labour (**G_Y - G_L**). In fact, it is the *single most important indicator of development*. Ohkawa (1993). Although differences between the two terms remain positive, the terms themselves move in different directions throughout the development process. Baumol (1986) supports such a conclusion . He also believes that GDP per worker is one of the most important predictors of future development paths.

It is observed that $w\Delta L/\Delta K$ is an incremental form of Lw/K or the *factor input ratio*, which can imply the type of technology adopted in terms of the intensity of the factor combinations. The higher the ratio, the more labour intensive the technology. Differences in I/Y suggest a willingness to absorb another economy's technology. The higher the ratio, the greater the willingness to adopt the technology. (Ohkawa, 1993).

In the case of residual growth per investment unit, an inverse U-shaped pattern is prominent. In the lower income countries, countries I through IV, the magnitude of the residual growth per investment term tends to increase while in the case of countries in group III, the residual falls. The residual increases again for countries in groups IV-V. Up to some point, the activities of the developing countries tend to augment the residual per investment term by accelerating innovative activities, while at higher Y/L levels, the developing activities are less vigorous. This trend is not extended into group V nations, which implies that there is a revival at this stage of development. Care is thus needed in cross country comparisons, especially between economies at different stages of development.

The variance within the residual term $\Delta\Psi/I$ for individual countries is generally associated with the differences in investment efficiency, as indicated by $\Delta Y/I$, although a wide variance in $w.\Delta L/I$ cannot be ignored. There is a tendency over time for convergence in this residual measure. (Ohkawa 1993).

It is observed by Ohkawa (1993) that in the case of the output approach, there is a neutral treatment of capital and labour, i.e. that there is no distinction made between them. The output measure aims at gauging the contribution of TFP as the source of aggregate output growth, where the contribution of conventional inputs is measured by $r\Delta K/Y$ and $w\Delta L/Y$. Ohkawa (1993) believes that at lower income levels, structural change plays a more influential role in development and so increases the contribution from the residual term. This view is consistent with Denison's (1967) work. In the final stages of development the 'end' is conceptually demarcated by the point at which the rate of residual growth stops its acceleration or begins to decrease. (Whether this is the effect of some type of asymptotic catch-up process is not examined, but it is one plausible explanation as to why residual growth might begin to fall). Changes in $\Delta\Psi/\Delta K$ tend to increase as an economy develops, perhaps reflecting the benefits of technology and organisational advances. Upgraded capability raises the level of product per worker.

Given a rate of return, the term $\Delta Y/\Delta K$ (or the incremental capital to output ratio, ICOR), varies depending on changes in $\Delta\Psi/\Delta K$ and changes in $w\Delta L/\Delta K$. (Ohkawa, 1993). Capital formation accompanies the residual on the one hand and creates employment on the other, ($w\Delta L/\Delta K$). The inclusion of w and not just ΔL, implies that some account is taken of changes in labour quality. In the neo-classical approach, the rate of change in capital stock is more important than the capital stock itself. It is recognised by Ohkawa (1993) that for the first three groups, growth in income (G_Y) was broadly similar to that of capital (G_K), but for groups four and five, capital growth exceeded that of income (or output) growth. This reinforces the assumption that diminishing marginal returns applies, or that the force driving income growth changes as the economy approaches higher income levels. As noted earlier, for all groups there is a constant trend of (**G_K - G_L >0**). That is, capital growth always exceeds that of labour.

In Ohkawa's (1993) approach, in calculating income shares, labour's share is first computed with the assumption that capital and labour's shares sum to unity.

$$\beta G_K = r\Delta K/Y^{**} \quad [2.3.7]$$

$$\alpha G_L = w/\Delta L/Y^{**} \quad [2.3.8]$$

where Y** stands for output at factor costs net of depreciation allowance.

Ohkawa (1993) maintains that developing nations tend to have increasing differentials of productivity and wages between their traditional and modern sectors. (This is discussed under the Balassa effect).

Table 2.1 Development Indicators

I/Y	The investment proportion, I/Y, does not change much, dropping only slightly in a generally increasing trend from countries I through V.
ΔI/Y	Investment efficiency $\Delta I / Y$, falls and thus forms a U-shaped pattern throughout the entire range of countries, I through V.
G_L	The rate of increase of G_L (growth in labour employment) turns sharply and becomes smaller as an economy develops.
K/L	The incremental K/L ratio, $I / w\Delta L$, increases substantially for nations IV-V, after showing moderate changes through the lower Y/L groups.
Group V	Group V countries can be characterised by a high sustained level of residual per investment, on average, despite a low level of investment efficiency. This can be explained by the developing countries successful attainment of technological advance of the capital-intensive type, in the face of limited labour supply.
ΔΨ/I	• ΔΨ/I increases for groups I to III, but falls for groups III to IV, then increasing for group V countries.

(Summary of Ohkawa's (1993) findings)

Chapter 2.3.1

Residual Growth and the Growth Accounting Framework

In the various works by Denison (1967, 1979), the *growth accounting approach* was adopted. Denison (1979) attempts to account for the residual growth slowdown for the United States (US). While various suggestions are interesting, the idea that a slowdown did in fact occur is suspect and has been challenged by others. Flaig and Steiner (1993) reject the notion that there was a structural break in the TFP growth rate in the 1970s. Flaig and Steiner (1993) do not believe that the change in TFP was due to negative supply side shocks, but rather they contend that economies of scale and capacity utilisation were more important factors. At the same time, it might be expected to see a higher correlation between TFP growth and the real exchange rate in the 1950 to 1970 period, rather than in the post 1970s period. Again this expected result may have a variety of explanations, including the increased variability in the real exchange rate.

Chapter 2.4

Characteristics of Technology

It is believed that technology originates from some kind of an innovation process, while imitation allows technology to diffuse. (Verspagen, 1994). In the case of convergence, the latter force is deemed to be pertinent. More specifically, the innovation process is believed to be more random than imitation. If it is possible to affect the speed of technological progress then it is a possible explanation for differential growth rates between nations.

By dividing the process of knowledge transference into innovation and imitation, we must decide which is the most powerful in maintaining competitive advantage. 'Learning by doing' effects may allow competitive advantage to persist. If 'learning by doing' effects exist, then they would allow inhibit convergence. (Brezis at al., 1993). However imitation is believed to provide the strongest contribution to catch-up. This is achieved by investing in increased training of labour, purchasing of embodied and disembodied capital, as well as intermediate goods. Mobility of factors facilitates the entire process of convergence.

Within Ohkawa's (1993) residual growth framework, the term G_R/G_Y is conventionally used to indicate the effect of technology. This simplifies to $I/\Delta Y$ and $\Delta\Psi/I$. The former measures the output efficiency of investment while the latter measures technological advance. Ohkawa (1993) suggests a suitable framework for dealing with technology by measuring **$w\Delta L/\Delta K$,** within the investment approach. It is observed that apart from developing countries, (who only experience a small fall in the ratio) a large drop in the ratio is found in the case of developed countries. The Harrod type of technical change, as represented by the *incremental capital to output ratio*, and the Hicks type as represented by α, are taken into account by Ohkawa (1993). α is defined as $\alpha G_L = w/\Delta L/Y^*$. In a simplistic manner the former can be represented by the term $\Delta Y/\Delta K$ and the latter by the term $w\Delta L/\Delta Y$. The product of these two terms gives $w\Delta L/\Delta K$. This implies that $w\Delta L/\Delta K$ can represent the combined effects of these two elements of technical change, at the conventional factor input level. Further, $\Delta Y/\Delta K$ plays a much more important role in influencing the factor input ratio. (Ohkawa, 1993).

This approach raises two concerns. Is it possible that technology favours one input over another? Secondly, is technology embodied in conventional inputs? If it is believed that technology is not contained within conventional inputs, then it is likely the residual term monitors changes in technology. If technology enters through changes in capital quality, then this will need to be included in any regression between the real exchange rate and the determinants of productive capacity. If it is suspected that the real exchange rate is highly persistent or non-stationary, then only changes in the productive capacity that are themselves permanent, would be significant. A similar argument is applicable for labour and labour quality.

Chapter 2.5

Domestic Resource Cost and International Comparability:

Nishimizu and Page (1986) examine the effect of productivity change and its relationship with comparative advantage. The paper proposes a simple decomposition of the domestic resource cost (DRC) measure of international competitiveness into three distinct elements:

1. changes in international prices,
2. changes in production techniques,
3. changes in TFP.

The decomposition provides a clear analytical link between two largely separate methodologies for assessing economic performance: cost benefit indicators based on the world price rule and TFP analysis. (Nishimizu and Page, 1986).

Nishimizu and Page (1986) assume that value added is a well behaved function of primary inputs and time, V = *f*(K, L, T), giving

$$\frac{dV}{V} = a_L \frac{dL}{L} + a_K \frac{dK}{K} + a_T dT \qquad [2.5.0]$$

where a_L is the value added elasticity of labour and a_k is the value added elasticity of capital. $a_T dT$ is the rate of change of TFP. DRC is defined as the single period, social cost benefit indicator, denoting the domestic factor cost at shadow prices of generating a unit of value added at international prices.

$$D = (w.L + r.K)/p.V \qquad [2.5.1]$$

Where w is a vector of shadow wage rates, r is a vector of shadow rental costs of capital, p is the world value added price, V is value added, and D is DRC. (Note that r and w in [2.5.1] are expressed directly in terms of foreign exchange). If DRC < 1, it implies that there is a comparative advantage in producing this product or set of products. What is of interest here is establishing that an economy possesses a comparative advantage in producing a given commodity. This comparative advantage will depend on the inputs that are involved in producing the commodity, be they labour, capital and/or technology. The difference between the cost of the input and the actual value added provided by that input is represented by equation [2.5.2].

$$\frac{dD}{D} = s_L \frac{dw}{w} + s_K \frac{dr}{r} - \frac{dp}{p} + (s_L - a_L)\frac{dL}{L} + (s_K - a_K)\frac{dK}{K} - a_T dT$$

[2.5.2]

where

$$s_L = \frac{wL}{wL + rK} \quad \text{and} \quad s_K = \frac{rK}{wL + rK} \qquad [2.5.3]$$

S_i are the shadow prices of labour costs and capital costs in total primary factor costs. This equation can therefore act as some kind of measure of non-comparability in international comparisons. Should prices of labour and capital be different than some internationally accepted "true" value, international comparisons become less meaningful.

The first two terms in [2.5.2] are the *factor cost* effects on D, the weighted average of proportionate changes in the shadow wages and shadow rentals, where the weights are cost shares at shadow prices. Increases in factor costs at shadow prices, ceteris paribus, increases D and implies a deterioration in comparative advantage. The third term is taken to be the *terms of trade effects.* This is a proportionate change in the world value added price describing the net changes in world prices of output and intermediate inputs. This can be shown by:

$$\frac{dp}{p} = \frac{p_x X}{p_x X - p_m M}\frac{dp_x}{p_x} - \frac{p_m M}{p_x X - p_m M}\frac{dp_m}{p_m} \qquad [2.5.4]$$

where X is a vector of outputs, M is a vector of intermediate inputs and p_x and p_m are vectors of their corresponding world prices.

In equation [2.5.2], the first three terms sum to give the change in world value added price net of factor price changes. In a long run equilibrium situation, this equals the negative of the dual price index of world TFP changes in the shadow pricing model underlying the methodology followed. (Nishimizu and Page, 1986). The next three terms capture information on the consequences of changes in production relationships for D. The first two give the effect of changes in factor proportions. The first order condition for price efficiency at shadow prices requires that the output elasticity with regard to factor inputs, a_L and a_K, equals its costs share at shadow prices, S_L and S_K. When this is not the case the weights in the two terms are non-zero. The movement towards (or away) from the optimum proportions will increase or decrease the DRC. If the activity is price efficient at shadow prices, then these two terms vanish. (Nishimizu and Page, 1986)

According to Nishimizu and Page (1986) the impact of a change in TFP is to alter the value added at world prices. The empirical results of their paper decompose the DRC into

- factor shares
- terms of trade effects
- factor proportion effects
- and TFP changes.

Nishimizu and Page (1986) believe that in competitive long run equilibrium, the price competitiveness effect should equal the rate of TFP change for the rest of the world. Further, in the short run, with trade distortions or an environment of imperfect competition in trade, one cannot expect changes in unit costs to be fully passed on from producers to consumers. They believe that it is reasonable to expect that the TFP change will be greater than the price competitiveness effect. The impact of changes in factor proportions on comparative advantage is small. According to Nishimizu and Page's (1986) analysis of Thai industry, TFP change provides the major source of change in international competitiveness. Changes in the production techniques provide little change in DRC.

Chapter 2.6

Conclusion

From the review of literature, it is apparent that there are sound reasons for choosing some TFP measure to gauge an economy's performance. Avoiding the pitfalls that exist, it is possible that a relative efficiency measure could prove useful in predicting income growth paths. This relative performance measure should contain a measure for all three inputs. Problems exists in identifying a measure immune to differences in national price levels.

The domestic resource cost approach suggested above appears to be a more comprehensive measure than that suggested by Ohkawa since it explicitly incorporates pricing considerations. It does not assume that a naïve perfect competition assumption holds. While Ohkawa (1993) notes that international comparisons are affected by prices, he does not offer a way of gauging the adverse effect on comparisons. Therefore the Domestic Resource Cost measure is a superior relative performance measure.

The conclusion that the terms of trade may contain information regarding the competitiveness of an economy is promising. (That is, the competitiveness of the economy relative to that of its trading partners and the rest of the world). Any relative measure that is chosen must remain comparable in an international sense.

Should the terms of trade prove significant in an analysis of the real exchange rate would this indicate that the real exchange rate contains information about the relative efficiency measures within the economy?

CHAPTER THREE

CONVERGENCE HYPOTHESIS

Chapter 3.0

Convergence Hypothesis

The *Convergence Hypothesis* purports that economies which lag behind leader or first world nations can in fact catch-up with these countries in both income and productivity terms. This implies that some process exists whereby economies that are inferior in terms of wealth, income or output, may over a period of time approach the leader economies' higher wealth paths, in per capita terms.

According to Bernard and Jones (1996) convergence is defined as a narrowing of initial differences in income levels over some time horizon. Faster growth by poorer regions is referred to as β-*convergence* while the reduction in cross regional variance of output is called σ–*convergence.* However, one does not necessarily imply the other. (Jorgenson and Kuroda, 1992). These interpretations of convergence are associated with the predicted output paths from the neo-classical growth model with different initial levels of capital. β convergence implies that countries with lower initial levels of capital stock (income levels), accumulate capital faster than average. σ–convergence predicts that cross regional variance in income will be declining during the transition to steady state. Once countries attain their steady state levels of capital, there is no further expected reduction in cross sectional output variance and expected growth rates are identical. Time series studies generally define convergence as transitory deviations from identical long run trends, either deterministic or stochastic. (Bernard and Jones, 1996). The possibility of convergence is not anticipated by all economic models. Endogenous growth models do not predict convergence since they allow for permanent non-diminishing returns. (Grier and Tullock, 1989; Brezis et al., 1993).

Dowrick and Nguyen (1989) believe that the choice of whether to define convergence in terms of income or productivity, depends on whether productivity, represented by some kind of a total factor productivity measure, is a characteristic of catch-up. If catch-up is only a technological phenomenon then it should only be defined in terms of Total Factor Productivity (TFP). If convergence is believed to be occurring because of factor accumulation, then perhaps income (GDP) would be more appropriate. Wolff (1994) believes that the patterns of aggregate growth and capital formation are either (a) a catch-up variety, where the closure of the gap between the follower countries and the leader is in terms of productivity levels, or (b) convergence, where there is decreasing dispersion in productivity levels of all nations. The former is measured using an index of unweighted average productivity levels for all nations, with a ratio of minimum to maximum productivity levels. The latter is measured using a coefficient of variation, defined as the ratio of the standard deviation to the mean. Wolff (1994) claims that for the 1960s and the 1970s, convergence was due to productivity catch-up, while convergence after the 1970s was due to increases in specialisation. If even the nature of convergence changes over time then correctly assigning causing variables to the process is difficult.

If convergence is occurring, it is likely that it is the transference of technology (the back-log of technology that exists or existed in the leader economies) which facilitates this process. Assuming that technology is one of the ways that this may have occurred, then a possible approach is a dual analysis. Since technology consists of embodied and disembodied technical change, the analysis should incorporate this dichotomy. Technology may exist within the capital stock and be transferred from one economy to another, via trade. Disembodied technology or knowledge would require a certain amount of preparatory investment on the part of the laggard economy. This is the subject of Chapter four, and the idea of Social Capability.

Chapter 3.1

Income Convergence

If income convergence is occurring, it implies that an economy's initial income contributes less to current income as time increases. The initial income level becomes less of a predictor of future income growth levels. If convergence is occurring, then some process makes initial starting wealth a less important determinant of future wealth over time. If convergence is occurring, it implies that income is increasing over time and that initial income is less important in deciding future income streams.

If this is the case then income does rise over time? Within the income generating process, some of the determinants are leading to permanent increases in income. A conclusion that some of the innovations in the income generating process are non-stationary is deemed appropriate.

Within the realm of the convergence hypothesis, income in the leader economy and that in the laggard, show a larger differential in period t-s, but this differential diminishes over time.

$$(Y_{t-s}^{i} - Y_{t-s}^{j}) > (Y_{t}^{i} - Y_{t}^{j}) \qquad [3.1.1]$$

The difference in income between the leader and the laggard economy in the past is greater than the difference now, or in the future. Convergence in income terms is occurring if the above is true. (A similar approach may be taken with regard to productivity convergence. If convergence is defined in terms of income variance, then a variance measure for productivity may be applied along similar lines).

Ohkawa (1993) accepts that convergence may be a non-linear process. In attempting to specify the process he uses a linear specification.

$$Y_t = \alpha + \psi Y_{t-s} + v_t \qquad [3.1.2]$$

The degree to which income in period t-s determines income in period t, diminishes as time increases. (i.e. as S gets larger). This forms a testable hypothesis for convergence. It is also possible to test whether the income generating process contains a unit root. (Christiano and Eichenbaum, 1989).

Chapter 3.2

Innovations in the Income Generating Process

Assuming that income convergence is occurring, what are the forces generating the process? The definition of convergence includes two aspects. One concerns itself with examining convergence in terms of one of the symptoms of development, that is income. However, this is not the cause of convergence, only a symptom of altering the nature of an economy. The nature of the shocks occurring within income are also of importance. Within the definition of σ–convergence, Bernard and Jones (1996) refer to the reduction of variance in output rather than just the rise in income over time. It is likely that this is related to the forcing variables that cause convergence. Whatever process drives convergence, it may also lead to reduced variance within the output measures. A potential exists within σ–convergence for some regions to converge but not others. Aggregate measures may conceal this fact.

Chapter 3.2.1

Variance of Innovations

According to Lichtenberg (1994), contrary to the beliefs of some analysts, the hypothesis of convergence and mean reversion are not equivalent. Under some assumptions the rate of convergence is independent of the degree of mean reversion, while under others, mean reversion is a necessary but not a sufficient condition for convergence.

Lichtenberg (1994) reaches this conclusion because innovations in income require a variance that is itself declining over time.

$$y_t = u_t + \pi u_{t-1} + \pi^2 u_{t-2} + \pi^3 u_{t-3} + \dots \qquad [3.2.1.1]$$

If we assume that u_t are independent, identically distributed (i.i.d.), innovations with mean zero and variance σ_u^2, then one can easily show that the variance of y_t is

$$\text{var}\, y_t = \sigma_u^2 / (1 - \pi^2) \qquad [3.2.1.2]$$

This does not depend on time. Even if the y_t series is characterised by mean reversion, $\pi<1$, the distribution of y_t will fail to converge if the variance of the error terms in not also converging. For this specification,

$$[(\text{var}\, y_t) / (\text{var}\, y_{t-k})] = 1 \qquad [3.2.1.3]$$

for all t and k.

Does this imply that the process which drives income, needs to have certain properties that lead to convergence, in income and in variance terms?

According to Lichtenberg's (1994) representation, income is composed of a series of innovations that transpire over time. Whatever drives the income process must itself be non-stationary. Income increases over time so that these innovations must have some kind of non-stationary nature. There would appear to be some permanent component within development.

If income is defined as some kind of AR(p) process, then income is

$$Y_t = \Sigma\psi_{t-p+1} Y_{t-p} + \varepsilon_t \qquad [3.2.1.4]$$

Income is rising over time so that $dY/dt > 0$.

Chapter 3.3

Where is convergence occurring?

Convergence does not occur when the hypothesis is tested for the world as a whole. (Baumol, 1986). Over time, countries that are laggard with respect to the leader economies continue to diverge in income and productivity terms. There is no catch-up occurring. The difference in income terms continues to exist and actually increases.

However, convergence does occur within certain samples of economies. (Baumol, 1986; C. Romer, 1986; Grier and Tullock, 1989, Barro et al. 1995). 'The history of post-war growth in the OECD area has been dominated by convergence'. (Verspagen, 1994, p.156). This would seem to imply that differences exist between economies. Convergence seems to be occurring within the OECD economies but not for the African economies in general. One must assume that the OECD economies possess some characteristics that the African economies do not. Alternatively, barriers may exist within some nations preventing them from catching-up. (Parente and Prescott, 1994).

Grier & Tullock (1989) find support for the convergence hypothesis in the OECD countries. Results are presented below in table 3.1.

Table 3.1 Grier and Tullock Regression Results

OECD	Coefficient in the tested regression is positive and significant, indicating that richer countries grow faster.
ROW:	Initial income positively related to growth for Rest of World (ROW), implying that richer countries grow faster.
OECD & ROW:	Population growth is positive and significant in both samples.
OECD:	Average inflation has no effect on growth.
ROW:	Inflation has negative effects and is significant.
OECD:	Regression explains 63% of the variation in the dependent variable.
ROW:	Regression explains 13%.
OECD and ROW	Results show that there is no comprehensive model that explains growth for the entire world. Idiosyncratic variations, what Abramowitz (1986) calls social capabilities, are much more important than can be inferred from the highly aggregated results presented[1].

Chapter 3.3.1

Sectoral Convergence

If convergence is a characteristic of an economy, does it follow that all sectors within that economy experience convergence?

Bernard and Jones (1996) observe that services and utilities show substantial evidence of catch-up, while at the other extreme, manufacturing appears to cause an overall increase in cross-country dispersion. Manufacturing appears to be leading the

1 The aggregated results are actually those referred to by Kormendi and Mequire (1985).

divergence in total factor productivity (TFP) terms. The reason that convergence may be occurring at the aggregate level is because of the increasing importance of other sectors in the economy, such as services. It is suggested that productivity differences in TFP and the aggregate measures of convergence transpire because of changes in the structure of the economy. It is also recognised by Bernard and Jones (1996), that there remain substantial differences in sectoral shares across countries. Although international trade theory predicts that factor prices should converge, the same is not true of factor shares. (Wolff, 1994). In addition, there is little tendency for these shares to become more similar over time. Since all sectors, except manufacturing, show convergence in productivity levels and the share of manufacturing is declining, the convergence of total industry productivity is less surprising. (Bernard and Jones, 1996). Such a conclusion is supported by Williamson (1991), who believes that the United States' post World War II 'slowdown' was due to services sector's stagnancy over the period.

If convergence is occurring in sectors that tend to be nontraded, will this information show up in the real exchange rate, which is predominantly a traded sector measure? The manufacturing sector tends to be used as the proxy for the traded goods sector. If divergence occurs here, it is reasonable that the real exchange rate may be slow to incorporate this information.

The notion that differential productivity growth rates may exist and have an effect on the economy was suggested by Balassa (1964) and supported by various other authors. (Bahmani-Oskooee, 1992). The concept that sectoral differences are being masked by aggregate measures is not new. This is of interest in that, if catch-up is occurring (for whatever reason), the ability to catch-up may be inhibited by the structure and nature of the economy.

In an attempt to isolate changes in different sectors, Ohkawa (1993) observes that structural change is a characteristic of development and indeed this is as predicted by growth models. He suggests using *product per worker* (PPW) as a basic yardstick of development, but by analysing PPW sectorally.

$$Y / L = Y_A / L_A . L_A / L + Y_I / L_I . L_I / L + Y_S / L_S . L_S / L \quad [3.3.1.1]$$

This is referred to as the *ratio approach* and examines the change in the sectoral relationship of PPW. Where Y is an output measure and the subscripts are as follows: A is agriculture, I is industry, and S is the services sectors, summing to equal all sectors in the economy.

Structural change is defined as the relationship between productivity growth and the reallocation of employed labour in the sectoral context. (Ohkawa, 1993). Differences in the marginal products of labour are assumed to occur in developing countries. A trend of convergence in Y/L means a trend of convergence in the sectoral wage ratio, although the two trends may not run exactly parallel to one another.

Ohkawa (1993) restates the idea that different sectors in the economy are responsible for convergence. During development, industry and services increase their share of output. Instead of a uniform trend, two directions are suggested. A trend of divergence for industry-agriculture and a trend of convergence for services-agriculture. Hence convergence (divergence) is a composite of these two processes.

According to Ohkawa (1993) each developing country has a domestic price structure that is indigenous to its economy. This idea is supported by other authors, including Marston (1990). Any analysis of production structure involves both income and productivity. The common view is that the sectoral ratio of PPW, in current price terms, involves only the productivity aspect. (Ohkawa, 1993). Sectoral PPW is defined in terms of an output measure for sector i (Y_i/L_i) relative to the output measure for the entire economy (Y/L):

$$\theta_i = (Y_i/L_i)/(Y/L) \qquad [3.3.1.2]$$

where i can be agriculture, industry or services. The product share is given by Y_i/Y, while the labour share is given by L_i/L. In cross sectional analysis, it is asserted that the product and labour shares fall together, with the former being larger. However the magnitude of the two, agriculture for example, $(Y_A/Y) - (L_A/L)$, does not follow a smooth line of decline. It is found that it increases for countries in groups I and II but decelerates rapidly for nations in groups IV and V. In the case of labour, the tempo of decline seems to be linearly accelerated, while in the case of product, the pattern is a zigzag. '..It is now clear that the pattern of shifting production structure is *achieved* by changes in the product share rather than in the labour share.' (Ohkawa, 1993, p. 147).

Ohkawa (1993) finds that more industrialisation tends to be associated with a greater discrepancy between product and labour, which contributes to the divergent trend. There is a recognised trend of a rising Y_I/Y_N, (output in industry relative to non-agricultural output) and a falling Y_S/Y_N (output in the services relative to non-agricultural sector) for western countries. The productivity-employment relationship changes according to the differences in technology and/or organisational and industry structure, which in turn varies with Y/L levels. Ohkawa (1993) observes that the properties of technology are different between sectors and this is a basic factor for distinguishing the productivity-employment relationship between sectors. It can be seen that capital intensity shows no sign of increase in economies in groups I to III, whereas for countries in the III to V group, it increases dramatically.

Again Ohkawa's (1993) data analysis suggests that at the sectoral level, the marginal product of labour in services is greater than in industry. In the *share approach*, it is found that divergence occurs at the lower income levels, whereas convergence is characteristic of the higher income groups. Ohkawa claims that this implies that the dominant factor is productivity and the effects of relative price changes are limited to a certain extent. Also the rate of productivity growth in the industry sector is slightly higher in agriculture through groups I through IV, followed by a reverse in the pattern for group V economies.

In the classical view, the long run price in industrial goods will follow a declining trend while that for primary products will increase. (Ohkawa, 1993). Chenery et al. (1986) see this change in price as a re-allocative mechanism which allows factor inputs to move to higher productivity areas. In a simple analysis of long term sectoral performance, output price and productivity are hypothesised to move opposite to each other, to the extent that a competitive market operates on both output and production factors. The convergence (divergence) process is composed of these two elements, both operating in a mutually inter-related manner through the market mechanism. The price effect is greater in groups I and II, but is negative in the groups III to IV. (Groups are as defined previously). Nevertheless *productivity increases are positive for all groups.* The trend of divergence becomes weaker in groups III, IV, and V, and the difference in price effects plays a dominant role. (Ohkawa, 1993). Prices and development become important in any international comparison. This is of relevance in any cross sectional and cross country comparison. (Summers and Heston, 1991).

Much of the changes in an economy due to development mentioned above are re-echoed by Chenery et al. (1986). In the case of Chenery et al. (1986) the belief is that increased development implies increases in the amount of intermediate goods in the economy. (A Smithian specialisation scenario). The movement of resources in an economy from less productive to more productive areas is a product of the evolution of the economy. This reallocation effect provides one contribution to output. (Denison and Chung, 1976).

Chapter 3.4

Factors Causing Convergence

Bernard and Jones (1996) findings comply with those above and the bulk of convergence is believed to driven by superior sectoral TFP growth rates for countries relative to the US. To this end the required focus depends on how we decide to measure convergence, which is itself a function of the factors that change as catch-up occurs.

Whatever factors are deemed to be causing convergence, it is necessary that they incorporate the fact that factor inputs tend to suffer from diminishing marginal productivity. To this end, some factor input will need to be identified that overcomes this problem and thus allows income to be an increasing function over time. Endogenous growth models, for their part, do not predict that convergence will occur. (Grier and Tullock, 1989). Some attempt must be made to identify a factor that possesses an increasing returns to scale property.

Chapter 3.4.1

Technological Diffusion

According to Schumpeter (Freeman, 1984), the capitalist system is noted for having periods where returns from factor inputs rise for a period and then fall. This is regarded as the nature of the capitalist system and some kind of wave is to be expected. It is likely that economies adopt or develop a new technology which is superior to the old. Eventually factor augmentation leads to diminishing marginal productivity and the economy reaches some new equilibrium level/path determined by this latest technology.

Fagerberg (1994) in a review of the various growth theories, including Solow's 1956 model, views technology as some kind of a public good, coinciding with the neo-classical approach. In growth theories developed by Post-Keynesians, technology is ignored. To counter the diminishing marginal productivity of conventional inputs, technology was added to the framework. Different transitional paths were believed to be the only reason for different per capita growth rates across nations. Fagerberg (1994) finds that by allowing for embodiment within capital, the importance of capital is increased in the long run model of growth.

The belief that some other element, apart from factor accumulation, is responsible for growth is widespread. (Solow, 1957; Kendrick, 1991; and Fagerberg, 1994). What is noteworthy about the convergence hypothesis is the fact that economies can adopt technologies they themselves have not created. This adoption or rather assimilation, allows for superior productivity performance from their own factor inputs, without investment in innovative capacity.

Technological development may take the form of innovation or assimilation. (Dosi and Fabiani, 1994). (Where innovation is defined to be a fixed proportional increase in labour productivity over the last innovation, with the capital to output ratio unchanged. (Silverberg and Soete, 1994)). Innovation implies that the economy invests in developing its own technology. Investment will occur in many areas without knowing which discovery will prove beneficial in economic terms. Although the overall body of knowledge may be augmented, this does not necessarily lead to a substantial increase in productivity. On the other hand, if an economy could adopt any technology it wants to, it would not face the same uncertainty. A nation with perfect foresight, could imitate technology which provided economically viable returns. Technology tends to be treated as a public good, as in Solow's approach. If a backlog of technical know-how existed and was readily accessible, it is possible for a laggard economy to augment its development rate and hence converge toward leader nations.

If technology is treated as a mobile factor, then under certain circumstances, catch-up could occur through an adoption process. Two issues are of importance here. If all factor inputs suffer from diminishing marginal product, it is necessary that this technological adoption process be continuous in nature. Alternatively, it may be the case that convergence is only occurring at this time because a back-log of technology exists, and can be adopted by laggard economies. This would imply that convergence will occur up to the point that this back-log is available to laggard economies. In epidemic growth models, knowledge transfer occurs due to an interaction effect. This belief supports the idea that openness to trade permits catch-up. Hence two factors may be responsible for the convergence phenomenon.

Chapter 3.4.1.1

Neutral Technical Change

It is necessary to ask what changes occur as technical progress ensues. Does it favour one input over another? Does it affect the relationships that exist before this particular innovation occurred?

Harrod neutral technical progress/change exists if and only if the technical change leaves, at a constant rate of profit, the capital-output ratio and therefore the equilibrium factor shares, unchanged. (Scarfe, 1977). Since Harrod-neutral change only affects the relationship between labour inputs and output, while leaving the relationship between capital and output unchanged, it is referred to as labour augmenting. This does not have to be the case. It is also possible to assume that Solow or Hicks neutral technical change occurs. However, it may be desirable to use labour as the base measure in cross sectional and time series comparisons. Many of the suggested proxies for convergence, Product per Worker (PPW) and Capital to Labour ratios (K/L) are defined in terms of labour.

Chapter 3.4.1.2

Technological Spill-overs

If technology is seen as a public good, how is it transferred from one economy to another? If we assume that technology is disembodied, then it takes the form of knowledge. Since knowledge may be used in more than one place at one time, it may have properties that essentially make it behave as if increasing returns to scale applied. The transfer of knowledge would allow an economy to gain from another nation's innovative capacity. (This is discussed in more detail later).

Chapter 3.4.2

Embodiment

It is assumed that technology is a mobile factor and one of the reasons for convergence. How does technology become diffused? Is technology itself embodied within factor inputs? (Wolff, 1994). This question pertains to embodiment and *vintage capital.* (Wolff, 1991). How does more recent capital stock differ from older capital stock? Does the investment in capital represent the potential return from that investment? Do changes in capital stock contain some component that is not present within older capital stock?

It is reasonable to expect that newer capital stocks are more efficient than older. Wolff (1991) notes that different countries have had different capital stock ages during the course of their development. This factor is believed to relate to their dominance within world markets. This would imply that capital embodies newer technology and that this is dependent upon capital stock age. Therefore, technology is transferred within and outside an economy through capital goods.

The degree of openness to trade and growth, would tend to be positively correlated, if trade allowed the dissemination of technology from one economy to another. Levine and Renelt (1992) find that investment as a proportion of GDP, is highly correlated with growth in incomes, and that the ratio of trade to output is positively correlated with the investment share. Dollar (1993) believes that trade, even among countries with similar technological capabilities, is still beneficial in that it promotes additional specialisation. It is postulated that countries have different propensities to accumulate capital in its different forms, presumably allowing potential gains from trade.

Wolff (1991) observes that TFP growth is positively associated with Capital/Labour (K/L) growth, and is strongest when capital intensity is growing rapidly.

> Results based on a regression analysis and on a vintage model are somewhat mixed but generally support the existence of an interaction effect between technology and increases in capital. Overall, convergence of labour productivity levels is found to be a consequence of all three effects. (Wolff, 1991, p.567).

It is posited by the same author that TFP levels for the group of seven (G7) converged over the period 1870-1979. Wolff (1991) finds that aggregate K/L ratios showed convergence in the long run, while technological advance and capital formation played relatively equal roles in labour productivity changes. Wolff (1991) estimates that the data shows a positive correlation of 0.79 between the rate of TFP growth and the K/L ratio over the period 1870-1979. Results generally support the interaction effect between technology and increases in capital.

It seems reasonable therefore to assume that changes in the capital stock and changes in its age structure provide a reasonable indication of how quickly countries are changing their technological capability.

Within an Neo-classical framework and analysing transitional dynamics, quantitative experiments with the fixed savings rate models of the 1960s showed lengthy transitions, thus potentially rationalising sustained differences in growth rates across countries. (King and Rebelo, 1993). They find that for realistic parameterisation of the production function, results suggest that neo-classical transitional dynamics can play a minor role in explaining observed growth rates. The physical capital accumulation process which is the key mechanism behind the neo-classical models' transitional dynamics, cannot account for much of the growth without generating very large marginal products at the early stages of development. King and Rebelo (1993) find it necessary to make the initial capital measures close to zero in order to simulate the observed transition paths seen in the data. This view is supported by Dosi and Fabiani (1994)

> Indeed the tension between the dynamic phenomena, such as technological change, and the static allocative properties summarised by a Solow type of production function shows up in the empirical estimations which often yield quite weird coefficients for marginal productivities and factor shares. (Dosi and Fabiani, 1994, p. 128).

However, if the definition of capital is allowed to broaden over time, this might improve the explanatory power of the neo-classical approach. King and Rebelo (1993) conclude that this 'transitional dynamics' problem forces them to look at models that contain some kind of endogenous growth mechanism. They also find that a version of the neo-classical model which sets capital's share close to unity, yields protracted transitional dynamics and avoids the high initial marginal products. From this, would one assume that capital was being undervalued in terms of its contribution to output? Is there some factor contained within more recent capital that remains unmeasured?

An important distinction is necessary before I proceed further. Capital Deepening is defined as the process of accumulating capital at a faster rate than the growth of the labour force. The capital-labour ratio is rising. (Pearce, 1983). Capital widening is the process of accumulating capital at the same rate as the growth of the labour force so that the capital-labour ratio remains constant. (Pearce, 1983). The distinction is useful as we are discussing the effect factor intensities on long run growth.

If factor inputs were being understated, this would imply a role for some residual term to account for changes in growth. It may in fact be the case that additions to capital (and human capital) stock are actually accounting for growth. Young (1994) for his part, believes that the neo-classical framework can still explain some of the 'phenomenal' growth stories seen after World War II, provided factor inputs are measured properly. Dowrick (1992) holds a similar belief. In his examination of newly industrialised nations, (NICs), he finds that increases in inputs are a significant factor in the growth process. 'The growth decomposition .... suggests that nearly half of this exceptional performance can be attributed to faster than average (growth of) factor inputs relative to the population.' (Dowrick, 1992, p. 606). It is further noted that employment deepening plays a more significant role than capital deepening in three of the five countries examined.

It is conceivable that more than one type of technology may exist within the world and that technologies have differing degrees of mobility. According to Brezis et al. (1993) technology may exist as normal knowledge which can be traded. However there may also be some type of 'learning by doing' effect associated with technology. Brezis et al. (1993) believe that if certain sectors of the economy experience more endogenous technological growth than others, say through learning effects, then this country has acquired a comparative advantage in such sectors. This advantage will tend to be reinforced over time. Given that convergence only occurs within certain samples, some factor must either make the technology transferable or some element must change within the economy adopting the new technology, so that it can itself make use of this technical development. This contention forms the basis for the Chapter following.

Chapter 3.4.3

Social Capability

If one assumes that technology is a public good, a mobile factor or that it is transferable across sectors and economies, then what prevents its adoption in some economies and not others? Divergence is observed when the all economies are examined. The convergence phenomenon occurs within certain samples of economies. The question is why then is convergence not a world-wide phenomenon? It would be logical to conclude that some factor is preventing all economies from experiencing convergence. Is it the nature of technology or some factor specific to an economy that inhibits technological transference?

The idea of *social capability* is proposed by Abramovitz (1986). It is suggested that a country's ability to adopt technology is dependent on factors within that nation. Social capability is likely to encompass such factors as the educational level and infrastructure. It is believed that an economy can adopt technology based on its social capability. The adoption of a particular technology depends on the level of social capability. The level of social capability determines the type of goods that are produced and the technological area that the economy competes in. Foster and Rosenweig (1996) find that a relationship exists between education and the adoption of new technology. However, a level of education is required to adopt more advanced technologies. For example, primary school education is appropriate for adopting new agricultural methods but is insufficient for more advanced technologies.

Attempts to increase social capability represent an explicit investment by the economy and is designed to augment factor inputs. In this case augmenting social capability would have the effect of increasing the effective units of labour, although the labour force is constrained by the growth of the population. (This assumes disembodied technical change). It is therefore necessary to account for this investment. (Young, 1994). Further the inclusion of human capital within the definition of capital would also have the effect of leading to more feasible transition paths under neo-classical assumptions and hence reconciles a problem associated with these types of models. (King and Rebelo, 1993).

Given that sectoral convergence is likely to occur and differential productivity within sectors is an accepted fact (Balassa, 1964), it seems reasonable to note that social capability may itself have been sector specific. If convergence occurred only within some sectors, such as services, but not in manufacturing, then this may have been due to some characteristic of social capability. It may be the case that the slow productivity growth in the nontraded sector permitted the extent of the convergence seen in the data. Similarly, it is argued that in the case of the Japanese economy, although its traded sector achieved high productivity growth, its nontraded sector did not. (Marston, 1989).

Consequently, measurement of the additions to the effective units of labour is essential. Investment in education must be designed to improve the effectiveness of labour. The fact that changes in technology may also augment labour or more accurately labour's productivity level, requires careful consideration. It is found by Foster and Rosenweig (1996) that investment in education increases the adoption rate for new technology. Certainly the unwillingness to invest in human capital inhibits the ability to assimilate another economy's technological capability. To allow catch-up to occur some attempt must be made to allow the domestic economy to alter characteristics within its structure, allowing it to benefit from the technological know-how that exists within the leader economies. The investment in assimilative capacity does not end with investment in capital goods.

Chapter 3.5

Conclusion

It is accepted therefore that convergence has in fact occurred for some economies. Some laggard economies have been able to increase their per capita income levels. They have increased their production paths over time. For those economies that were able to converge to the leader economies of the World, we would expect to see changes in their exchange rates relative to the leader economies. Their exchange rates should have appreciated to reflect this increase in productive capacity.

Without convergence it is difficult to see how a long run appreciation of a currency is justified. On the other hand, divergence should lead to a depreciation of a nation's exchange rate. It is the change in the wealth producing ability of the economy that leads to a change in the exchange rate.

The fact convergence has not typified all economies requires explanation. The logical conclusion is that not all economies are the same. There are those economies which have failed to alter their production paths. A possible explanation for this phenomenon is found in the next chapter.

CHAPTER FOUR

SOCIAL CAPABILITY

Chapter 4.0

Social Capability

As previously stated, the ability of nations to converge or develop over time is an accepted empirical fact. However convergence is limited to certain samples of economies. (C. Romer, 1986). The World economy is characterised by divergence. There would appear to be some inconsistency. Either the properties of technology are not transmittable to all economies, or certain countries are unable to assimilate the technology of a more advanced nation.

The intention of this chapter is to isolate the factor or group of factors that promote convergence in some economies while restricting it in others. By explicitly identifying this phenomenon it is further possible to explain why some exchange rates converge over time while others diverge. From the literature reviewed, the idea of social capability provides a reasonable explanation why convergence typifies some economies and not others.

If divergence characterises one set of economies, these economies may have barriers to technology as claimed by Parente and Prescott (1994). Alternatively, some economies may not have developed the social capability to assimilate another economy's technological ability. (Abramovitz, 1986). Social capability is the capacity of an economy to adopt another nation's technical achievements. Since capital goods are internationally traded goods, it is unlikely that the inadequacy to adopt technology resides within the embodied area. It would be more reasonable to assume that the problem exists with disembodied technical change.

How does social capability manifest itself? The inclusion of human skills within the definition of capital has been suggested in the past for a number of reasons. This treatment of labour allows the overall 'capital' measure to approach unity and is believed to provide more realistic transitional dynamics within growth models. The increasing proportion of the services sector within economies has also promoted the desire to examine labour and changes in effective labour units. Analysing the labour side of the economy may lead to an understanding of social capability.

In this chapter I intend to analyse the factors that are necessary for convergence to occur. The focus on social capability becomes an analysis of the labour side of the economy. It becomes evident that the labour side of the economy has not received the attention that it deserves. The work by Solow (1956) provides a convincing explanation for growth and differential growth rates. The model requires some refining. Mankiw et al. (1992) provide a more accurate explanation of growth and differential growth by including an effective labour measure. Their model explains 80% of the differential growth rates observed. Of course Mankiw et al. (1992) model has the advantage of more reliable data provided by the work of Summers and Heston (1988). This is an important point since the work of Ohkawa (1993) and others warn against the comparability of international statistics.

The chapter further examines the contribution made by labour using the idea of human capital. The augmentation of human skills represents an explicit commitment of resources and this must be included in growth models. I investigate a possible measure for the return on human capital in an attempt to isolate labour's contribution to income. While Mankiw et al. (1992) believe that the marginal product of labour ranges from 1/3 to a 1/2, this figure is based on the use of a wage measure. I find that there is great difficulty in justifying that the marginal product of labour is reflected in changes in the wage level. The problem of international comparisons is further hampered by the fact that prices for goods tend to be more correlated nationally than internationally. Therefore the use of a wage measure as an indicator of labour's contribution to growth becomes even more difficult to defend.

What I conclude from this analysis is the fact that there are serious problems in attempting to isolate the contribution of the labour side of the economy to the overall growth of a nation. Nevertheless the labour side of the economy is essential to this analysis since it is a possible common denominator value for a relative efficiency measure.

Chapter 4.1

Assimilative Capacity

Technological diffusion has occurred from first world countries to laggard economies. (Wolff, 1991). The opening up of trade and foreign direct investment appears to have promoted the dissemination of technology. Verspagen (1991), uses a non-linear model, allowing for catch-up or falling behind. The tested model included a technology gap variable (GDP per capita), social capability (proxied by education), investment (in equipment), and innovative activity (measured by patents).

Social capability or assimilative ability, is the purported reason for the inability of some economies to adopt newer technologies and thus develop. Convergence occurs within certain samples of economies notably within the OECD. (Grier, 1989). This implies that the OECD economies may contain certain attributes that allow technology to diffuse unhindered.

Investment within education attempts to increase human capital. (Feldstein, 1994; Gemmell, 1996; Foster and Rosenweig, 1996). The involvement of government in investment projects provides an additional reason for increases in social capability. Both increase the ability of the economy to use technology that it has not developed itself. The stock of technology amassed by the first world or leader economies provides an incentive for lesser developed countries to copy and assimilate this technology. By developing the ability to import this technology they remove the need to pursue independent innovation programs to promote growth.

The innovation process does not guarantee success, only an increased likelihood of same. It is conceivable that the return from the innovation process is less than if one attempted to imitate another economy's technology. The latter is likely to be a more deterministic process with an increased chance of success. Catch-up becomes more likely as investment is made in assimilating the technology through changes in human capital and through investment in the infrastructure needed to benefit from this new technology. Failure to invest in this area inhibits the ability of an economy to incorporate alien technology into its own productive capacity framework. Both Mankiw et al. (1992) and Ohkawa (1993) claim that the addition of an educational variable within an income growth analysis creates a better understanding of economic development. Countries that possess the social capability to assimilate a technology, do so and compete in that area. This leads to a situation that countries vie in those technological areas that they can duplicate. Therefore development takes the form of the aptitude to compete in more and more advanced technologically based industries. Increased social capability facilitates the adoption of technology. (Foster & Rosenweig, 1996).

Romer (1987) claims that conventional growth accounting substantially underestimates the role of capital accumulation in growth. The correct weight in the rate of growth of capital in a growth accounting framework may be closer to 1 than 0.25. The true elasticity of output with regard to changes in capital may be greater than the share of capital in total income because of positive externalities associated with investment. This view is consistent with the long run growth of output and productivity and explains growth without introducing exogenous technological change. *Therefore the introduction of human capital is a way to increase the role of capital in the development and transition of an economy.*

Chapter 4.2

Human Capital Measurement

The addition of human capital as an explanatory variable in the interpretation of income growth and economic development, seems to be a natural and necessary progression. It is unreasonable that technology could only be transmitted through the aggregation of physical capital. King and Rebelo (1993) claim that overall, for realistic parameterisation of the production function, results suggest that neo-classical transitional dynamics can play a minor role in explaining observed growth rates. That is, the physical-capital accumulation process, which is the key mechanism behind the neo-classical model's transitional dynamics, cannot account for observed growth without generating very large marginal products at the early stage of development. It is their conclusion that this forces one to look at models that contain some kind of endogenous growth mechanism. They also find that a version of the neo-classical model that has a capital share close to unity yields protracted transitional dynamics and avoids the high initial marginal product. But this model is clearly unrealistic unless one broadens the definition of what capital is. Indeed the underestimation of the investment in human capital is one source of explanation as to why the Solow residual appears to be so high within NICs. The addition of human capital into the production function, allows capital to reach a near unity value and thus provides some explanation for the income deviations observed cross sectionally. (Mankiw et al., 1992; King and Rebelo, 1993).

Chapter 4.2.1

Human Capital

The concentration on human capital as a possible explanation for differential growth is based on the following argument. If capital mobility is accepted , then divergent growth patterns should diminish over time. Although barriers may exist in LCD's (Parente and Prescott, 1994) and some second world countries, capital mobility seems to be a reasonable assumption. Even within the first world countries or OECD, differentials in growth are observed. Therefore some other factor is responsible for differential growth patterns. The existence of some nontradable input within economies is a possible explanation for these differential income and productivity growth patterns. (Buiter and Kletzer, 1992).

The explicit recognition that education and skill levels are contained in the human capital stock is necessary for an understanding of growth experiences. Increases in the labour supply would be expected to occur as the economy develops. Through the natural rate of increase in the population and changes in the participation rate, the labour force will rise. This is a characteristic associated with economic development.

Movement away from labour intensive areas creates an excess supply of labour in those areas, principally resource based industry. Areas that provide new employment tend to pay a higher wage than resource based industry. Hence labour relocates to these growing employment areas.

This increase in the labour force ignores the investment made in education that tends to occur as an economy develops. Failure to account for this investment increases the size of the residual or total factor productivity term. It also implies that capital is the sole requirement for development and convergence toward leader economies.

Investment in skill enhancement is an explicit allocation of resources. (Lipsey and Kravis, 1988). As an economy develops, there is a move away from investment in physical capital and a move of resources into human capital. (Williamson, 1991). Gerschenkron (1962) believes that the dominance of the US as an economic power was due to two factors. One of these factors was the US investment in education and R & D which allowed it to maintain its lead as dominant economic power with respect to laggard economies. Although knowledge may be a public good or technology may be internationally mobile, if a 'learning by doing' effect is present this could help explain why convergence has not occurred for all economies at the same speed, and why some leader economies have not had their position or comparative advantages eroded.

Increases in investment in education would be expected to increase the ability of economies to assimilate new technology and to increase the efficiency of present endowments. In effect, the efficiency units associated with the labour factor would rise. (King and Levine, 1994).

Chapter 4.2.2

Labour Models

Solow (1956) proposed that the study of economic growth should be conducted by assuming a standard neo-classical production function with decreasing returns to scale applying to capital. Solow assumes that the rates of saving and population are exogenous and shows that these two variables determine the steady state level of income per capita. Since savings and population rates vary across countries, different countries can have different steady states. Solow's model shows that saving and population affect income in positive and negative fashion. A higher savings rate implies a richer economy while a higher population growth rate leads to a poorer economy. Mankiw et al. (1992) support the Solow (1956) predictions and claim that the model explains over 50% of the cross-country variation in income per capita. A problem with Solow's predictions is that they fail to correctly predict the magnitudes of the effects that savings and population have on income. Some other variable needs to be included within Solow's (1956) labour model to account for the variation in income. Further, the inclusion of an additional variable would overcome the criticism of neo-classical growth models. That is, the models predict unusually long transition paths.

It is necessary to analyse some of the more recent labour models in order to uncover what aspects within the labour measure promote growth. King and Levine (1994) suggest using the Solow-Denison-Maddison's accounting framework to analyse the growth in income. Income is a Multiplicative function of labour, capital and technology. The effect of labour is augmented by the inclusion of a labour efficient measure.

$$Y = AK^{\alpha}(nN)^{1-\alpha} \qquad [4.2.2.1]$$

n is the number of units of output per unit of labour input - a labour efficiency units measure. Y is income, K is capital and N is the labour force. A is technology. The marginal product of the inputs is given by α and there is a constant returns to scale assumption. Technology is expected to increase with the educational and training level of the economy. Since countries differ in size, it is desirable to deflate the above by some population or labour force measure. Again it should be noted that it would be a mistake to ignore any scale effects that are likely to exist for large economies, something smaller economies would fail to possess. Deflating [4.2.2.1] by N gives:

$$y = Ak^{\alpha} n^{1-\alpha} \qquad [4.2.2.2]$$

Taking natural logs we obtain

$$\Rightarrow \ln y = \ln A + \alpha \ln k + (1-\alpha)\ln n \quad [4.2.2.3]$$

where y = Y/N, denotes output per person or per worker; k is K/N, or capital per worker. In the growth accounting framework this becomes

$$\Delta y/y = (\Delta A/A) + \alpha(\Delta k/k) + (1-\alpha)(\Delta n/n). \qquad [4.2.2.4]$$

Changes in income are a function of changes in technology, capital, labour and the marginal product of capital which is determined by capital's contribution to growth. The A term becomes the TFP growth measure and Δ is the first difference operator.

For a comparison of two national measures of output per person equation [4.2.2.4] is simply divided by the output per person equation associated with that economy.

$$[y_i/y_j] = [A_i/A_j][k_i/k_j]^{\alpha}[n_i/n_j]^{1-\alpha} \qquad [4.2.2.5]$$

Subscript i and subscript j represent the two countries. A specific treatment is provided for changes in the labour measure to account for additions to labour occurring over time. The above treatment of output uses labour as the denominator value. Since labour is a relatively nontraded input the treatment is interesting. Some manipulation of equation [4.2.2.5] may provide a solution to our relative efficiency measure.

The explanation of growth by Mankiw et al. (1992) emphasises the roles of population and savings. It is assumed that both population and savings are exogenously determined forcing variables. Technology is treated as an exogenously determined variable. The model is augmented by Mankiw et al. to include human capital and this specification is believed to explain 80% of the variation in income over time and across countries.

$$Y(t) = K(t)^{\alpha} (A(t) L(t))^{1-\alpha.} \qquad [4.2.2.6]$$

Y(t) is income in period t. K is capital in period t and A and L are technology and labour respectively. Technology is time dependent. The marginal product of capital has a value between zero and one. $(0<\alpha<1)$.

Growth rates are exogenously determined. Labour is assumed to be driven by some natural process (an exponential function) as is technology.

$$L(t) = L(0)e^{nt} \quad [4.2.2.7]$$

$$A(t) = A(0)e^{gt} \quad [4.2.2.8]$$

L(0) represents the labour force in time period zero and the growth rate is determined by n. In the case of Technology, the period zero level of technology is given by A(0) and its growth rate is determined by g. g is the advancement in technology and n is the rate of population increase.

Here the model includes technology in the labour measure, explicitly recognising the fact that changes in labour are occurring over time. Disembodied technology is being contained within the labour measure since investment in education allows labour to assimilate new technology and later to create its own.

A steady state is achieved on the basis of movements in the savings and population rates. From the original Solow (1956) model more than half the variation in income per capita can be explained by these two variables alone. However, the model does not correctly predict the magnitudes. This is the motivation behind adding in human capital as a possible explanation of income growth and variation across countries. Solow's model predicts that countries will attain different steady states, and thus convergence is not expected to occur. Mankiw et al. (1992) find that once differences in savings and population growth rates are accounted for, there is convergence at roughly the rate that the model predicts.

The number of effective units of labour grows at the rate n + g, where g is the advancement in knowledge and is assumed by Mankiw et al. (1992) to be non-country specific. The model assumes that a constant fraction of output *s* is invested. Thus the capital to output ratio k is given by

$$k = K/AL \quad [4.2.2.9]$$

and the output to labour ratio is given by

$$y = Y/AL \quad [4.2.2.10]$$

Both measures incorporate the effect of technology explicitly.

The evolution of k is determined by

$$\dot{k}(t) = sy(t) - (n + g + \delta)k(t)$$

$$\dot{k}(t) = sk(t)^{\alpha} - (n + g + \delta)k(t)$$

[4.2.2.11] and [4.2.2.12]

k is the stock of capital per effective unit of labour, k=K/AL, and y is the level of output per effective unit of labour, y=Y/AL. n is the growth rate of labour as defined above and g is the growth rate of technology. δ is a depreciation rate of capital and α is capital's share in income. Equation [4.2.2.12] implies that k converges to a steady state value k*, defined by $sk^{*\alpha} = (n+g+\delta)k^*$, or

$$k^* = [s/(n+g+\delta)]^{1/(1-\alpha)} \qquad [4.2.2.13]$$

The steady state capital-labour ratio is related positively to the rate of saving and negatively related to the rate of population growth. Substituting [4.2.2.13] into the production function and taking logs, the steady state income level is given by equation [4.2.2.14].

$$\ln\left[\frac{Y(t)}{L(t)}\right] = \ln A(0) + gt + \frac{\alpha}{1-\alpha}\ln(s) - \frac{\alpha}{1-\alpha}\ln(n+g+\delta) \qquad \textbf{[4.2.2.14]}$$

Where δ is the depreciation rate and α is the share of capital. It is assumed by Mankiw et al. (1992) that α is 1/3, giving an elasticity of income per capita with respect to s of 0.5. Hence n+g+δ has an elasticity of -0.5. **g,** the advancement of knowledge, is assumed not to be country specific. A(0) reflects not just technology but resource endowments, climate, institutions, etc.. This may differ across countries as represented by equation [4.2.2.15].

$$\ln A(0) = a + \varepsilon \qquad \textbf{[4.2.2.15]}$$

where a is a constant and ε is some country specific shock. The decision to include a country specific shock within the technological process allows for the possibility that there is some factor contained within the technological process which is non-tradable. Such a factor could be human capital or the educational system within the nation. This is similar to the interpretation by Buiter and Kletzer (1992). Nevertheless, Mankiw et al. (1992) arrive at a final equation [4.2.2.16], and this becomes the empirical specification that is tested.

$$\ln\left[\frac{Y}{L}\right] = a + \frac{\alpha}{1-\alpha}\ln(s) - \frac{\alpha}{1-\alpha}\ln(n+g+\delta) + \varepsilon \qquad \textbf{[4.2.2.16]}$$

From this specification, income per capita or per worker is shown to be a function of investment, changes in technology, changes in labour, and the depreciation rate (δ). From [4.2.2.16], increases in income per capita are determined by investment and changes in n, g, and δ.

The treatment above illustrates how using labour as a base measure, it is possible to isolate a number of clear contributors to growth. The use of an income per capita measure is also something I will make use of in my own model.

Chapter 4.3

Human Capital Stock

Does an estimate of human capital stock provide an explanation of differential growth paths? Let a unit of human capital be defined as a member of the population whose age is greater than 15 and less than 65. The unit of human capital is defined as having an economic value greater than zero. This implies that anyone who is in the workforce more than 50 years ago, would now be obsolete. (This is similar to the approach followed by Nehru, Swanson and Dubey, 1993). This provides a way to normalise the population with respect to skill and educational levels.

If V_i is the amount of the population in the age category i, then $\Sigma V_i = V$, and economic units have a value greater than zero, when they are between V_{15} - V_{64}.

$$L_i = \Phi(V_i). \quad [4.3.1]$$

and

$$\Sigma L_i = L \qquad [4.3.2]$$

where $15 \leq i < 65$

$$L = \Phi \sum_{i=15}^{i<65} V_i \qquad [4.3.3]$$

Where L is the size of the labour force, and Φ is the participation rate.

In an attempt to normalise the labour stock it is likely that agents over 50 years in the potential workforce now have an economic value of zero. Any members of the labour force from 50 years ago should now be inactive. If data is available from this period it provides a reasonable starting point for international comparisons. By assuming the above we can now compare the additions that investment has brought to the human capital stock.

The participation rate is assumed to be some positive function of the income level within the economy and perhaps the educational level. A participation rate can be estimated roughly by looking at population growth rates and labour force statistics. It is likely to be increasing over time. Among first world countries this population increase tends to slow and approaches similar values. (Psacharopoulos, 1985). Again this should help to improve comparability of human capital and isolate the contribution of labour to the growth process.

Chapter 4.3.1

Factor Shares

Data on population size is readily available. It is likely that the participation rate coupled with the skills level provides a greater contribution to productivity and income levels. Increases in factors of production are important determinants of growth and income. Changes in the participation rate and changes in the education level should isolate the changes in productivity levels attributable to labour.

We are left with the estimation of the human labour stock size. As mentioned earlier it can be normalised to zero, by using data starting from 1945. We are concerned with increases in the size of the labour force since that period. It is likely that there is a difference between the participation rates of the female side of the labour forces and the male, with the former showing an increase over the period. This higher female participation rate may be nullified to some extent since the female portion of the labour force tends to get paid a wage level below that of her male counterpart.

Should we simply examine increases in the labour force from a unit perspective or should we deal in hours? In the case of the leader economies, we see a reduction in working weeks, increases in holidays etc. Simply examining the number of workers may be an inappropriate measure of the true increase in this factor. Although participation rates may have increased, actual time spent at work is likely to have been reduced.

Assume

$$\Phi = \phi(Y) \quad [4.3.1.1]$$

That is the participation rate is a function of income. Perhaps a more reasonable representation is

$$\Phi = \phi(Y/L) \qquad [4.3.1.2]$$

The participation rate would be expected to be some function of the income per capita. Isolating those active members of the population (V)

$$\Phi = \phi_i (Y/V_i) \qquad [4.3.1.3]$$

Where $15 \leq i < 65$. That is the participation rate within a particular section of the population i.

As per capita income rises so also does the participation rate within the economy. Reductions in under-employment and unemployment lead to increases in efficiency. Should this be attributed to education or simply to the better allocation of resources?

The participation rate may be calculated by dividing increases in the workforce by increases in the population. It is possible that an economy might experience "bulges" in the distribution of its age structure, making larger/smaller sections of the population eligible to enter the workforce. In both time series and cross sectional analysis this may be of relevance. The natural rate of increase in economies tends to converge as the economy moves into the most developed stage. This should make cross sectional analysis within stages of development more comparable. However the different rates of participation or employment deepening can provide a substantial contribution to income growth over time.

Chapter 4.4

Educational variables

Investment in education provides the medium through which resources are channelled through labour. Investment in education alters the skill level of the workforce, increases its assimilative capacity, if not also its innovative ability. Innovative capacity tends to be proxied by patents and expenditure on R&D. There is some controversy over whether these measure accurately reflects innovative ability. It is obligatory to acknowledge that this is happening. Investment in education now makes the labour side of the model, or labour efficiency units, an endogenous part of the overall system.

Education has become the focus of many authors in an attempt to explain the variations in output and income seen in the data. The inclusion of education further provides more practical transitions for economies within growth models. (Psacharopoulos, 1985; Buiter and Kletzer, 1992; Nehru, Swanson and Dubey, 1993; Barro and Lee, 1994; Feldstein, 1994; Gemmell, 1996). The problem facing us is to apportion the contribution of education to growth. It is intended to examine a number of potential estimation procedures.

Investment in education and the potential earnings foregone by delayed entry into the labour force may provide one indication of the cost of investment in education. Assuming agents that stay in education, do so to increase earnings in the future, or that the marginal product of labour is similar to the wage level, the difference between the minimum wage and that offered at other levels of education may provide an indication of potential earnings foregone. (Mankiw et al., 1992).

Using *school enrolment rates* (SERs) provides information on the size of the workforce participating in education as well as a stock value of skills. (Gemmell, 1996). Gemmell suggests splitting SERs into three levels, with a fourth for 'on job training'. Results for that paper show that although 'on job training' does provide additional skills, formal education is the most significant contributor (of skills) to the human capital stock. It is noted in fact that secondary education appears to be the most significant educational variable in regressions using education and growth in income. (Gemmell, 1996). In the case of Psacharopoulos (1985) it was believed that primary education provided the highest return. It was also noted that education for women provided a higher return than for men, even though women received lower earnings in all countries.

An estimate of the labour force times the skill level in the economy should provide an approximate estimate of effective units of labour. Nehru, Swanson and Dubey (1993), define the addition of skills to the human capital stock as the size of the labour force times the length of time in education. This is referred to as the sum of *person-school years*. Overall the intention is to calculate the rate of change in the skill level of the economy, which leads to increases in the effect units of labour. The problem is in calculating the increase in labour productivity coming from increases in skills. The participation rates and the school enrolment rates show the increase in factor size. See Appendix F for a more comprehensive review of Nehru's calculation of capital stock

Chapter 4.5

Proxies for the Return on Education

The suggestion that using a "loss of earnings" estimate as a proxy for the return from education and investment therein has been noted by a number of authors. (Parente and Prescott, 1994; Mankiw et al., 1992). If additional skills are provided through education this would be expected to increase the marginal product of labour. In Psacharopoulos (1985) the author regresses the type of education in different countries against wage earnings. Earnings foregone by labour and/or additional earnings, should provide a reasonable estimate for the return on education.

Unfortunately, increases in the wage level are likely to be some function of the domestic price level in the economy. It is argued that changes in productivity may be reflected in the wage level. Bernanke (1982) points out that a barrier to structural analysis of labour productivity change is that many of the key exogenous variables which affect productivity (technological change, determinants of product demand, labour supply, and/or the cost of non-labour inputs) may be quite difficult to measure. In the analysis of productivity disturbances, 90% of the variances in labour productivity are due to shocks to the production function and to capital costs, while changes in the product demand and labour supply, together with transitory influences, are relatively insignificant factors.

In Lawrence (1995) it is argued that compensation per worker actually increased in line with output per worker. When nominal compensation is deflated by a production price index (in this case the business sector GNP deflator) rather than by the CPI, this production wage closely tracks the growth in output per worker from 1979 to 1991.

It is difficult to attempt to apportion returns to labour using the wage level. A lack of international labour mobility would tend to allow international returns from education to persist. Psacharopoulos (1985) finds that in the case of developed economies, a tendency exists for the gap between the returns from capital and labour to narrow. In developing countries there is a clear advantage for human capital over physical capital investment. A higher return exists for labour in developing economies versus developed economies.

We are thus left with the problem of correctly estimating the contribution that education brings to human capital and hence the contribution to income growth.

Chapter 4.6

Labour Input and Labour Productivity

The difficulty facing us is to identify some variable that actually reflects the contribution of labour to growth. An obvious starting point is to examine whether the wage level in one economy reflects its marginal product. Secondly we would need to examine whether wages were internationally comparable. Certainly Ohkawa (1993) warns against depending on wages for international comparisons when comparing countries at different stages of development.

If labour is defined in the following manner

$$L = \ell(G, \Phi). \qquad [4.6.1]$$

Labour supply (L) is some function of a set of factors G, and the participation rate. Φ is the participation rate and is some function of income. (Tax rates would also be of relevance but will be avoided at this time).

$$\Phi = \phi(Y) \qquad [4.6.2]$$

$$\phi'(Y) > 0 \qquad [4.6.3]$$

The skill level (S) is some function of the time in education and the level attained.

$$S = f(E_t, E_i). \qquad [4.6.4]$$

If changes in the education level lead to changes in the wage level or if differences in wage levels exist for workers with different skill levels, then

$$W - W_{min} = \omega(S) \Rightarrow W^* = \omega(f(E_t, E_i)). \quad [4.6.5]$$

That is, the difference in a particular wage and minimum wage ($W-W_{min}$) is some function of skills (S) which is in turn some function of time in education (E_t) and the type of education (E_i).

This implies that increases in output that are attributable to capital productivity gains are not passed on to labour in the form of increases in the wage level. Wage increases come from increases in the educational level, which is itself a function of resources allocated to augmenting skills.

However, there is a strong relationship between prices within national boundaries. This casts doubt on our ability to use wages as an indicator of labour's productivity in international comparisons. Prices tend to move more in line with changes in national variables rather than changes in the international environment. (Marston, 1990). This is as expected, given that labour mobility is higher nationally than internationally. Simply using the wage level as a comparison between countries may not therefore be appropriate. Moreover, there may not be an international wage within certain industries with which to make comparisons.

If we attempted to identify which factors are related to the wage level, then perhaps some specification like:

$$W^* = \omega_1 E_t + \omega_2 E^p + \omega_3 E^s + \omega_4 E^v + \omega_5 CPI_t + u_t \qquad [4.6.6]$$

is appropriate.

Here E_p is primary education as a fraction of total education at a particular time period, E_s is secondary education as a fraction of total education at a particular time period, E_v is tertiary education as a fraction of total education, with all three dependent on time. CPI is the consumer price index and WPI is the Wholesale price index.

It would be expected that the wage level increases with prices within the economy. It is then necessary to deflate the wage level by that amount. Does the wage level of the economy move in general or is it more likely that lower wage levels move due to changes in the price structures of the economy? Further, do higher wage levels reflect changes in productivity? If general movements in the wage level are indicative of changes in the CPI, estimation of the correlation of changes in the wage level across all sectors may provide a reasonable estimate of the CPI's effect on W.

It is likely that the traded sector provides a better insight into international price shocks, therefore estimation of the following equations may also be appropriate.

$$W^* = \omega_1 E_t + \omega_2 E^p + \omega_3 E^s + \omega_4 E^v + \omega_6 WPI_t + u_t \quad [4.6.7]$$

$$W^* = \omega_1 E_t + \omega_2 E^p + \omega_3 E^s + \omega_4 E^v + \omega_7 (CPI_t - WPI_t) + u_t \quad [4.6.8]$$

Increases in the labour force are assumed to come from the natural rate of increase (exogenous variable) times the participation rate in the economy. Increases in the marginal product of labour are assumed to come from investment in education, and the opportunity earnings sacrifice associated with delayed entry into the labour force.

$$V_i \Rightarrow W > 0 \qquad [4.6.9]$$

where $15 \leq i < 65$.

Those units of labour that exist within the age groups 15 to 64, would be expected to have an economic value close to $W_{min.}$ Wages received that exceed this level would be expected to be based on some higher productivity level, assumed to be a function of the skill level.

Without education, these units would be entitled to a wage level at or near the minimum rate in the economy.

$$S\Phi(V_i) \Rightarrow (W - W_{min}) > 0 \qquad [4.6.10]$$

where $S \geq 1$ implies that $E_t \geq 0$, and $i \geq 15$ and $i < 65$.

Following Mankiw et al. (1992), and assuming that V is generated by some process represented by an exponential function.

$$V_t = V_0 \, \Lambda^{gt} \qquad [4.6.11]$$

$$\ln V_t = \ln V_0 + \ln \Lambda^{gt} \qquad [4.6.12]$$

$$\ln V_t = gt\Lambda \qquad [4.6.13]$$

Labour grows at some exponential rate (g), determined by the rate of natural increase in the economy.

If [4.6.8] implies that there is a relationship between the wage level and the expected productivity increases brought about by increases in social capability, then this should be incorporated into a general model of real exchange rate determination. If the wage level is not an accurate measure of changes in productivity or a reflection of skill enhancement, then the above analysis fails.

Chapter 4.7

Conclusion

It is expected that changes in the educational level of the economy lead to an increase in the skill level of the economy. This may be reflected by a change in the wage level, but this may be hindered by a number of factors. It would be expected that the investment in education and skill development, combines to increase social capability and this aids the ability to assimilate new technology.

It is necessary to use some proxy to represent the investment in education other than changes in wage levels. A regression of wages on prices, indicates that the two are highly correlated. The residual term is small, ruling out the possibility that increases in the real wage rate actually reflect increases in labour productivity. As an alternative, it is decided to use some output proxy.

It is unfortunate that estimates of the contribution from labour investment are difficult to measure and estimates exhibit such variance. However, should there be one reason why one economy performs in a superior fashion to another, then it is likely that labour and its attributes are the reason. This avenue is pursued further.

CHAPTER FIVE

PERFORMANCE MEASURES

Chapter 5.0

Performance Measures

This chapter deals with two issues. It focuses firstly on productive capacity and the nature of technology. It examines development in an aggregate sense and then proceeds to explore development in a dichotomous framework. The economy comprises both a traded and a nontraded sector. It is important to determine whether the two sectors are so different as to warrant a separate analysis. It may be the case that the contributions of the traded and nontraded sectors are so different that in aggregating their contribution, I will fail to identify the true relationship between relative efficiency and the real exchange rate.

The exchange rate and the real exchange rate tend to be associated with the traded sector of the economy. The hypothesis suggested in this work is that the real exchange rate actually reflects the performance of the entire economy not just the traded sector. The efficiency of both the traded and nontraded sectors of the economy should affect the real exchange rate. It is necessary to provide support for this opinion. I propose to examine the work of authors who emphasise the dichotomous nature of economies.

The traded sector is open to international competition. The traded sector would be expected to be more efficient than the nontraded sector. Does the real exchange rate give a greater weighting to the traded sector of the economy and is this relevant to the analysis? The concept of differential productivity growth is examined in order to investigate whether this is true. Is differential growth a symptom of the dual nature of the economy?

The nature of productive capacity is examined first. Productive capacity is best measured using a labour measure. By focusing on a labour measure, I believe that I can encapsulate both the traded and nontraded sectors contribution to income growth. In this way I believe that it is possible to overcome the problems associated with differential growth and allow the use of an aggregate measure of economy performance.

Chapter 5.1

Productive Capacity

The overall intention of economic activity is to increase the standard of living. Utility is defined in terms of the ability to provide for present and future consumption patterns. Productive capacity is altered by either increasing factor inputs or increasing the efficiency with which inputs are used. It is necessary to examine both factor inputs and technology in an attempt to measure productive capacity. Changes in productive capacity over time should affect the ability of the economy to change its output production path.

The diminishing marginal product assumption ensures that growth models of the economy have a non-explosive nature. The convergence phenomenon associated with the post World War II period challenges this assumption and implies that the assumptions of neo-classical growth models need to be modified or replaced to accommodate convergence. The need to explain convergence and/or create a model that predicts sustained growth has encouraged interest in endogenous growth models. However it is argued by Young (1994), that this is unnecessary. Young (1994) claims that factor inputs have been underestimated. Others have suggested that some factor input must provide increasing returns to scale to counter the diminishing returns assumption. One such input could be technology or knowledge.

Rather than changing the specification of the production function from constant returns to scale (CRS) to increasing returns to scale (IRTS), it may be assumed that some exogenous factor exists and counters the diminishing marginal product assumption. (Romer, 1987). According to Silverberg and Soete (1994), externalities are a way of dealing with IRTS without relinquishing perfect competition assumptions. One factor that can allow a CRS production function to counter the diminishing marginal returns assumption is technology or knowledge. This approach is common in the growth literature. Solow's original model (1956) has been augmented by some authors to expand the definition of factor inputs and to endogenise knowledge and technology based improvements with existing factor measures.

Here I intend to examine the nature of technology and to better understand how it is transferred between economies. There are two aspects of technology.

Embodied technology consists of technology that are incorporated in the output of the economy. Capital goods are regarded as traded goods. The importation of capital goods is one possible avenue by which a laggard economy could attain technology which it itself had not created. Obviously openness to trade could increase speed of dissemination of technology between economies. Therefore increases in embodied technology enhance productive capacity.

The increase in the speed of capital accumulation would be expected to reduce the age of the capital stock. It is believed that a change in the average capital stock age would imply newer technology. Hence capital stock age should act as a proxy for technological embodiment.

Technology is not always embodied within capital goods. Changes in how inputs are altered in the production process provides a means for output to increase over time. This is referred to as disembodied technological change or learning effects. Disembodied technology is only transferable if the economy has the capability to adopt it. Therefore social capability and disembodied technology are interrelated.

Chapter 5.2

Development Measures

It is assumed that changes in capital per capita, capital per worker, or increases in income per capita, reflect different levels of economic development. Higher measures reflect superior development.

By examining relative development measures it may be possible to isolate relative country efficiency. It is possible to test the convergence hypothesis by observing whether changes in various income per capita measures, relative to the US, lead to changes in the nominal and/or the real exchange rate. In this case a bilateral rate is appropriate. A similar approach is also applied to capital per worker. This is discussed in more detail later.

Chapter 5.3

Relative Performance Measures

Relative performance measures include total factor productivity and changes in the terms of trade. Both measures allow one to identify economies with superior economic performance. As mentioned earlier both measures have drawbacks and care is needed when drawing conclusions from them. Yet support exists for their use.

Changes in the terms of trade can be interpreted as indicating superior performance of one economy relative to another. Terms of trade effects have been shown to affect exchanges rates for Canada, (Amano and Van Norden, 1995) and for Australia and New Zealand. (Gruen and Wilkinson, 1991). Arize (1994) using the Johansen (1988) procedure, supports the hypothesis that the real exchange rate and the trade balance are cointegrated.

As discussed previously, the residual term can be used to measure changes in output not captured by growth in conventional inputs. This residual term, or total factor productivity term can be used as a relative performance measure for economies. The question that remains is what factors are being measured by this residual term?

Changes in the terms of trade reflect changes in the relative performance of industries or products. Depending on the definitions used, relative terms of trade changes could provide information on changes in relative performance. However the terms of trade is associated with the external side of the economy. Is this a reflection of efficiency for the traded sector or the entire economy?

Chapter 5.4

Relative Sectoral Performance and Aggregate Performance Measures

Do the relative performance measures chosen reflect the efficiency of the entire economy or are they specific to the traded sector only.

Cumby and Huizinga (1991) propose to investigate whether there is some predictive element involved in the determination of the real exchange rate. The permanent component of the real exchange rate is defined as the infinite horizon forecast of the real exchange rate conditional on the information set selected. This definition of the real exchange rate corresponds to the value of the real exchange rate that would arise if all shocks realised to date, had exerted their full dynamic effect, as well as yet unrealised future shocks. The real exchange rate is hence some function of an information set and a set of shocks that will occur to it in the future. The question then is what are the factors contained within that information set?

The economy is composed of various sectors which tend to be organised in terms of the functions that they perform. Within the productive capacity, a dichotomy exists between those industries that trade in the external markets and those that limit themselves to domestic markets. The problem is that these two subsets of productive capability have different characteristics. The intention is to show a relationship between the real exchange rate and the productive capacity of the economy. If the real exchange rate tends to contain information from the traded sector and not from the nontraded, then our focus should be limited to the traded. Is this the case?

The traded sector tends to incorporate the manufacturing sector and resource based industries including agriculture. (Since agriculture tends to be highly subsidised it is often removed from the analysis). It appears to be the case that the traded sector provides much of the impetus for development and tends to be the technological leader within the economy. In fact, increases in the tertiary sector appear to be generally smaller than the rise of productivity in agriculture and manufacturing. (Balassa, 1964). The nontraded sector tends to lag behind in terms of technological advance and productivity growth. Therefore the economy does not grow in a uniform manner.

The disadvantages of aggregation are noted elsewhere (Mullen and Williams, 1994), but there is difficulty in addressing the problem. 'It appears likely, however, that more useful results can be achieved if, instead of attempting to rely on aggregate indexes, more attention is paid to the behaviour of sectoral indexes with appropriate disaggregation.' (Balassa, 1964, p. 595). A trade-off exists between taking an overly in-depth view versus creating an economically and statistically tractable analysis. It seems appropriate not to ignore the differences that exist between traded and nontraded sectors. Shocks coming from outside the economy are reacted to in different ways and at different speeds. This is also true in the case of technology. Technology tends to be adopted by the traded sector of an economy first and then by the nontraded sector.

What is explored here is the concept that differential productivity growth is a symptom of this dual nature of the economy. Such an idea was first suggested by Balassa (1964), in attempting to rationalise the failure of PPP, and to explain why deviations from some long run real exchange rate path tend to persist.

Balassa (1964) notes that since the services sector enters the calculation of PPP, but does not enter the exchange rate, the PPP between the currencies of any two countries, expressed in terms of the currency of the country with the higher productivity levels, will be lower than the equilibrium rate of exchange. The greater the productivity differences in the production of traded goods between two countries, the larger will be the differences in wages, prices of services and correspondingly, the greater will be the gap between PPP and the equilibrium exchange rate.

It is posited that given a group of countries, a uniform increase in productivity takes place in the sectors producing traded goods, accompanied by a smaller rise in productivity in the services sector. The marginal rate of transformation and the price ratio between the traded commodities will then remain unchanged, while the relative price of the nontraded goods will rise. Since the latter does not enter the international trade arena, PPP calculations will incorrectly indicate the need for adjustment in exchange rates. The problem is hence one of mismeasurement. The exchange rate is believed to incorporate information regarding the traded output of the economy, while PPP calculations are based on all output. From this, one would tend to conclude that the exchange rate contained information related to one area of the economy only. The results from Balassa's paper are believed to be sensitive to the disaggregation methods used. (Rogers and Jenkins, 1995). Balassa (1964) recognises this flaw himself. He was aware that comparisons were inhibited by index number problems used in the PPP calculations. Neither country's representative basket of goods was identical to the country of comparison. Yet Rogers and Jenkins (1995) conclusion supports the Balassa's hypothesis, but this support occurs only with highly disaggregated data.

Hsieh's (1982) paper attempts to explain deviations of real exchange rate from PPP with the differences between countries' relative growth rates in labour productivity between traded and non-traded sectors. It is believed that deviations from PPP may be accounted for in some way by the different weights used to construct baskets for individual countries. This is believed to be especially true for non-arbitrage goods contained in the nontraded sector. A model is proposed where the real exchange rate can be expressed in terms of wages (which determine changes in prices) and productivity. Results support the productivity differential model.

Marston (1990) provides a more rigorous analysis of systematic movements in the currencies of the G5 countries. According to Marston (1990) the real exchange rate appears to have a random component, but this is not the case when one examines the sectoral real exchange rates. It is observed that the internal price structure of economies are highly correlated but this is not the case for international comparisons. Similar sectors in an international setting have quite a low degree of correlation and it is believed that this is due to the high degree of variance in the nominal exchange rate interfering with the normal pricing relationships. The conclusion is important in that it follows the line of reasoning of Balassa (1964). Balassa believed that it was possible for aggregate and sectoral real exchange rates to diverge if productivity growth was faster in the traded sector than in the nontraded. Marston (1990) finds empirical support for the differential productivity hypothesis. It is found that almost all of the changes in the real exchange rate between economies, are due to their differential productivity growth rates and differences in growth of the sectors within those nations. The analysis concentrates on the G5 countries and finds that for all economies, manufacturing productivity is higher than for the rest of the economy. (Marston, 1990). Hence, the real exchange rate is sensitive to the deflator used. The degree of bias introduced by choosing a sectoral rather than an economy wide deflator, depends on the behaviour of the economy with regard to the sectoral productivity growth rates.

> It is possible to show that the real exchange rate defined for different sectors of an economy move closely together with one another even though each of the sectoral real exchange rates taken alone has a large random component. The sectoral real exchange rates are tied together by internal price links due to factor mobility within each national economy. Any differences between real exchange rates which develop, moreover, can be explained almost entirely by productivity differentials, at least in the long run. (Marston, 1990, p. 1).

The links between productivity growth and the real exchange rate are the unit labour costs and prices. (Marston, 1990). It is believed that labour mobility would cause the wage rates of an economy to converge while capital mobility would tend to reduce consistent differences in mark-ups between sectors within an economy. Mark-up differences are used to monitor changes in the supply and demand forces acting within the economy and spectrally. Higher demand in one period would imply an increase in profits through higher mark-ups. (Assuming that factors are mobile and that investment moves to the sector with the highest return).

Marston (1990) suggests using the following equation

$$R_m - R = -[(H_m - H) - (H_m^* - H^*)] + [(W_m - W) - (W_m^* - W^*)] + [(M_m - M) - (M_m^* - M^*)]$$

[5.4.1]

where R is the real exchange rate, W is the wage level, M are mark-ups and H is the productivity. The subscript m refers to the manufacturing sector while notation without a subscript refer to the entire economy.

Equation [5.4.1] states that if the domestic economy has a greater productivity growth differential between manufacturing (subscript m) and the rest of its economy, than does its trading partners, (represented by an *), then the real exchange rate based on the value added (VA) deflator for manufacturing, will have to fall through time, relative to that based on the GDP deflator. The value added deflator is given by P=W-H+M.

According to Marston (1990), differences in real exchange rates are related to three factors:

- the differential growth in productivity between sector i and manufacturing,
- the differential growth in wages, and
- the differential growth in mark-ups.

Asea and Mendoza (1994) believe that the relative price of nontradables is determined by the ratio of the marginal products of labour in the tradable and nontradable sectors. This ratio can be expressed as a log-linear function of the investment-output ratio in the tradable sector. The investment-output ratio is shown to be a function of exogenous parameters describing preferences and technology. The results suggest that relative labour productivity differentials do explain the long run behaviour of the domestic relative price of nontradables. Unfortunately, the relative price of nontradables is far less successful in explaining observed cross country differences in the long run CPI-based and GDP deflator-based real exchange rate. Asea and Mendoza (1994) attributes this result to the failure of PPP in tradables goods, and to a rejection of either the cross price elasticity forms of the production and utility functions, or to the balanced growth constraints.

Asea and Mendoza (1994) show that in the short run, the ratio of marginal products of labour determines only the supply of nontradables relative to tradables. Demand is determined by households marginal rate of substitution between the two goods. Balassa's (1964) theoretical analysis claims that the ratio of sectoral marginal products of labour determines the relative price of nontradables. It is claimed then that the model cannot then predict how aggregate output per capita should relate to domestic relative prices. Asea and Mendoza (1994) conclude that although the observed positive relationship between aggregate output per capita and the real exchange rate remains as a stylised fact, it cannot be derived from the theoretical principles underlying Balassa-Samuelson's original formulation. The proposition that the relative marginal product of labour explains domestic relative prices is well supported by the data. Unfortunately, relative prices are less helpful at explaining real exchange rate movements. However, there may be a long run relationship between the real exchange rate and prices. This is contested in the literature. There are times when a cointegrating relationship exists between the nominal and real exchange rate, but this is neither uniform across countries, nor across time.

It would seem reasonable to conclude that differential productivity growth is an empirical fact. Whether this information is contained within the real exchange rate depends on how the real exchange rate is defined. Obviously changes in the real exchange rate will be sensitive to the deflators used. This is a reasonable and acceptable result. Unfortunately this leads to a bias in the independent variable. The intention is to show that a relationship exists between the real exchange rate and the entire economy, not just information contained within the traded sector of the economy. Care is therefore needed in our final estimation procedure. The deflator used when defining the real exchange rate may affect results.

Chapter 5.5

The Relationship between Terms Of Trade And The Real Exchange Rate

Changes in the terms of trade appear to affect the real exchange rate. Within the framework analysed, such changes should reflect alterations in wealth or in productive capacity. A positive change in the terms of trade would be expected to lead to a positive movement in the real exchange rate. An increase in the terms of trade reflects a change in the buying power of an economy's output. However, as pointed out by Stein (1990), the reason why a change in aggregate demand and supply occurred is more important than just identifying that a change in the terms of trade has occurred. The type of shock affects both the magnitude of the terms of trade change and the persistence of this change. It is necessary to analyse why the terms of trade shifted, in order to predict where and for how long the trade balance will remain in this new position, and hence what movement is observed in the real exchange rate. The terms of trade are a symptom of economic fundamentals, not an end in themselves.

Stein (1990) attempts to analyse the factors that determine the value of the US $ relative to the other countries within the G-10. He notes the failure of other models to explain and predict changes in the dollar over the period 1973-1 to 1987-4. This 'failure' extends to the generalised Mundell-Fleming model and to the random walk hypothesis. The generalised Mundell-Fleming model predicts different results than the fundamental equilibrium real exchange rate (FEREX) model. It is also noted that the assumptions on which it is based do not appear to be supported by the evidence. It is proposed here that economic fundamentals determine the value of the real exchange rate and its path i.e. its trend in the random walk approach. These economic fundamentals are not populated within the traded sector only. This would seem to imply that the real exchange rate contains more information than that contained in the traded sectors of economies.

According to the Eatwell et al. (1987), the determination of the terms of trade is technically nothing other than that of finding the equilibrium vector(s) of relative prices of general equilibrium models in which there is a world market for tradable goods and internationally mobile factors, and national markets for non-traded goods and internationally immobile factors. It also notes that it is a mistake to expect any single concept of the terms of trade to be an unambiguous indicator of changes in the gains from trade, when there are shifts in the fundamental determinants of tastes, technology, and factor endowments.

The terms of trade may be interpreted as a change in the export-import position of an economy. It reflects a change in the consumption patterns of an economy as well as its production capability. In Ostry (1989), a general change in the terms of trade alters both the level and the composition of aggregate real spending, part of which falls on nontradable goods. This will affect the demand or supply of the nontraded sector. To ensure market clearing, a new relative price structure - a new path of the equilibrium real exchange rate - is required. According to Amano and van Norden (1995), in the tradition of small open economy models, the terms of trade are treated as exogenous variables that play a key role in determining not only the real exchange rate but the whole distribution of resources and activities throughout the economy. Hence the terms of trade should be interpreted as a symptom of changes in the characteristics of an economy. It provides an indication of superior performance if changes in productivity performance lead to positive changes in the terms of trade. Such a change may persist provided that the productivity differential is maintained.

The response of agents is hence an important criteria in examining the impact of a terms of trade change on the real exchange rate. Stockman (1987) believes that the reactions of agents to a shock decides the kind of relationship that exists between the real exchange rate and the terms of trade. According to Stockman (1987), the elasticity of substitution of foreign and domestic products and the income elasticity of money demand play key roles. In the case of Ostry (1989), the response of the trade balance to a change in the terms of trade can be decomposed into a direct effect, which is the effect of a terms of trade disturbance holding constant the path of the real exchange rate, and an indirect effect, operating through the response of the real exchange rate to a change in the terms of trade and the resulting feedback of the real exchange rate to the trade balance. It is shown that the latter effect is generally non-zero and therefore the response of the trade balance to a change in the terms of trade will differ according to whether the model incorporates nontraded goods. Further, it is shown that because the direct and indirect effect depends on different parameters of the model, they may be either of the same or opposite sign.

Three channels are identified by Ostry (1989) for the transmission of terms of trade effects. A change in the commodity terms of trade leads to a substitution among goods within the period. Thus a deterioration of the terms of trade leads to a substitution among goods in period zero. It leads to an increase in the consumption of nontradable goods in period 0, if the two goods are net (Hicksian) substitutes, or to decreased consumption if they are net compliments, all other things being held constant. This is referred to as **intratemporal** substitution effect. Secondly, if the rise in the price of importables is confined to period 0, the real (consumption based) rate of interest also rises. Since p_0 / p_1 rises, it means that consumption is period zero is more expensive. This induces substitution of aggregate spending from period 0 to period 1. This rise in tomorrow's consumption relative to today's, due to a change in the intertemporal relative price while other factors are held constant, is called the **intertemporal** substitution effect. Thirdly, a rise in the price of importables in this period, reduces overall wealth. The magnitude of the wealth effects depends on the volume of imports at the initial terms of trade. (Ostry, 1989).

Within the nontradables sector, domestic demand must equal the exogenous endowment of nontradables, in each period. (Ostry, 1989). There are no such requirements in the traded sector since the trade account imbalances allow discrepancies between demand and supply of tradables, period by period. A rise in the price of nontradable goods in period t always has a larger effect on excess demand in period t than in the other period. One of the first propositions of Ostry's (1989) paper is that the nature of the response of the real exchange rate to a temporary current disturbance in the terms of trade, depends on the relative magnitudes of the temporal, intertemporal, and welfare effects. If nontradables and importables are Hicksian substitutes, the temporal substitution effect favours a contemporaneous real appreciation, whereas the (net) intertemporal and welfare effects favour a real appreciation. (Ostry, 1989).

It is seen that a change in the terms of trade of an economy, leads to a change in the decisions of agents within that economy. The terms of trade has price effects, both in a static analysis and in a dynamic context. This must be incorporated within an analysis of the real exchange rate. The response of agents to a change in the terms of trade will affect the direction and magnitude of changes in the real exchange rate. This analysis by Ostry (1989) focuses on the demand side of the economy. This is traditionally seen as the source of temporary shocks to an economy and one would expect the degree of persistence for such a shock to be low. Unless something is done to maintain a positive wealth effect or a permanent change in the consumption pattern of the economy due to a change in the economy, the shock should lead to reversion to the real exchange rate's initial value, since in the long run, nothing "real" has happened. (A permanent change in tastes would imply a higher degree of persistence for demand side shocks). This focus on the demand side of the economy, leaves the supply side unexplained. It is noted by Stockman (1987) that his "modified equilibrium exchange rate model", while it explains the variability of the exchange rate for demand side shocks, it fails to do so for supply side shocks. Shifts in the supply side only create this excess variability of the exchange rate if the elasticity of substitution between foreign and domestic goods is smaller than the inverse of twice the income elasticity of money demand.

In Stockman's (1980) paper, he finds that the model developed shows how a change in the terms of trade caused by relative supply and demand shifts, is divided between nominal price changes in each country and an exchange rate change, creating a correlation between the exchange rate and the terms of trade. The greater the change in the terms of trade and the larger the role of changes in the exchange rate in affecting the terms of trade changes, the greater the variability of exchange rates. The more persistent the shifts in the supply or demand for goods, the more persistent the deviations from PPP. The correlation of the exchange rate with the terms of trade will be greater for countries with more homogenous monetary policies. Exchange rate changes caused by change in monetary factors will not affect the terms of trade.

Ostry (1989) also examines the effect of a permanent change in the terms of trade of the economy. It is found that given an initial trade balance position, the relative magnitudes of the temporal elasticity of substitution and the ratio of imports to consumption of importables, are important factors that determine the behaviour of the trade balance. This contrasts with previous findings (models that ignored non-tradable goods) which concluded that the initial borrowing position of the country was the main factor determining the behaviour of the current account as a result of a permanent terms of trade shock. (It should be noted that capital mobility was assumed in the analysis).

Changes in the terms of trade are a function of shocks, both demand and supply side. If the terms of trade represents purchasing power of a commodity or factor inputs, changes therein should appear to affect the real exchange rate. The changes in the real exchange rates appear to be dependent on both the type of shock and the reactions of agents. The reactions of agents may then decide the time needed for the shock to dissipate, or whether the shock is compounded by their reactions. This is especially true of the Stockman (1987) analysis. The degree of persistence in the exchange rate would imply that there must be a high degree of persistence in these shocks. Therefore, a shock that is registered by a change in the terms of trade leads to a change in the real exchange rate, but this change is unfortunately dependent on both the shock itself and on the response of the agents.

Chapter 5.6

Conclusion

Is the real exchange rate a function of price levels in different countries in the long run? Since the evidence on the PPP hypothesis tends to answer in the negative (although some long run analysis have found support for PPP) then I must conclude that this is the case. Among the reasons why PPP fails to hold is the fact that the price levels used in the construction of the real exchange rate ignore the fact that not all goods are tradable or perfect substitutes. Since price changes are due to the interaction of supply and demand, if the signals are not adequately reflected within a relative measure of "price", the real exchange rate will fail to measure changes in the entire economy. The higher the proportion of tradables in the economy, the greater the expectation that PPP will hold. The relationship between the terms of trade and the real exchange rate would be expected to be stronger for commodity backed currencies. Work done on the Australian and New Zealand currency, make this assumption. (Gruen and Wilkinson, 1991). At the same time, analysis of the Canadian dollar by Amano and van Norden (1995) assumes that the Canadian dollar is a commodity backed currency and hence more sensitive to changes in the commodity terms of trade. However results from their paper fail to support this assumption. The terms of trade is not a causal variable. It is a symptom of the interaction of other variables.

The change in the real wealth of an economy will determine changes in consumption and investment patterns. If the shift in real wealth occurs and is of a permanent nature, this must surely be contained in the real exchange rate. A positive change in the terms of trade should manifest itself through a change in the real exchange rate. A change in the terms of trade under the hypothesis that the real exchange rate behaves like the share price of an economy, implies a change in the earnings potential of an economy. According to Turnovsky (1991), in his analysis of both changes in the mean and the variance of the terms of trade, (or in the distributions that cause change in the terms of trade), in all cases the key element determining the response of the economy is the *effect on the rate of growth of real wealth*, to which all other real quantities are directly tied in equilibrium. Turnovsky (1991) extends the model developed by Stulz (1988) who used a stochastic model in examining the terms of trade effects. He considers the relationship between unanticipated changes in the terms of trade on the one hand and consumption expenditures, together with the current account balance, on the other. His main result is to show how the effect of an unanticipated change in the terms of trade on consumption and the current account, depends upon the differential between the expected real rates of return on foreign and domestic bonds. In the absence of such a differential, the agent would chose a portfolio of assets such that an unanticipated change in the terms of trade has no effect on consumption through the current account. This would seem to imply that changes in the terms of trade do indeed affect the earnings potential of an economy. If the terms of trade affects the real exchange rate, does this mean that the real exchange rate might also contain this information?

Just as in the case of the real exchange rate, the terms of trade may be defined in different terms. In the case of Amano and Van Norden (1995), it was necessary to split the terms of trade into commodity terms and energy in order to show that a cointegrating relationship existed between the terms of trade and the real exchange rate. It was not enough to leave the terms of trade aggregated. Both of the studies carried out by Gruen and Wilkinson (1991) and Amano and Van Norden (1995), were based on currencies that are regarded as commodity backed currencies. This would have increased the importance of commodity terms of trade changes in affecting the real exchange rate.

Any relationship involving the real exchange rate is again sensitive to the deflator used. Johnson (1993) finds that when the real exchange rate is measured using implicit output deflators, between 1951 to 1991, the real exchange rate appears to be stationary. If the real exchange rate is measured in terms of a CPI or a WPI deflator for that period, then it becomes non-stationary. Despite this deflator problem, changes in wealth are still one obvious determinant of the real exchange rate.

From the above analysis I conclude that wealth effects are a more important determinant of the terms of trade. Increases in wealth relative to other economies should therefore lead to appreciation of the real exchange rate.

Methodological issues are examined in the next two chapters and a model is presented in an attempt to establish a relationship between the real exchange rate and relative efficiency.

CHAPTER SIX

NON-STATIONARY TIME SERIES

Chapter 6.0

Introduction

The analysis to date provides evidence that permanent changes do occur to productive capacity over time. Permanent changes in the productive capacity of an economy do occur for those economies that possess the correct level of social capability. How do we deal with these permanent shocks to the output path of an economy.

Permanent shocks to a series of data lead one to conclude that the series may itself be nonstationary. That is to say, when the series experiences a shock it moves to a new long run equilibrium path. If a series experiences a shock but returns to its original path after a period of time, it is referred to as being stationary. It is essential to establish whether a series is stationary or not. Nonstationary data require special treatment and invalidate normal estimation procedures.

It is therefore necessary to establish the true nature of both our performance measure and the real exchange rate. We need to test whether both series are nonstationary and then deal with the implications of nonstationary time series on estimation.

In this chapter I deal with the issue of nonstationarity. It is established that the series I am concerned with is nonstationary. This finding requires that I chose an estimation procedure that can deal with the problem of nonstationary time series. From an examination of the literature on nonstationarity, I conclude that using a cointegration procedure can effectively overcome the problems associated with nonstationarity.

What follows is an explanation of nonstationarity or unit roots. While a relatively new area in statistical terms, the amount of literature is extensive. As mentioned in Chapter one, the test for PPP is often couched in terms of unit roots. If the exchange rate contains a unit root then PPP does not hold. There is no long run forcing variable causing the exchange rate to react to differential inflation rates and return to an equilibrium path. The theory of PPP and its empirical support is widely contested.

Among the reasons why proof for PPP is inconclusive is because tests for unit roots suffer from low power. The tests available find it difficult to distinguish between highly persistent series and those that are actually nonstationary. Unfortunately exchange rates fall into this category. This issue is examined later in this chapter.

An incorrect conclusion regarding stationarity would lead to the use of an erroneous estimation procedure and hence invalid results. There is a need to establish whether relative efficiency and/or the (real) exchange rate are stationary or nonstationary. This is the first step in our estimation procedure.

Chapter 6.1

Unit Root Concept

Non-stationarity (wide-sense stationary, covariance stationary, or second-order stationarity) occurs when a series' mean and variance depend on time. That is to say, as time progresses both the mean and variance depart from any predicted value. If this series is predominantly changing in one direction, the series is said to exhibit a trend. (Maddala, 1992).

Stationarity is divided into strict stationarity and weak stationarity. According to Maddala (1992), a time series is said to be strictly stationary if the joint distribution of any set of n observations, $X(t_1)$, $X(t_2)$, ... $X(t_n)$ is the same as the joint distribution of $X(t_1+k)$, $X(t_2+k)$,...., $X(t_n+k)$ for all n and k. For a Strictly stationary time series, the distribution of X(t) is independent of t. It is not just the mean and variance that is constant. All higher moments are independent of t. In practice this is a very strong assumption and it is useful to define stationarity in terms of the first and second moments of the joint distribution only. (Maddala, 1992). A time series is said to be weakly stationary if its mean is constant and its auto-covariance function depends only on the lags within the series, that is

$$E[X(t)] = \mu \text{ and } cov[X(t), X(t+k)] = \gamma(k) \qquad [6.1.1]$$

$$\text{note that: } X(t) = var\ X(t+k) = \sigma^2 = \gamma(0). \qquad [6.1.2]$$

The normal way of dealing with a nonstationary series is to difference the data. (It is suggested by Maddala (1992) that a series should be regressed on time if it is believed that the series is a trend stationary process (TSP) and to difference it if the series is believed to be a difference stationary process (DSP)). This returns the series to some central value. Unfortunately this removes long run information from the data set.

The nature of this investigation is a long run analysis. The cointegrating methodology, suggested by Engle and Granger (1987) provides a more acceptable method of identifying long term relationships and provides an alternative to differencing data to arrive at a stationary data set. It attempts to identify long run relationships in a set of data integrated of similar order. Since the exchange rate and the real exchange rate seem to take a long time to recover from a shock, or to move to a new equilibrium position, the methodology seems appropriate. Attempts to perform normal regression analysis without first identifying the order of integration of the data makes the results meaningless. (Taylor, 1990). Further, since most economic time series are in disequilibrium moving to equilibrium, dynamic interrelationships are being ignored. (Kennedy, 1992).

Chapter 6.2

Trend Stationary vs. Difference Stationary Processes.

Nelson and Plosser (1982) showed that macroeconomic data are better characterised as random walks with drift than as stationary series with a time trend. They suggest defining a process in the following form:

$$y_t = \alpha + \rho y_{t-1} + \beta t + \varepsilon_t \qquad [6.2.1]$$

They use a Dickey Fuller (DF) (1979) test to examine whether the series is a difference stationary process (DSP) or a trend stationary process (TSP). The series is DSP if $\rho = 1$, and $\beta = 0$. It is a trend stationary process if $|\rho| < 1$ and $\beta = 1$. The problem is that the usual least squares distribution theory when $\rho = 1$, is inappropriate. Dickey and Fuller (1979), show that the least squares estimate of ρ is not distributed around unity under the DSP hypothesis, but rather around a value less than one. This negative bias diminishes as the number of observations increases. (Maddala, 1992). Dickey and Fuller (1981) tabulate the significance points for testing the hypothesis $\rho = 1$ against $|\rho| < 1$. Nelson and Plosser (1982) conclude from their application of DF tests to time series data, that the DSP model is more appropriate, and that the TSP model would be the relevant one only if we assume that the error terms are highly correlated.

Chapter 6.3

Unit Root Concept in an Autoregressive Setting

Testing for unit roots may take the form of applying a DF test to a first order autoregressive equation of the form:

$$y_t = \alpha + \rho y_{t-1} + \varepsilon_t \quad [6.3.1]$$

The standard expression for the large sample variance of the least squares estimator $\hat{\rho}$ is $(1-\rho^2)/T$, which would be zero under the null hypothesis. (T is the number of observations). Hence it is necessary to derive the limiting distribution of $\hat{\rho}$ under H_o, $\rho = 0$, to apply the test. (Maddala, 1992).

In the case of testing $\rho = 1$, $\beta = 0$, Dickey and Fuller (1981) suggest using a Likelihood Ratio (LR) test. These F values from this test are much higher than those in usual tables.

If the correct specification of a model takes the form

$$y_t - y_{t-1} = \beta + \varepsilon_t \qquad [6.3.2]$$

and $\beta = 0$, the series is referred to as a trendless random walk, or a random walk without drift. If the specification is changed to

$$y_t = y_0 + \beta t + \Sigma^t_{j=1} \varepsilon_j \qquad [6.2.3]$$

then the variance is given by $t\sigma^2$. The variance increases over time. There may not be a trend in mean if $\beta = 0$ but there is still a trend in variance. If this model is indeed a DSP but is estimated as a TSP, a problem exists. It is clear that eventually the trend in variance will inevitably be transmitted to the mean and a significant t statistic will be observed. (Maddala, 1992).

Chapter 6.4

Low Power of Unit Root Tests

The concept of a unit root within some process is based on the belief that shocks to a particular system or series, are in fact permanent. It is necessary to identify if a series is itself non-stationary. If it is obvious that a series is integrated of an order greater than zero, then we must now alter our estimation techniques to take this into account. Problems arise if we fail to correctly identify the type of processes that we are dealing with. From a statistical perspective, the presence of non-stationarity means that the standard critical values of tests are inappropriate. (Corbae and Oularis, 1988). In a broader economic framework, a non-stationary series requires a reinterpretation of conclusions.

The test normally used to identify the presence of a unit root in a series is the Dickey-Fuller (DF) or Augmented Dickey Fuller (ADF) test. Kim (1990) finds fault with the Dickey-Fuller Test and applies Engle and Yoo's critical values to the test, since these allow for higher order autocorrelation. The ADF is used in situations where the autoregressive process has a higher order than one. An ADF is often seen as a way of dealing with autocorrelated errors. (Kennedy, 1992). The test is reasonably straight forward but it suffers from low power. (Hakkio, 1986). The test finds it difficult to distinguish between a series that is highly persistent and one that does in fact contain a unit root. Enders (1988) supports this criticism, noting that the confidence interval size is large and thus the conclusion one way or the other is inconclusive. As mentioned earlier, the exchange rate and the real exchange rate both suffer from a high degree of persistence. In fact in the case of the nominal exchange rate it may even be the case that it is an explosive process. (Abauf & Jorion, 1990). This makes it more difficult to correctly identify the specification for the real exchange rate process. Other tests are suggested including the Phillips and Perron (1986) Z statistic used in Corbae and Oularis (1988). Corbae and Oularis (1988) observe that the ADF and the Phillips and Perron Z statistic both allow for a fitted drift in the time series model. The ADF accounts for temporally dependent and heterogenously distributed errors by including lagged innovation sequences in the fitted regression. In contrast, the Phillips and Perron procedures account for normally distributed, identical independent (n.i.i.d) processes using non-parametric adjustments to the standard DF procedure. But as Hakkio (1986) points out, a similarly low power is noted for this test. Additionally the ADF test assumes that there is no moving average in the error component. (Kennedy, 1992).

Kwiatkowski et al. (1992) claim that the standard conclusion drawn from empirical evidence is that many aggregate economic time series contain a unit root. However, it is important to note that in this empirical work and within previous work, the unit root is the null hypothesis to be tested. The way in which the classical hypothesis testing is carried out assumes that the null is accepted unless there is strong evidence against it. It is suggested that the null be checked assuming the stationary alternative. Kwiatkowski et al. (1992) claim that others have found it difficult to distinguish between DSP and TSP. In the case of Kwiatkowski et al. (1992) they apply a test to the Nelson-Plosser data and find that the results depend on the way that the deterministic trend is accommodated. For almost all series they reject the hypothesis of level stationarity, but for many of the series it cannot reject the hypothesis of trend stationarity. (This is found in the case of unit roots tests in Appendix A).

According to Engle and Yoo (1987), vector autoregressive regressions (VARs) provide a convenient representation for both estimation and forecasting of a system of economic time series. The forecasting performance of unrestricted VARs have not been particularly good and the question of whether to pre-process the data by transformations such as differencing has been suggested. This allows the analysis to be conducted on a stationary series. Unfortunately, unrestricted VARs do not perform particularly well and this has perplexed investigators. Engle and Yoo (1987) show that if all variables are differenced, as would appear appropriate from their univariate properties, then the system no longer has a multi-variate linear time series representation with an invertible moving average. Essentially, the system has been over-differenced. Engle and Yoo (1987) are also sceptical of the critical values offered by Dickey and Fuller (1979) and provide their own critical value estimates.

There are thus serious problems associated with regressions involving series of different integration orders.

Chapter 6.5

A Non-stationary Conclusion

If we assume that we have correctly identified a series as containing a unit root, then this series will move to a new path after some shock. However this shock must by its nature be real or I(1). This is a basic assumption when we later apply various cointegration techniques to a system of equations. Only series of similar orders of integration can affect one another. However within the error correction models this does not have to be the case and stationary variables may be added. This is also true within the case of the Johansen procedure. The inclusion of stationary variables is done to improve the behaviour of the error terms in the error correction model.

From the unit root literature, it is essential that in whatever model or estimating procedure the analysis is cast, all the series must be integrated of the same order. If changes in the real exchange rate prove to be permanent in nature, these series must contain a permanent component. Changes that are transitory and hence I(0) should not affect the real exchange rate since it is assumed to be I(1).

A starting point in the analysis is the realisation that we are dealing in terms of the economic fundamentals of an economy. Real changes lead to reactions in the real exchange rate. This is not a new concept and most models of the exchange rate contain a set of variables to incorporate changes in the economic fundamentals of the nation. (Stein, 1990; Lim, 1992). The importance of monetary phenomena in the short run is unfortunately strong and these transitory changes may tend to swamp information contained within the economic fundamentals. If monetary shocks have high frequency, this could lead to the impression that the exchange rate (and perhaps the real exchange rate) follows a random walk in the short run. (Meese and Rogoff, 1983). Monetary shocks are transitory in nature, I(0) and should not be determinants of the long value of the real exchange rate. (Amano and Van Norden, 1995; Meese and Rogoff, 1988; Zhou, 1995). This fact is supported empirically and is what one would expect. From the review of the work on differential productivity growth, it is observed that when countries have similar inflation experiences, differential productivity growth becomes more important in explaining exchange rate movements.

Four questions appear from the above analysis:

- Is the real exchange rate I(1)?
- Are changes in productive capacity I(1)?
- What indicators of convergence are I(1)?
- What cointegrating relationships exists in the data series?

The last two questions are examined in the Chapter seven.

Chapter 6.5.1

Conclusion Regarding the Real Exchange Rate:

In testing the real exchange rate, we find that in general it is I(1) within the sample under consideration. Tests available for stationarity include the Dickey-Fuller, the Augmented Dickey Fuller, Phillips-Perron (1988) and a test suggested by Kwiatkowski et al. (1992), which tests for a null hypothesis of stationarity against a unit root alternative. Also included is the Phillips-Hansen and the Park Choi (G(p,g)) tests. (Gruen and Wilkinson, 1991). A complicated testing strategy exists, beginning with the most general auxiliary regression and working towards a more specific, moving from one set of critical values to another. Kennedy (1992). The usual tests noted above assume that the error term is non-spherical. Phillips (1987) extended by Perron (1988) and Phillips and Perron (1988), suggests a non-parametric based correction to the DF test, for use whenever it is suspected that the errors are autocorrelated or heteroscedastic. It consists of calculating the DF statistic, a t- value obtained from running the auxiliary regression, and then adjusting this statistic before consulting the critical values appropriate for that version of the DF test. Monte Carlo studies suggest that the small size properties of the DF tests are better for the cases of non-normal errors and heteroscedasticity. The Phillips-Perron test is to be preferred if the errors are autocorrelated or if the sample size is quite large. (Kennedy, 1992).

The tests only examine the possibility of one unit root in the series. The trials suggested are further restricted by the fact that they have difficulty in discriminating between an I(1) and I(0) process with a shift in its mean. In addition, all these tests assume that there is no moving average process in the error term, which adversely affects all tests, but to a varying degree. (Kennedy, 1992).

Chapter 6.6.

Evidence Of Unit Roots.

The analysis here focuses on the use of the real exchange rate and not the nominal exchange rate. However both are used. The direction of causation runs from the real exchange rate to the nominal exchange rate. (Stein, 1990; LaFrance and Van Norden, 1995). Mussa (1986) in Blundell-Wignall and Gregory (1990) pointed out that movements in the relative good prices between countries are typically smooth and that short run variability in the real exchange rate mainly reflects movements in the nominal rate. According to Blundell-Wignall and Gregory (1990), this pattern is consistent with that in Australia and New Zealand. The evidence for the hypothesis that the nominal exchange rate contains a unit root is overwhelming. (Grilli and Kaminsky, 1991). According to Grilli and Kaminsky (1991), the conclusion that a unit root exists in the real exchange rate is less convincing.

If the real exchange rate is defined in terms of relative prices and the nominal exchange rate, and the latter two are I(1), then is there a cointegrating relationship between the real exchange rate and prices or real exchange rate and the nominal exchange rate? If the real exchange rate is I(0) could it affect the nominal exchange rate which is believed to be I(1)? If this is not the case, but the specification is correct, then the cointegrating relationship must be between prices and the nominal exchange rate.

This is supported by authors such as Johnson (1993), who finds that in the long run the real exchange rate is in fact I(0). He observes that even with the correct specification of the series, it is still difficult to distinguish between a TSP and a DSP. If the TSP has a large but not a unit root, then the power of the test will be low. This is also true of the Phillips-Perron test which has low power in some dynamic specifications near the unit root.

Abauf and Jorion (1990) make a similar conclusion in their analysis of data from 1900 to 1972. These authors discover that within a system of univariate autoregressions, constraining the autoregressive coefficient to be the same across countries, leads to more precise parameter estimates than the usual country-by-country setting. Evidence of mean reversion is found. Results seem to imply that the real exchange rate is captured by a first order autoregressive process, the root of this process being slightly below unity. It is admitted that substantial deviations from PPP occur. The paper attempts to estimate the autoregression model in a multivariate setting which should allow for more powerful tests. The drawback of this method is that the distribution of these test statistics is unknown and must be obtained from simulation analysis. The generalised least squares (GLS) method, which limits the autoregressive term to be the same across countries, yields much more powerful tests. Abauf and Jorion (1990) believe that multivariate models provide much better approximations than univariate analyses. A further criticism of the AR(1) specification is that it restricts the dynamics of real exchange rates to only one of three possibilities: an explosive process, a random walk, or a monotonic adjustment to a constant value. In order to allow for a more general dynamic specification, lagged values of real exchange rate changes were added by Abauf and Jorion (1990) to the model suggested. The evidence proposes that the value of the parameter, which determines the adjustment speed of the long run PPP, is close to unity. Simulations demonstrate that if the value is near to 0.99, for a 50% initial deviation from PPP, an adjustment length of 69 months is required to reduce the deviation to 25% departure from PPP. With a value of .98, the half-life falls to 34 months. It is clear that as we move away from unity, the half-life of the shock begins to drop dramatically. This is noted by other authors and may in fact be due to a problem with the decay function specification.

There are obvious problems discerning between highly persistent series and those that are indeed unit roots. Solutions have taken the form of increasing the power of tests, or more precise specification of the series in question. It is suggested by Diebold et al. (1990), that this may also be due to the fact that ARIMA representations are themselves restrictive. Diebold et al. (1990) decided to analyse long memory models which can better handle low frequency data. One such model examined is the Autoregressive Fractional Integrated Moving Average (ARFIMA). The model has the advantage that it possesses the ability to display significant dependence between observations widely separated in time. Standard ARIMA processes are short memory, because of the autocorrelation (or dependence) between observations τ periods apart

$$(\rho_{\chi}(\tau) \sim k^{\tau}) \qquad [6.6.1]$$

where $0 < k < 1$ and $\tau \rightarrow \infty$. ρ is the parameter capturing the autocorrelation factor. In contrast, the defining characteristic (in the time domain) of ARFIMA processes is a slower, hyperbolic, autocorrelation decay.

$$(\rho_{\chi}(\tau) \sim \tau^{2d-1}) \qquad [6.6.2]$$

where $d < 1/2$ and $\tau \rightarrow \infty$.

From this approach, Diebold et al. (1990) conclude that the real exchange rate does in fact exhibit mean reversion, hence PPP holds. On the other hand, disparate degrees of persistence are noted for different real exchange rates. Obviously any conclusion is dependent on the period used, the model chosen, and the exchange rate being examined.

Johnson (1993) discovered that in specifications that are unconstrained, models tend to ignore the short run variation owing to the PPP relationship. Because of excessive short run variation in the nominal exchange rate, the unconstrained model cannot capture the long run effect of exchange rate change on prices.

I believe that the unit root conclusion may be a temporary phenomenon. PPP's failure to hold could be a Post World War II phenomenon and in the long run PPP does hold.

Chapter 6.7

Sensitivity of Stationarity to Higher Frequency or Longer Low Frequency Data

Grilli and Kaminsky (1991) show in their analysis of the US$/Stg£ rate for 1885-1986, that the real exchange rate appears to be mean reverting for the entire sample. However, once specific periods are chosen, the unit root cannot be rejected. It is concluded that the shocks to the real exchange rate may be long lasting but overall the real exchange rate is mean reverting. This conclusion is based on the use of Phillips (1987) and Phillips and Perron (1988) tests, which allow for weakly dependent and heterogenously distributed innovations but have the same asymptotic local power properties as the Standard Dickey-Fuller test. However this test is believed to suffer from serious distortions in the presence of moving average errors with negative serial correlation.

Evidence suggests that since World War II, mean reversion has not been a characteristic of the real exchange rate. Using a test statistic suggested by Grilli and Kaminsky (1991), to measure the permanent and temporary components within the real exchange rate, it is found that in the post World War II period, 70% of the variance of changes in the real exchange rate were permanent in nature.

> It is felt that the fluctuations in the real exchange rate after World War II were more likely to be driven by supply or real demand shocks, such as oil shocks in the 1970s or the fiscal shocks in the 1960s and in the 1980s. (Grilli and Kaminsky, 1991, p. 207).

In the pre- World War II period, it was found that transitory fluctuations were more important. Mean reverting behaviour was observed for the real exchange rate in that period. This conclusion is supported by Davutyan and Pippenger (1985) who compared the workings of PPP in the 1920s and the 1970s. Those authors compared the standard errors for PPP in the two periods and found that real shocks did not interfere with PPP any more in the 1970s than it did in the 1920s. Whether this should be taken as meaning that PPP failed equally badly in both periods, or if it implies that real shocks were not the reason for the failure of PPP to hold in the post Bretton Woods exchange rate environment, is unclear.

La France and Van Norden (1995) claim that the explanations of the exchange rate based on monetary shocks, tends to break down when countries share broadly similar inflationary experiences and the influence of other factors becomes dominant. Following this logic, if the pre World War II period experienced more monetary shocks than real, PPP should have held. Studies for high inflation countries find support for PPP. (Johnson, 1993). When monetary phenomena become less important, real factors should become more significant determinants of the real exchange rate.

Johnson (1993) observes that the length of the sample data is essential to any conclusions drawn from the data. Increasing frequency instead of lengthening the time horizon from which data is taken, is not believed to uncover long run phenomena. (Kim, 1990; Hakkio and Rush, 1991). To identify a long run phenomenon like PPP, lengthening the time horizon is required, not an increase in data frequency. Although there is support for PPP (US$ and the Canadian $) in the sample 1920-1991, in shorter samples, 1920-38, 1951-1971, and 1971-1991, the evidence disappears. It is noted by Johnson (1993) that, within short samples, prices may contain two unit roots, and indeed this is put forward as the reason for the failure of PPP from 1970-91.

Chapter 6.8

Real Exchange Rate Is I(1)

The conclusion that the real exchange rate is stationary is contested by others. It is even noted by Johnson (1993) that his results are sensitive to model specification, normalisation, inclusion of a deterministic trend and sample size. According to Amano and Van Norden (1995), Kim (1990), Gruen and Wilkinson (1991) and others, the real exchange rate is in fact I(1).

Taylor (1990) presents evidence that the real exchange rate contains a unit root in its time series representation, which cancels out on first differencing. The hypothesis is tested using an Augmented Dickey Fuller (ADF). 'The power (*of the ADF*) is also tested using Monte Carlo methods and it is found to be quite powerful against a range of stationary local alternatives'. (Taylor, 1990, p. 1311).

The approach taken by Taylor (1990) is such that time series data, which contain a unit root, has the property that its first difference will have a stationary Autoregressive Moving Average (ARMA) representation. An ADF test is used. If Y_t is represented as

$$Y_t = \lambda_0 + \lambda_1 Y_{t-1} + \lambda_2 Y_{t-2} + \dots \lambda_{n+1} Y_{t-n-1} + e_t \quad [6.8.1]$$

where e_t is a white noise disturbance. This can also be represented as

$$\Delta Y_t = \lambda_0 + \left(\sum_{i=1}^{n+1} \lambda_i - 1\right) Y_{t-1} - \left(\sum_{i=2}^{n+1} \lambda_i\right) \Delta Y_{t-2} - \left(\sum_{i=3}^{n+1} \lambda_i\right) \Delta Y_{t-3} \dots - \lambda_{n+1} \Delta Y_{t-n} + e_t$$

[6.8.2]

where Δ is the first difference operator

$$(\Delta Y_{t+i} = Y_{t+i} - Y_{t+i-1}). \quad [6.8.3]$$

Now a necessary condition for the autoregressive process [6.7.1] to be stationary is

$$\sum_{i=1}^{n+1} \lambda_i < 1 \qquad [6.8.4]$$

If it is desired to test the null hypothesis of non-stationarity i.e.

$$H_0 : Y_t \sim I(1). \qquad [6.8.5]$$

one should run the ordinary least squares (OLS) regression

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 \Delta Y_{t-2} + \dots + \alpha_n \Delta Y_{t-n} + e_t \quad [6.8.6]$$

to test the null hypothesis

$$H_0: \alpha_1 = 0. \quad [6.8.7]$$

If this cannot be rejected, then neither can the expression [6.8.5]. According to Taylor (1990), since one is concerned with a stationary alternative ($H_1:\alpha_1<0$), a one sided test of the hypothesis in expression [6.8.6] should be performed. The problem noted in implementing the test is that under the null hypothesis, Y_t, will theoretically have a variance which makes the standard t test for expression [6.8.7], invalid. Thus the distribution of the t-ratio will be unknown. One possible solution suggested is to use a standard 't-ratio' for the estimated value of α_1 in equation [6.8.6] and to calculate critical values for this statistic using a variety of sample and nominal test sizes via Monte Carlo methods. It is recognised that care should be taken about drawing strong inferences from such tests, without first examining their power characteristics against a variety of local alternatives. This involves a variety of Monte Carlo experiments. It is concluded here that the ADF appears to be quite powerful against a range of local alternatives.

Kim (1990) concludes that all exchange rates and price series, appear to be integrated of order one. Taylor (1990) suggests that most real exchanges rate examined appear to be best represented by an ARMA (2,1) specification. Kim (1990) warns that in tests for a unit root in the residuals, the estimated residuals from the cointegrating regressions for finite samples will appear more stationary than the true values in the error term. The use of the DF test will therefore tend to give an erroneous result. Kim (1990) decides to use the critical values suggested by Engle and Yoo (1987), on the grounds that they allow for the higher order autocorrelation present in the error terms. In the case of tests for a unit root in the real exchange rate, they are rejected in all cases except in the instances of the Canadian $, the Japanese ¥ and the Pound Sterling. It is believed that PPP is less likely to hold in cases where there are differential productivity growth rates between two countries.

Chapter 6.9

Real Shocks and the Real Exchange Rate

Real shocks drive the real exchange rate. The high degree of persistence seems to be due to the structure of the economy. The conclusion is that only real factors, which are I(1), affect the real exchange rate. It is believed that the effect of real shocks dominates nominal shock effects, for both exchange rates over the short and long frequencies. (Lastrapes, 1992). Lastrapes (1992) states that given the experience of the current floating exchange rate period, real and nominal exchange rates are probably integrated processes. This characterisation of exchange rates implies that they are subject to permanent shocks. But this does not mean that an integrated process needs to incorporate only permanent shocks. A transitory component can exist unless the process is a random walk. These permanent shocks are believed to be technology, resource endowments, and preferences. In Lastrapes (1992) a bivariate approach is taken so that the nominal and the real exchange rate are included in the analysis. Lastrapes (1992) believes that additional information may be contained within the nominal exchange rate which would allow one to recover estimates of the different types of shocks from the data record. According to Lastrapes (1992) this type of approach is conspicuous in that it does not restrict the permanent component to be a random walk. It does however depend on the assumption that the joint behaviour of real and nominal exchange rates (and implicitly relative prices) contains reliable information about the underlying sources of fluctuations. It is later noted in the empirical findings of the model that there is no cointegration between the real exchange rate and the nominal exchange rate and this implies that prices must be non-stationary. This implies that there is no linear long run equilibrium relationship between the nominal and real exchange rates over the flexible rate period for the countries under investigation, assuming that the real exchange rate is defined in terms of relative prices. In particular, Lastrapes (1992) found that it is necessary that real and nominal exchange rates had sufficiently distinct reactions to the shocks over the long run in order to identify a relationship. While examining the impulse response functions, (an impulse response function shows the current and lagged effects over time of changes in the error terms on the dependent variable (Maddala, 1992)) it was observed that the dynamic response of the nominal exchange rate to a real shock, is very similar to that of the real rate. This is taken to suggest that permanent shifts in the real exchange rate due to real shocks, mainly occur through nominal exchange rate changes, and not to movements in relative prices. (Lastrapes, 1992). Additionally, there is a definite overshooting effect in the nominal exchange rate when there is a nominal shock. Nominal shocks are absorbed by the nominal exchange rate and not just price levels, over the short and long run. It is further claimed that this non-zero nominal exchange rate response, can explain why nominal and real exchange rates are not cointegrated. A nominal shock can lead to a permanent divergence between nominal and real rates, i.e. a permanent change in the price level ratio. If the nominal shock is only reflected in the goods prices, then the data would yield an impulse response function that converges to zero for the nominal exchange rate, at an infinite horizon. It is also seen that the responses of real and nominal rates to a real shock are similar, and nominal shocks have a permanent impact on the nominal exchange rate. In all cases (except in the case of the Canadian $), the immediate impact of a real shock on each rate is smaller than the long run effect. The opposite is true for nominal shocks. From the empirical results of the model, in all cases, it is discovered that real shocks dominate nominal shocks in their explanation of real exchange rate variance.

Does this imply that nominal shocks cause greater variance in the short run? This would tend to comply with observed short run variance in the real exchange rate.

Lippert et al. (1994) take the position that PPP fails to hold because it does not incorporate real shocks into its analysis. They assume that the real exchange rate is in fact an unobservable variable, which is a factor in the determination of the nominal exchange rate. They model the real exchange rate, the relative price of domestic goods in terms of foreign goods, as a function of the demand for and supply of goods. Changes in the real exchange rate come from changes in factors that affect the supply of and the demand for domestic and foreign goods. Lippert et al. (1994) claim that the factors believed to affect the supply of goods are productivity, technology, and corporate taxes. The main factor affecting demand are assumed to be consumer tastes and personal income taxes. The work extends that of Stockman (1987) and Neary (1988). The presence of a unit root is examined using an ADF test with four lags. None of the variables except US productivity, reject the unit root. Stockman (1987) suggests a specification in econometric form, in log differences of :

$$\Delta R = \alpha + \beta_1 \Delta PROD + \beta_2 \Delta PROD^* + \beta_3 \Delta TECH + \beta_4 \Delta TECH^* + \beta_5 \Delta CTX + \beta_6 \Delta CTX^* + \beta_7 PTX + \beta_8 \Delta PTX^* + U. \qquad [6.9.1]$$

Where R = real exchange rate

PROD = productivity

TECH = technology

CTX = corporate taxes

PTX = personal income taxes, (Demand factor)

and an * represents the corresponding foreign value of the variable.

Tastes are ignored. It is concluded that changes in permanent factors influence the behaviour of the real exchange rate. These may be a contributing source to the behaviour of the nominal exchange rate.

Chapter 6.10

Conclusions

The fact that the real exchange rate is mean reverting (I(0)) in the long run may not be relevant to the analysis. If convergence is only a post World War II phenomenon, then could this be taken as further evidence that there is a direction of causation between the advent of convergence and the change in the real exchange rate from an I(0) process to a I(1) process. Information seems to support the hypothesis that permanent factors are responsible for the changes in the real exchange rate and from there, to the movements in the nominal exchange rate. It seems likely that the avenue to pursue is that of real factors, some of which have been identified above. It is necessary to examine the order of integration of those factors contained within productive capacity and/or social capability and from there to explore any existing cointegrating relationships. The theoretical background need to explore such a relationship is examined in the chapter following.

CHAPTER SEVEN

COINTEGRATION

Chapter 7.0

Cointegration Methodology

It is intended to show that the real exchange rate of an economy is cointegrated with the information contained within X_t (Equation [1.0.1]). From the literature reviewed on the area of cointegration and the real exchange rate, X_t should contain some indications of economic fundamentals and relative performance measures. These include productivity, thrift, and changes in comparative advantage. (Baille and Selover, 1987). X_t is defined more explicitly in Chapter nine. The measure chosen is designed to capture the ability of a nation to generate income over time.

The cointegration procedure can be applied using a *residual based approach.* Two variables that are believed to be cointegrated are regressed on one another. The residuals are then tested for stationarity. If the residuals are stationary, it can be implied that the two series are cointegrated. If no cointegrating relationship exists between the two series, then the residuals would be non-stationary.

An alternative to the Residual based approach is to use an *error correction model* (ECM). This model incorporates information from both first difference data and data in level form. (Kennedy, 1992). Following this approach, and noting that the residual based approach has a number of drawbacks, a cointegration methodology based on the work of Johansen (1988) and Johansen and Juselius (1989) provides a superior estimation method.

Chapter 7.1

Dealing with Stationarity

It is essential for the cointegration methodology to provide meaningful results, that the dependent and independent variables be integrated of the same order. Again stationary variables may be added to the ECM but their function is to ensure that the error terms behave as close to Gaussian errors as is possible. (Kennedy, 1992). Although this seems a reasonably straightforward requirement, as mentioned before, the power of unit root tests is low. This has been tackled in some ways by using alternative critical values (Engle and Yoo, 1987). Problems in discriminating between highly persistent series and actual unit roots still exist. It is observed by Kennedy (1992) that because tests for cointegration are based on looking for a unit root in the residuals rather than in raw data, unit root tests for cointegration have different limiting distributions than those of simple tests for unit roots, such as the DF and the ADF. Therefore, they require special critical values, which are tabulated by Engle and Granger (1987) and Engle and Yoo (1987).

If we presume that the real exchange rate is in fact non-stationary in the period examined, (accepting that it may in fact be stationary/mean reverting over the very long run), then only non-stationary variables should be cointegrated with it. (Stein, 1990; Zhou, 1995). The belief that the real exchange rate may in fact be I(1) would imply that there was no force acting upon it that would encourage it to return to some equilibrium value. If one accepts that the real exchange rate is non-stationary then it should remain at this post shock value indefinitely. However this argument seems to imply that only one type of shock affects the real exchange rate, when in fact shocks may be positive or negative.

The cointegration methodology is grounded in the *error correction methodology*. We are dealing with some factor that forces non-stationary variables to return to an equilibrium path or value, over time. Two series may themselves be non-stationary but there may be a linear combination of the two which forms a linear relationship that is stationary. This linear relationship prevents the two series from drifting apart over time. This relationship is incorporated within the error correction model.

I assume that the development of an economy continues in a positive monotonic fashion. Income continues to increase over time although the rate at which this occurs may change. Christiano & Eichenbaum (1989) examine the hypothesis of whether the GNP does in fact contain a unit root. They find that the conclusion is sensitive to the model specification and incorrect specification obviously affects conclusions drawn. Cochrane (1988) asks whether GNP is better characterised as a random walk or as a trend stationary process. He finds that the random walk component within GNP is quite small. An AR(2) process around a deterministic trend or a difference stationary ARMA process with a very small random walk, provides a good approximation of GNP. This re-emphasises the low discriminatory power associated with the tests in this area.

Since the real exchange rate is a relative measure, then the speed of development relative to another economy is a pertinent factor in the analysis. Relative measures must be included in the X_t data set. Although some shocks would be expected to be stationary, their effect should peter out over time. The expected conclusion that monetary phenomena are transitory is supported by the data. (Stein 1990; Gruen and Wilkinson, 1991; Lim, 1992; Amano and van Norden, 1995; and Zhou, 1995). Long run monetary neutrality is not rejected by the data. (Kim and Enders, 1991). The remaining factors should be permanent in nature or contain permanent components. The focus returns to economic fundamentals as an explanation for the changes in the real exchange rate and the variance within.

Chapter 7.2

Specifying and Testing the Null Hypothesis

The null hypothesis for cointegration is that there is in fact no cointegrating relationship between the dependent and independent variable(s). This follows on from the hypothesis testing with regard to the unit root. In that test, the null hypothesis was that the series did contain a unit root. If it is the case that the null hypothesis of the unit root is accepted then, the cointegrating methodology requires that the new null hypothesis be one where there is no cointegrating relationship.

Initially the hypothesis testing takes the form of setting the alternative hypothesis (H_1) to be one cointegrating vector. If the null is rejected then the analysis progresses to setting H_1 to be two cointegrating vectors.

For example, Baille and Selover (1987) test a monetary model of the exchange rate using equation [7.2.1] and following the approach suggested by Engle and Granger (1987).

$$s_t = \beta_1(m_t - m_t^*) + \beta_2(y_t - y_t^*) + \beta_3(r_t - r_t^*) + \beta_4 E_t(p_{t+1} - p_{t+1}^*) + u_t \qquad [7.2.1]$$

Where m is the money supply, y is income, r is the interest rate and p are prices. An * indicates the corresponding foreign country value.

Baille and Selover (1987) define a series x_t with no deterministic component and with a covariance stationary invertible moving average representation after differencing d times. x_t is integrated of order d, $x_t \sim I(d)$. If two variables, x_t and y_t are both I(d), then it will generally be true that a linear combination

$$z_t = x_t - ay_t \qquad [7.2.2]$$

will also be I(d). It may happen that $z \sim I(d-b)$ where $b>0$ and x_t and y_t are then said to be integrated of order (d,b). It may also happen that x and y are both I(1) and that the equation z_t in [7.2.2] is I(0).

If x_t represents a g dimensional vector of random variables and all the components are I(d) then if there exists a vector $\alpha \neq 0$, such that

$$z_t = \alpha' x_t \sim I(d\text{-}b) \qquad [7.2.3]$$

then α is known as the cointegrating vector. (α' is the transpose of α). For the basic monetary model [7.2.1] to contain a long run equilibrium relationship it is necessary that z_t in [7.2.3] be I(0), so that z_t will rarely drift from zero and equilibrium will occasionally occur. A VAR representation in first differenced form for x_t will then only be valid if it is of the form,

$$A(L)\Delta x_t = -\gamma z_{t-1} + u_t \qquad [7.2.4]$$

where u_t is a stationary process, γ is $g \times r$ in dimension matrix where $r \leq g-1$ and A(L) is a $g \times g$ matrix with elements that are polynomials in the lag operator. (Baille and Selover (1987) note that Engle and Granger (1987) and Granger (1986) discuss ways of dealing with the g =2 case, although precise inferential procedures in higher order models are currently unresolved).

The ADF is applied to identify the order of integration. The hypothesis of a unit root in an autoregression is tested by means of estimating the model:

$$\Delta x_t = \beta x_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta x_{t-i} + \varepsilon_t \qquad [7.2.5]$$

and testing H_0: $\beta=0$ versus H_1: $\beta>0$, so that the null hypothesis implies a unit root. The critical values of the one sided test are sensitive to the sample size and the inclusion of a constant term.

Problems are noted with this test and it is challenged by Chen and Tran (1994). According to Chen and Tran (1994) the ADF is prone to low power and is inclined toward accepting the null hypothesis of a unit root. The ADF is sensitive to whether monthly or annual data is used and tends to reject the null using annual data. In the methodology followed here we remain using the ADF test, allowing for both the trended and non-trended case. Different lags are added. Should the ADF result prove sensitive to the number of lags, then it may indicate that the result should be treated with scepticism. In the case of the ADF used in Microfit 3.0, the critical values (or response surface estimates), used are those suggested by MacKinnon (1990). The sample chosen is for 1950 to 1990. Where appropriate, the sample is split, or curtailed. This proved important for UK data where unit root conclusions were sensitive to the sample chosen.

Chapter 7.3

Procedure

It is decided to adopt the Johansen procedure in estimating the cointegrating vectors contained within the system of equations. (The model used is discussed in Chapter nine and the equation to be tested empirically is shown here).

$$\left(\frac{R^i}{R^{us}}\right) = \lambda\left(\frac{L^i}{L^{us}}\right)^{\alpha} \qquad [7.3.1]$$

Where R^i is the real exchange rate for country i and R^{US} is the real exchange rate for the United States. L^i is the labour residual designed to capture the contribution made by the human capital measure within the economy. L^{US} is the labour residual measure for base country, in this case the United States. λ is designed to capture the relationship between the real exchange rate and the relative efficiency of economy i with the base economy, the United States. It is the matrix of cointegrating vectors.

The Johansen procedure is regarded as a superior estimation procedure due to the many problems associated with the Engle and Granger method. Arize (1994). Strauss (1995) concurs and also uses the Johansen procedure (Maximum Likelihood estimator) in examining the real exchange rate and the forces that act upon it. The Johansen Maximum Likelihood (ML) procedure (based on Johansen (1988, 1989) and Johansen and Juselius (1990)), provides a unified framework for the estimation and testing of cointegrating relations in the context of a VAR error correction model.

The Johansen estimation method is based on the error correction representation of the VAR(p) model with Gaussian errors:

$$\Delta x_t = \mu + \Gamma_1 \Delta x_{t-1} + \Gamma_2 \Delta x_{t-2} + \ldots + \Gamma_{p-1} \Delta x_{t-p+1} + \Pi x_{t-p} + Bz_t + u_t \quad [7.3.2]$$

where x_t is an m×1 vector of I(1) variables, z_t is an s×1 vector of I(0) variables, G1, G2, ..., Gp-1, P are m×m matrices of unknown parameters, B is an m×s matrix, and u_t ~N(0, S). The I(0) variables are included in the model to ensure that the disturbances u_t are as close to being Gaussian as possible. z_t may include seasonal dummies or innovations in variables that are exogenous to the VAR system under consideration.

The Johansen method provides ML estimates of the parameters of the VAR(p) model defined in the above equation [7.3.2]. This is subject to the condition that the matrix Π has reduced rank, r <m. That is H(r): $\Pi = \alpha\beta'$ where α and β are m×r matrices, and β' is the transpose of β. Johansen (1989) shows that, under certain conditions, the reduced rank condition [2] implies that the process Δx_t is stationary, x_t is non-stationary, and that $\beta' x_t$ is stationary. The stationary relations $\beta' x_t$ are referred to as the cointegrating relations. Having discovered the number of cointegrating relations (r) in the data, this is specified and α, β, and Π are generated by Microfit 3.0. β is the ML Estimated Cointegrating Vector in the Johansen Estimation procedure; α is the ML estimate of the short run adjustment matrix and Π is the long run matrix generated.

The trace and maximum eigenvalue statistics proposed by Johansen are computed to test the different hypothesis concerning the rank of Π, namely r. A Likelihood ratio statistic can also be computed for the three different types of restrictions on β.

It is essential that $0<r<m$. If r=m, then the matrix Π will be a full rank and all linear functions of x_t will be stationary.

Chapter 7.4

Conclusion

The above analysis provides the statistical background for the model to be tested. The ECM approach is superior to the residual based approach. What remains then is to chose an appropriate model that can isolate a relative efficiency measure. In the chapters following a model is introduced and a data set is chosen.

CHAPTER EIGHT

DATA SET AND VARIABLES

Chapter 8.0

Potential Significant Variables in the Analysis.

The data set chosen is in accordance with the hypothesis that the real exchange rate is related in some way to the economy, in terms of economic fundamentals, development and relative performance.

The (real) exchange rate is chosen as the dependent variable. The empirical testing can be approached in two ways. Using the convergence hypothesis, a bilateral rate can be used, the leader economy being the US. All economies are compared to the US. In the more general sense, where we wish to examine whether the real exchange rate of the economy changes as the economy's performance relative to the rest of the world, a real effective exchange rate would seem more appropriate. However, in the case of an effective exchange rate, data starts around the mid nineteen seventies. Hence there is greater data availability and a longer run of data for bilateral rates.

The choice of how to deflate the real exchange rate is also appropriate. Whether to use a CPI, WPI or some GNP deflator is more problematic. In cases where one is testing the PPP hypothesis, the WPI tends to return more significant results. However the WPI better reflects the traded sector and this is not the entire economy. It is arguable that the CPI would provide a better indication of the economy's real inflationary position and a better indication of its overall workings.

It is further observed that the dependent and independent variables are being measured by a price level which itself is a symptom of the economic activity. This may introduce estimation problems and would imply some kind of endogeneity within the estimation procedure.

Chapter 8.1

Independent Variables

The independent variables chosen are such that they should indicate the degree of development within the economy over time. It is also necessary to include a measure of relative performance. This is more problematic. This is dealt with in Chapter 9.

Chapter 8.2

Productive Capacity and Specification

It is assumed here that an agent would not carry on functions that were contrary to increasing overall utility. The overall intention of economic activity is to increase the standard of living. Utility is defined in terms of the ability to provide for present and future consumption patterns.

Changes in productive capacity over time should affect the ability of the economy to change its output production path. Changes in factor inputs, or changes in the efficiency with which factor inputs are modified to produce a level of output, should lead to increases in the output path of an economy. It is necessary to apportion proxies to the factors that are believed to affect the output level of the economy.

The diminishing marginal product assumption ensures that models of the economy have a non-explosive nature. The assumption of constant returns to scale is supported by Chan and Mountain (1983). However some force must be allowing convergence. The convergence phenomenon, especially in the post World War II period, seems to suggest that the neo-classical approach and its assumptions need to be modified or replaced to accommodate this characteristic. It is argued by Young (1994) that this is in fact not the case. However others such as P. Romer (1986) have suggested that some factor input must provide increasing returns to scale. This input is believed to be technology. It is posited here that changes in technology and the dissemination of knowledge (knowledge spill-overs) takes two forms.

Chapter 8.3

Capital Stock

Capital stock measurement is one of the problematic areas identified. t is suggested that the investment rate provides a better estimate of the real capital stock of the economy. This is reasonable especially when differential depreciation rates and policies are in force, both within and between economies. Nehru and Dhareschwar (1993) provide data on gross domestic fixed investment rates from 1950-1990 as well as gross domestic fixed investment in producer durables (as a share of total GDFI).

Chapter 8.4

Social Capability

It is probable that technology is not always embodied within capital goods. Changes in how inputs are altered in the production process also provides a means for output to increase over time. The idea of disembodied technological change, learning effects, or the idea of social capability also explain the observed facts regarding convergence in the world as a whole.

Here it is deemed appropriate to use some kind of an education proxy. Such information is provided by Nehru and Dhareschwar (1993). Those authors provide data on both physical and human capital. In the case of the latter they provide data on time spent in education as well as data on primary, secondary and tertiary education. Further, Psacharopoulos (1985) shows that the return on human capital in developed economies is about 9% per year spent in education. It is noted that different types of education provide varying returns. Psacharopoulos (1985) also observes that returns from education within the competitive sector are higher than those within the public sectors. This fact has been ignored by some. Thus returns from the competitive sector are also included in this measure of return on human capital.

Chapter 8.5

Labour Stock

We are interested in the participation rates within the economy as well as the growth of the effective labour units in the economy. It is believed that labour quality is an important factor in development and this is referred to as social capability. Changes in assimilative capacity through changes in the skill level of the economy would be expected to affect income paths in the future. Since they represent a real investment, ignoring changes in the labour quality would reduce the contribution of labour to the development process.

School enrolment rates are taken from Nehru, Swanson and Dubey (1993). Other proxies are required for changes in the skill level and returns from education. Using educational investment levels may provide additional information. A measure to reflect loss of earnings may better reflect changes in the labour quality through skill augmentation.

Use of the wage level or differences between the wage and minimum wage level may indicate a return from changes in the skill level. This is suggested by Mankiw et al. (1992) but is questionable. Whether the neo-classical assumption is correct and the wage level indicates the marginal product of labour is again disputable. It is believed that this difference in $W\text{-}W_{min}$ should reflect the difference in the marginal product of labour. If the minimum wage applies to generally unskilled labour force participants, why pay a wage level higher than W_{min}? Presumably labour with additional skills is rewarded with a wage level higher than that pertaining to unskilled labour. However, support for the neo-classical assumption that the wage level equals the marginal product of labour is questionable.

Chapter 8.6

Development Proxies

It is believed that the level of development affects the explanatory power of dependent variables. Development does not appear to be a linear process. Hence factors that are important at the initial stages would be expected to change over time as development progresses.

Here it is decided to include proxies for development. If the above is true, the level of development will dictate the dependent variables that are important in affecting the real exchange rate. If this is not the case then it may indicate that individual characteristics of the economy exist that affect the real exchange rate.

The development proxies used include data on capital stock per capita (K/N) and capital output ratio (K/Y). King and Levine (1994) provide data on capital stock per capita and capital output ratio from 1950 to 1988, both in 1985 international prices.

It is also of interest whether the development is biased in terms of capital or labour. It would be expected that capital increases at a faster rate than labour. Hence the K/Y ratio would tend to rise as development ensued.

Due to the non-linear nature of development and various index problems (Summers and Heston, 1988, 1991), analysis is limited to economies in the G7 and Australia.

CHAPTER NINE

MODEL

Chapter 9.0

Model

It is intended here to outline a way of generating a relative performance measure within a production function framework. At the same time, we continue to follow the methodology above and believe that the real exchange rate or nominal exchange rate may be explained by some information set X_t.

To this end

$$RXR_t = f(X_t) \qquad [9.0.1]$$

$$\{F_t, Q_t\} \in X_t \qquad [9.0.2]$$

$$RXR_t = f(F_t, Q_t) \qquad [9.0.3]$$

I expect the information set to contain proxies to represent economic fundamentals (F_t) plus relative performance measures for the economy, Q_t.

Economic fundamentals may be encompassed within some kind of a production function framework. It would be reasonable to assume that this would contain elements such as labour, labour productivity, capital and capital productivity. It will also prove necessary to account for residual growth using a residual term. This term will act as a catch-for-all term (due to misspecification or measurement errors) or to encompass some features of growth not contained within conventional measures. It is this measure that is of particular importance. This residual term could then act as an indicator for relative efficiency. It is further assumed that capital is mobile. Capital should not be the reason for observed differential growth patterns observed cross sectionally. Different rates of capital accumulation will affect growth within the economy. No one capital stock is superior to another. That is to say that no country specific characteristics exist within the indigenous capital stock.

$$F_t = h(K_t^{\beta}, L_t^{\alpha}). \quad [9.0.4]$$

If h is defined as a non IRTS production function then some other force would be needed to counter the diminishing marginal product associated with neo-classical growth models. Hence

$$F_t = \Theta.h(K_t^{\beta}, L_t^{\alpha}) \quad [9.0.5]$$

Let Θ be technological change. Assume that for now it is an exogenous function. Θ can be assumed to be some positive monotonic function. If we subsume h within Θ, can we assume that technological change is a well behaved, monotonic convex function. Θ changes with time. Assume further that K and L are used in a fashion that allows them to enter the production function in a multiplicative fashion. If we define [9.0.4] as a Cobb-Douglas production function then we can assume that α and β sum to unity.

$$F_t = \Theta_t(K_t^{\beta}. L_t^{\alpha}) \quad [9.0.6]$$

Changes in F are a function of changes in labour, capital, their relative marginal products and technology.

It is recognised that β and α may both be time dependent. Subsume their potential time dependency in the notation for simplicity's sake. It is necessary to explain the forces that drive the arguments of the function.

Chapter 9.1

Capital Stock

The capital stock is assumed to increase due to a commitment of resources. The capital stock is a reflection of the desire to commit resources as well as being related to the process that drives increases in resources.

Due to problems estimating capital stocks, it may be appropriate to estimate the capital stock using investment rates in the economy times the income level. The application of some standard depreciation charge is more problematic.

$$Y_t = C_t + S_t \qquad [9.1.1]$$

Income Y, is composed of Consumption (C) and Savings (S). Assume that $S_t = I_t$

$$I_t = Y_t - C_t \qquad [9.1.2]$$

The rate of investment is a function of the interest rate in the economy. This is interpreted as incorporating two types of information. It contains information regarding the supply and demand of funds, and the imbalance therein. It also reflects the underlying rate of thrift within the nation. When S and I reach equilibrium, the interest rate, the rate of equilibrium within the economy is taken to reflect the time preference of money.

Hence

$$I_t = M(Y_t, i). \qquad [9.1.3]$$

$$i = \rho(\iota, \sigma, (\iota/\sigma)) \qquad [9.1.4]$$

$$\sigma = U(C^e_{t+1}/C_t) \qquad [9.1.5]$$

$$\iota = \sigma. \qquad [9.1.6]$$

The time preference of money in the economy must reflect the expected utility of future consumption over present. Assume that this is exogenous. Short run deviations are expected so that the interest rate may deviate from its equilibrium value. In the long run however, it should reflect σ.

$$i = \rho(\iota, \iota, \iota/\iota) = \rho(\iota) \qquad [9.1.7]$$

$$I_t = M(Y_t, \rho(\iota)) \qquad [9.1.8]$$

$$K_t - K_{t-1} = I_t \qquad [9.1.9]$$

ignoring depreciation for now.

$$\Rightarrow$$

$$\sum_{i \geq 1}^{t} I_i = K_t - K_0 \qquad [9.1.10]$$

$$\Rightarrow \sum_{i \geq 1}^{t} I_i + K_0 = K_t \qquad [9.1.11]$$

The capital stock is some function of historical investment. It is possible to normalise this by assuming that capital stock in the past must be retired at some stage.

If we assume that t = 10, then using a net present value approach, what depreciation charge allows the capital stock from period 10 to make a negligible contribution to income? That is to say what depreciation charge can be chosen that leads to the assets being worth nothing?

$$K_t = \frac{I_0}{(1+\zeta)^{10}} + \frac{I_1}{(1+\zeta)^9} + \frac{I_2}{(1+\zeta)^8} + ... + \frac{I_9}{(1+\zeta)^1} + \frac{I_{10}}{(1+\zeta)^0} \qquad [9.1.12]$$

$$K_t = \sum_{i=0}^{t} \frac{I_{t-i}}{(1+\zeta)^i} \qquad [9.1.13]$$

As t tends to infinity the contribution from older investment provides a negligible contribution to income. It would be more accurate to assume that the depreciation charge changes with time and is hence time dependent. Assuming that capital is retired due to obsolescence and wear and tear means that the rate of technological change will affect values of ζ. However not enough is known about the process that drives Θ.

Assume that capital stock was created an arbitrarily long period ago. From the above, it is now obsolete. This removes the necessity for estimating the actual capital stock from that period, that is K_0. If i is equal to 40 years, then one may assume that capital from a period of 40 years ago provides a negligible contribution to current income and future income streams. This methodology could allow the normalisation of the capital stock. It is then a case that additions to the capital stock provide explanations for subsequent growth.

The capital stock is made obsolete by both depreciation in the standard sense and by obsolescence. Obsolescence is regarded as occurring when changes in technology cause older capital stock to become inferior to newer capital stock. This occurs to the extent that a company must replace older capital if it wishes to remain competitive within that industry.

It is reasonable that the types of capital investment affect output capacity. It may be necessary to disaggregate the capital stock measure in some way. For example, investment in consumer durables is likely to be more highly correlated with changes in income. Infra-structural investment tends to provide a much longer investment horizon than other investment types and the actual return from such investment is believed to be high. Hence

$$K_t = \sum_{v=1}^{n} \left(K_t^v\right) \qquad [9.1.14]$$

where n is the total number of different investment opportunities with differing return characteristics.

Let v be the type of capital stock. It is possible to define capital in terms of the industry into which the capital input enters. (Dependent on data availability). This may provide more meaningful estimates of the effect of capital upon output variation.

Since the exchange rate is an external measure, a greater weighting is likely to be given to the traded sector. Investment concentrated in this area may be more highly correlated with exchange rate changes. The traded sector tends to be more capital intensive than the nontraded sector. However this gives an incorrect impression. What of investment in infrastructure? Does the traded sector benefit from this?

Chapter 9.2

Capital Productivity

The productivity of capital is some function of technology (Θ). It is assumed that increases in the marginal productivity of capital are due to changes in the embodied technology of the capital stock. The marginal product of capital is believed to change as a result of changes in technology. Since this is assumed to be occurring throughout time at some rate, then changes in the capital stock age affect the technological content of the capital stock and hence its marginal product. I assume that a backlog of technology exists, hence although technological change is a more complicated function, it is likely that this may be approximated by some constant rate or function of time.

The age of the capital stock must also be some function of investment, the marginal propensity to invest. If we assume that the only way that technology can enter capital is through an increase in its marginal product, then changes in β occur because of changes in technology. This should then be captured in the age of capital.

$$dK/dt \cong dI/dt \qquad [9.2.1]$$

β is that contribution to output that comes from increases in output not accounted for by labour, labour productivity, and increases in the capital stock. Increases in β should come from changes in the technological content of capital. Technology is an monotonic increasing function. As time increases, technology improves. Hence β is time dependent.

$$\beta = \kappa(\Theta_t). \qquad [9.2.2]$$

Θ be a monotonic increasing function, its first derivative is positive. Since it is difficult to identify what technology is, a better approach would be to analyse its symptoms. It is believed that capital is mobile, then capital productivity and hence β should not be the reason for differential growth rates. In the ratio approach adopted here, the β's are set constant for all countries. This forces any increases in technology through the residual term.

We are still left with estimating a reasonable value for β. Failing direct measurement of capital productivity, if an estimate of β can be obtained that leads to reasonable income growth paths, then additional productivity gains may be forced into the residual term.

Chapter 9.3

Labour Stock

Population growth, as is often the case with growth models, is assumed to be exogenous. This is a reasonable assumption. The rate of natural increase is a function of the fertility rate and the mortality rates of the economy. However, the participation rate is likely to increase with income levels and is hence endogenous. We are interested in the increases in the participation rate since this provides an indication of the utilisation rates within the economy.

$$L_t = \ell(G_t.\Phi) \qquad [9.3.1]$$

Increases in the participation rate should mean an increase in the contribution provided by the population of the economy. (Reciprocally there is a fall in the dependency ratios of the economy). As the economy develops and labour mobility ensues, there should also be a reduction in the degree of underemployment. Assuming the proper functioning of the economy, there will also be a reduction in the unemployment rate as labour resources provide positive additions to productive capacity and wage flexibility allows for disequilibrium problems to be resolved. This increase in output may be captured by some structural change measure. If this is one reason for increases in output, especially at initial stages of development, it would be expected to diminish over time. Inputs would tend to move to areas which maximise their respective productivities. (This contribution would be high for less developed economies. That is, skilled labour provides a higher return than in developed economies).

The growth rate of the population is some function of the difference between the mortality (m) and the birth rate (b) of an economy. These are assumed to be exogenously determined. This is a reasonable assumption if we limit ourselves to developed economies.

$$G_t = d(b - m).\Pi_{t-i} \qquad [9.3.2]$$

That is, the population is some function of the mortality and birth rates of an economy, times some starting population (Π_{t-i}). Again it is possible to normalise population to zero. Assume that the b and m act so as to allow the population to grow slowly over time.

Π_0 can be seen as an initial population measure. Changes in Π_{t-i} denote different starting points in the nation's population growth over time.

The participation rate of the economy (Φ) is given as some function of income. Further, it is assumed that there is a positive relationship between the two, but that eventually a maximum participation rate is reached. This maximum is based on the trade off between leisure value versus work time and their respective returns.

$$\Phi = \phi\,(Y/L) \qquad [9.3.3]$$

and where the first derivative is positive but the second derivative is negative.

As income rises in the economy, the participation rate would be expected to rise, up to the point where the marginal return from an extra hour of labour equals a unit of leisure time. The price levels within an economy tend to be more highly correlated than similar products between different economies. As mentioned in Chapter 4 this may also be the case with wage rates.

Data on labour force participation rates already exists. Convergence toward a similar participation rate is noted. As the participation rate increases or as underemployment is reduced, changes in productivity would be expected. Should we only use potential labour force measure (population 15-64) or is it more appropriate to use actual labour force measures? Actual labour force times an employment rate would also be subject to the capacity utilisation effects observed by the TFP measures. That is, increases in productivity are observed at the end of a recession and a fall in productivity is noted at the end of a boom, as companies are slow to reduce their labour forces even though market signals a fall in demand. Potential labour force rates would be more stable than actual employment rates.

$$L_t = \ell\,[(\Pi_{t-i}\ g)(\Phi_t)] \qquad [9.3.4]$$

Since

$$\Phi_t = \phi(Y_t/L_t) \ \text{ or } \Phi_t = \phi(Y_t/N_t) \qquad [9.3.5]$$

where N_t is the population at time t.

Chapter 9.4

Labour Productivity.

Excluding increases in the factor input, changes in the marginal product of labour would be expected to occur because labour had itself become more productive. Since investment in education represents a real commitment of resources, this must be incorporated into the labour measure. One way of approaching this is to look at changes in the skill level of the economy over time. Alternatively it is possible to look at the direct expenditure by the economy on labour.

It is possible to allow technological change to enter the labour measure by adding in an educational or skill measure within labour.

$$\alpha_t = \mathcal{S}(E_t, E_i, \vartheta_t) \qquad [9.4.1]$$

Where E_t is the time spent in education; E_i is the type of education.

ϑ_t = spending on education per worker, at time t.

$$\vartheta_t = j(Y_t). \quad 0<j<1 \qquad [9.4.2]$$

j represents the proportion of income designated to educational spending. j may change over time.

It is noted by Foster and Rosenweig (1996) that an endogeneity problem exists. Does the wage level reflect increases in technical change or does it reflect changes in schooling levels? Foster and Rosenweig (1996) suggest that in order to extract estimates of technical change from information on productivity, it is necessary to control for the changes in the productive inputs. It is found in the paper that only primary education had a significant effect on returns from investment and technical change. Higher levels of schooling proved to be insignificant. However the paper focuses on agricultural development and the introduction of new technology in this area. It is seems reasonable that higher levels of schooling would prove significant in other sectors. Following this line of argument it would be rational to expect that tertiary education would provide its highest return in the advanced economies or those attempting to adopt technology in hi-tech areas. Primary education would not provide the necessary receptive environment to assimilate technology at that stage of development. In the study conducted by Foster and Rosenweig (1996), it is found that education leads to an increased likelihood of adoption of new technology, although education on its own does not lead to increased output. It appears that schooling is a preparatory mechanism. Added to a policy of technology adoption, it leads to returns from education and skills augmentation. In the approach of that paper, technology is introduced in different areas, with varying levels of schooling. If areas with superior schooling outperform other sectors, then it would tend to imply a return from education. It is found that the two effects, education and technical change compliment one another.

The problem is that technology may enter through both capital goods and knowledge. Failing to account for increases in technology from these areas still leaves the residual term to indicate changes in technological content of output. The investment in educational infrastructure should prove beneficial provided that more advanced technology is being adopted by the economy. It is not a sufficient condition, but is a necessary starting condition.

Superior growth rates should be observed when the skill level is increased and when technological change is occurring. This would reinforce the argument that capital goods are not the sole cause for the lack of convergence observed in the world as a whole. Rather it is the failure to increase disembodied technology and provide a receptive environment that leads to the failure to converge.

The problem of identifying a proxy for education remains. If it is decided that differences between wages and some minimum wage do in fact reflect changes in the marginal product of labour, then wage differentials provide a reasonable measure for the return on education. If this assumption is incorrect, then following a more direct route and using spending on education as a % of GNP may be more accurate. The advantage with using the $W\text{-}W_{min}$ approach is that we treat time spent in education as being rewarded by some increase in returns from labour. One also takes account of the earnings forgone by those that stay in education. This is ignored in the direct method. Alternatively some hybrid may capture the commitment of resources more accurately.

Precursory regression analysis indicates that nominal wages are highly correlated with inflation measures. Hence the residual term between the regression of wages on inflation rates is quite small.

The marginal productivity of labour changes as a result of education and skill level. This should be reflected in changes in the wage rate and also measured by spending allocated to education. Since labour's contribution may be either through explicit improvements in the quality, or through technological improvements, we have chosen to incorporate changes in the skill level of the economy within effective units of labour, (ς_t).

Failing this, an output per unit of labour measure could act as a proxy for returns to education, given our assumptions. Again Foster and Rosenweig's (1996) criticism is noted. Given the complementarity between social capability and the introduction and adoption of technology, the use of this output measure is justified. This output term can be used to account for the increase in the effective units of labour occurring over time.

Chapter 9.5

Effective Labour Units

Following the approach taken by Psacharopolous (1985) it is decided to as given that the return on human capital for advanced economies is 9%. This figure has been calculated for seven of the eight countries in the sample under consideration, with an additional estimate made for Australia. The 9% return on education is the return per year of education. The effective units of labour is hence labour force times years in education times 9%. This return is calculated taking both the returns from the competitive and public sectors into account.

Let

$$L_t = G_t\,\Phi_t \qquad [9.5.1]$$

$$S_t = E_t.(E_R) \qquad [9.5.1]$$

$$\varsigma_t = L_t.\,S_t \qquad [9.5.1]$$

L_t is the labour force and is the population times the participation rate. S_t is the skill addition from education to the labour force. E_R is the return from education and E_t is the time spent in education. Hence ς_t, is the effective labour force, that is the labour force times the addition made through education. Consequently, an explicit account is made of the additions made to labour through investment in human capital.

This ς_t is used in preliminary regressions to estimate the marginal products of labour and capital. The difficulty in measuring labour's contribution to income growth still remains. It may then be the case that a relative measure would be more appropriate.

Chapter 9.6

Relative Measures

The extent to which conventional measures fail to account for all growth observed in income implies that an additional measure is required.

There is a place for a residual term in this investigation, especially in a time series analysis. By permitting a residual term, we are explicitly recognising that conventional inputs fail to account for all observed growth patterns. In this case the residual term will act as a catch-for-all term. It is the belief of some authors, notably Young (1994), that the neo-classical model does in fact provide a reasonable explanation for observed growth patterns, provided that conventional inputs are measured correctly. It is the failure to correctly measure conventional inputs that forces one to look to a 'catch-for-all' term.

As has been noted earlier, TFP is believed to provide a positive contribution throughout the entire development process. Ohkawa (1993) claims that one of the few measures that remains positive during the development process is product per worker. Two points are noteworthy. Firstly, some common process enters these measures. Secondly, they do not appear to suffer diminishing marginal returns. It would be desirable that relative PPW or relative TFP measures be correlated or cointegrated with the real exchange rate and/or the nominal exchange rate.

If Y_t^* is that income level predicted by conventional inputs then

$$Y_t - Y_t^* = \Psi_t \qquad [9.6.1]$$

where

$$Y_t^* = (K_t^{\beta} . L_t^{\alpha}) \qquad [9.6.2]$$

Since the exchange rate is a relative measure we will define predicted output as that relative to the US. Set β and α so that they are equal for all economies. Then

$$\left(\frac{Y^i}{Y^{us}}\right)-\left(\frac{Y^i}{Y^{us}}\right)^* = \left(\frac{TFP^i}{TFP^{us}}\right) \qquad [9.6.3]$$

$$\left(\frac{Y^i}{Y^{us}}\right)^* = \left(\frac{K^i}{K^{us}}\right)^{\beta}\left(\frac{L^i}{L^{us}}\right)^{\alpha} \qquad [9.6.4]$$

Time subscripts are omitted.

Should differential growth rates persist then this would be due to some nontraded factor. Labour seems to be the obvious choice for a relative efficiency measure. If the TFP or residual measure is subsumed within the labour side of the production function, then a relative performance measure is created.

$$\left(\frac{Y^i}{Y^{us}}\right)-\left(\frac{K^i}{K^{us}}\right)^{\beta}\left(\frac{L^i}{L^{us}}\right)^{\alpha} = \left(\frac{TFP^i}{TFP^{us}}\right) \qquad [9.6.5]$$

$$\left(\frac{Y^i}{Y^{us}}\right)-\left(\frac{K^i}{K^{us}}\right)^{\beta} = \left(\frac{L^i}{L^{us}}\right)^{\alpha}\left(\frac{TFP^i}{TFP^{us}}\right) \qquad [9.6.6]$$

If we subsume the TFP or residual term within the labour measure we obtain

$$\left(\frac{Y^i}{Y^{us}}\right)-\left(\frac{K^i}{K^{us}}\right)^{\beta} = \left(\frac{L^i}{L^{us}}\right)^{\alpha} \qquad [9.6.7]$$

Having calculated a relative efficiency measure, (see Appendix B), that is $(L^i/L^{us})^{\alpha}$, this term is then examined to see if a cointegrating relationship exists between it and the real exchange rate. Hence $(L^i/L^{us})^{\alpha}$ becomes the information set X_t in equation [1.0.1].

$$\left(\frac{R^i}{R^{us}}\right) = \lambda\left(\frac{L^i}{L^{us}}\right)^{\alpha} \qquad [9.6.8]$$

[9.6.8] forms the basis for the cointegration relationship.

Chapter 9.7

Estimation of Marginal Products

It is assumed that since the marginal products sum to one and β is constant across countries, then the relative labour measure in [9.6.8] should capture any relative efficiency in one economy over another.

Fischer (1993) in his paper, sets r = 0.4 and w = 0.6, where r = α and w = β. He calculates a relative TFP measure. Choosing values for the marginal products is quite problematic. The restriction that the marginal products sum to one is necessary otherwise large economies would retain their position as leader economies by virtue of the magnitude of their factor inputs. Values for β need to be quite high according to Romer (1987). Romer (1987) believes that a β should be near unity. This means that capital is left as the driving force behind growth, a conclusion consistent with the neo-classical interpretation of the growth process. The values suggested by Fischer (1993) are quite low and it is found that setting a value for labour around 0.1 produces a better predictor for income, Y*. Even after incorporating an effective labour measure, the marginal products do not approach Fischer's (1993) estimates.

One caveat exists within this approach. The decision regarding the marginal products introduces a multiplicative error into our relative performance measure. A slight change in the marginal product value would lead to a large change in the labour-residual term. Failure to correctly calculate the marginal products leads to a situation where the errors generated are multiplicative not additive. The residual terms could be quite large. Ψ_t could represent the extent to which the price of capital and that of labour, do not reflect their respective marginal products, and/or the mismeasurement of factor inputs. Relative TFP measures would be expected to lead to changes in the real exchange rate.

Morrison (1992) notes that TFP is subject to secular and cyclical changes. Therefore adjustment of any TFP measure for capacity utilisation effects (χ) should lead to improved results.

$$\Psi_t^* = \Psi_t(\chi_t) \qquad [9.7.1]$$

However, these capacity utilisation effects would be expected to wash-out of the system in the long run. Again it can be argued that the ability to maintain high capacity utilisation rates is a symptom of the economy's labour force. Rigidities within it, in terms of wage flexibility or retraining times, would ensure that under-utilisation persisted. Therefore the residual term generated should still contain accurate information regarding a country's relative efficiency.

The calculation of the residual term involves fixing wage and interest rates. This I believe ensures that the only contribution to increases in income comes from factor input increases or changes in the residual term. I assume that no country specific factors exists that would allow one country's capital or labour to remain superior to another economy's. Superior performance now enters through the relative labour residual term (Lilus) in [9.6.8].

This ignores the possibility that technology can enter through labour productivity and/or capital productivity. This would necessitate β and α changing over time. A Chow Test could be performed on the estimates of α and β to test their stability over time. However, by leaving them constant, relative changes again enter through the relative labour-residual term.

This approach ensures that the labour-residual terms plays the principal role in explaining changes in income. However, initial runs of the data indicate that the production function specified here works better if countries are allowed to have different marginal products. This is problem is overcome by using values for α and β that minimise the residual term in [9.6.5] for the base economy. These values are then fixed for the entire sample and estimation of relative efficiency continues using these values in equation [9.6.8].

From the literature reviewed within the TFP area, TFP does remain positive throughout development process. One must conclude that technology provides positive contributions to income. (This assumes that w and r measure accurately the marginal products of labour and capital).

Chapter 9.8

Residual Based Approach.

Following a residual based approach and setting the marginal products of capital and labour equal to some fixed value, it is now implied that capital and labour provide the same contribution to income levels throughout the world. That is to say, no one capital or labour input is superior to another economy's. This being the case, the Labour-residual term (Lilus), now captures any country specific factors that make one economy more efficient than another.

By restricting α and β to sum to one, any increasing returns to scale property now appears through the residual term. If factor inputs are measured correctly, then the residual term provides a meaningful indication of technological contributions. If capital and labour inputs are not correctly measured, then the residual contribution provides information on mismeasurement as well.

With this approach, superior residual growth implies superior performance and this is believed to affect the real exchange rate over time. That is, superior performance implies increases in the wealth of an economy and therefore an increase in the relative purchasing power of that economy. Over time, consistent performance leads to an appreciation of the country's real exchange rate. As mentioned earlier, adjustments to this residual measure may improve the quality of the relationship.

The setting of values for α and β forces the contributions from country specific growth to enter through the residual term. If the country is experiencing the benefits of catch-up or structural change, then this also feeds into Ψ. The exchange rate is a bilateral one then a ratio approach is appropriate.

CHAPTER TEN

EMPIRICAL ESTIMATION

Chapter 10.0

Empirical Estimation

This Chapter outlines the data set chosen and the empirical estimation of the model presented in Chapter 9.

Chapter 10.1

Data Sources

Initially, an attempt was made to estimate values for α and β using a Cobb-Douglas production function. Marginal product estimates were available from Fischer (1993) as mentioned earlier. Estimates calculated here (see Appendix D), give a larger role for capital and more reasonable estimates for income.

Capital measures were taken from Nehru and Dhareschwar (1993). These estimates were slightly higher than the capital to output ratios calculated by King and Levine (1994). Labour measures and participation rates were taken from the Penn World Tables 5.0, (Summers and Heston, 1984, 1988, 1991), and additional population measures were available in Nehru and Dhareschwar (1993). Labour was calculated from mid-year population measures times the economy's participation rates. The participation rates were implied by two measures available in the Penn World Tables 5. The rate was calculated by dividing the real GDP per capita (RGDPCH) by the real GDP per worker, (RGDPW), both rates in 1985 international prices. The estimate was compared with direct estimates available from DATASTREAM. The former were chosen because the data sets were available for a longer period, namely 1950-1990. The DATASTREAM data was compiled from OECD databases, but lacked consistency, both in terms of data runs and some estimates. Effective units of labour are calculated using the rate of return from education calculated by Psacharopoulos (1985), times years spent in education obtained from estimates by Nehru and Dhareschwar (1993). The idea of using effective units of labour was not used in calculating the variable Lilus.

However, using effective units of labour and the participation rate data seemed reasonable when attempting to arrive at an accurate value for α and β. Inflation data, while not used in estimation, were used in preliminary comparisons of capital stock estimates. This data was available from Bruno and Easterly (1995).

Bilateral exchange rates were available from the Penn World Tables 5.0. Real exchange rates were calculated using inflation proxies in the Penn World Tables. Real exchange rates and some effective exchange rates were also available from DATASTREAM. In the case of the effective rates, most began in 1975. The analysis was limited to bilateral rates, using the US as base country. These were available directly from the Penn World Tables. A database maintained by Cornell University (USA) provided information on effective exchange rates, inflation and industrial production. These rates were only available from the mid eighties onwards and further data limitations precluded the application of our procedure to the effective exchange rate. Nevertheless such a comparison could prove enlightening.

The real exchange rate was calculated using the price level (P) in the Penn World Tables 5 (PWT5). (See Appendix E, for the list of variables available from the Penn World Tables site). The real exchange rate (RXR_t) was calculated using

$$RXR_t = XR_t(P^f_t/P_t) \qquad [10.1.1]$$

Where XR_t is the nominal exchange rate (in this case the bilateral rate relative to the US \$), P_t^f is the foreign price level (in this case the US price level) and P_t is the domestic price level (in this case that of the non-US economy). (See Appendix D for calculations).

Summers and Heston (1991) warn against the problems of using prices in both cross sectional and time series analysis. According to them

> In this international dollar currency relative prices of individual goods are set at the (weighted) average of relative prices for the same goods in all countries, and the level of prices is normalised so that the GDP of the United States is the same

in international dollars as in American dollars. A more symmetric treatment of relative prices would be to express them in terms of the world as a whole rather than a particular country, but this runs counter to the customary practice of using the United States as the country of reference. It should be emphasised that a benchmark study's international comparisons based on this approach are invariant under a change in base country. However, in developing international comparisons such as those used in PWT 5.0, the choice of base country does make a difference. (Summers and Heston, 1991, p. 334).

The P measures (see Appendix E) are used here for the sake of consistency. Summers and Heston's (1991) paper provides more detailed explanations and support for the methodology followed in PWT5. Their current data and collection procedure is in line with World Bank suggestions from 1990, and this is noted by Summers and Heston (1991). As was noted by Ohkawa (1993) and by Summers and Heston (1991), comparisons between countries of similar income levels proves more meaningful. This is particularly true in international price comparisons. The evidence from International Comparison Project, (ICP), is that PPP does not hold. Although exchange rates differ from PPP significantly, they do so in a systematic way. 'The national price level of a country, defined as the ratio of its PPP to its exchange rate, is a rising function of the level of its income or stage of development.' (Summers and Heston, 1991, p. 334).

Initial Regression were run using Econometrics Toolkit (1992) while cointegration estimates were obtained from Microfit 3.0.

Chapter 10.2

Estimation

Using the equation [9.0.6], estimates for α and β were chosen for the base economy. These estimates were chosen on the basis of maximising the predictability of income in the base economy only. (See Appendix D). These were then set constant for all economies. Relative performance measures were then calculated using equation [9.6.8] and the estimates of α and β. These relative performance measures (Lilus), were then used in an analysis of the real exchange rate. Applying the Johansen Maximum Likelihood procedure to equation [9.6.8], we attempted to identify whether a cointegrating procedure existed between the real exchange rate and relative efficiency measures, and the nominal exchange rate and Lilus.

Values are estimated for α and β using Excel and then OLS linear regression techniques. In the case of the latter, the equation was logged so that the marginal products enter in a linear fashion. It is noted that there appears to be serial correlation in the residuals, as reported by the Durbin Watson test statistics. When a linear restriction is added in, that is when $\alpha+\beta = 1$, this serial correlation or autocorrelation in the residuals increases. A constant term is included in the OLS regressions. The interpretations for this depends on the specifications used. If we assume that it is the technological content within the economy, then no new assumption is required. This constant could reflect the state of the economy's technical ability at the start of the period. It is reasonable to expect this to differ across economies. Although technology is treated as a public good, it may not exist everywhere at once. Time may be needed for the diffusion of technology. Further, it is observed from previous studies, (Baumol, 1986), that initial output per worker differs cross sectionally and affected future leadership positions in the world.

Following Ohkawa's (1993) work, the possible non-linearity of development implies that a non-linear estimation procedure may be appropriate. This possibility is noted.

Initial regressions are used to estimate appropriate values for α and β. It is decided on the basis of these regressions to set α =.11, and hence β =.89. These values are believed to provide most accurate estimate for US income over the period 1950 to 1990. An arbitrary rate of depreciation is set but its function is to make the analysis more realistic. These marginal product estimates are then set for all economies using equation [9.6.8].

It is intended to show that a cointegrating relationship exists between the relative labour measures and the exchange rate and/or the real exchange rate.

Unit root tests are applied to the real exchange rate, the nominal exchange rate and the relative performance measure. (Referred to as Lilus in Appendix A). Unit root tests are applied using an Augmented Dickey Fuller (ADF) to the entire sample, and to the two subsamples, 1950 to 1970 and 1970 to 1990. Results again are shown in Appendix A. Unit root tests are also applied to the first differences of Lilus and the exchange rate measures. XR is the nominal exchange rate and RXR is the real exchange rate. Again this is carried out for all three sample periods.

From here a cointegrating relationships is applied to the two terms, that is RXR and Lilus. Further test for a cointegrating relationship between the Lilus measure and XR are applied. In both cases, the exchange rate is the dependent variable and relative efficiency measure is the independent. This was specified in this format within Microfit 3.0. Within Microfit, the cointegration relationship is examined under three possibilities:

- Trended Case with a Trend in DGP and a linear deterministic trend in the non-stationary vector (x_t).
- Trended Case with no Trend in DGP but a linear deterministic trend in the non-stationary vector x_t.
- and a Non-Trended Case, with no trend in DGP and no trend in x_t.

According to Johnson (1993), unit root tests support the conclusion that models without deterministic trends are appropriate in a cointegration analysis of the nominal exchange rates and national prices. Whether this is applicable here is uncertain.

Regressions are run using split samples, to further test the robustness of conclusions. Further, because estimates from returns on education are open to criticism, effective units of labour are removed from the data and the Johansen procedure is reapplied to the entire period. This uses information relating to capital stock estimation from Nehru and Dhareschwar (1993) and income terms offered by the Penn World Tables and Nehru and Dhareschwar (1993).

Chapter 10.3

Results

Results from the unit root tests run on the exchange rate, the real exchange rate and the relative labour residual measure are shown in tables 10.1 to 10.3. The unit root conclusions regarding the labour-residual terms are shown in Appendix A. The DF and ADF tests examine both the trended and the non-trended case. The tests are applied to the entire sample and two sub-samples, that is 1950-1970 and 1970-1990. Results vary in some cases. The results also vary across samples. This is particularly true for the Japanese (¥) nominal exchange rate. For the period 1950 to 1970, ADF(1), ADF(2) and ADF (3) tests reject the unit root hypothesis. However the three terms are shown to be non-stationary. See Table 10.1 to 10.3, for a summary of unit root results.

Note that 1 indicates a unit root and 0 indicates a stationary series; n indicates a non-trended test for ADF and t indicates an ADF test carried out on trended data.

Table 10.1 Real Exchange Rate with Data in Levels

Country	1950 -1990						1950- 1970						1970 - 1990					
	ADF (1)		*ADF (2)*		*ADF (3)*		*ADF (1)*		*ADF (2)*		*ADF (3)*		*ADF (1)*		*ADF (2)*		*ADF (3)*	
	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t
Aus	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1
Bd	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cn	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fr	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
It	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Jp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
UK	0	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1

Table 10.2 Nominal Exchange Rate with Data in Levels

Country	1950 -1990						1950- 1970						1970 - 1990					
	ADF (1)		*ADF (2)*		*ADF (3)*		*ADF (1)*		*ADF (2)*		*ADF (3)*		*ADF (1)*		*ADF (2)*		*ADF (3)*	
	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t
Aus	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1
Bd	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cn	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fr	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
It	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1
Jp	1	1	1	1	1	1	0	1	0	0	0	0	1	1	1	1	1	1
UK	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 10.3 Lilus with Data in Levels

Country	1950 -1990						1950- 1970						1970 - 1990					
	ADF (1)		*ADF (2)*		*ADF (3)*		*ADF (1)*		*ADF (2)*		*ADF (3)*		*ADF (1)*		*ADF (2)*		*ADF (3)*	
	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t
Aus	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1
Bd	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cn	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fr	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
It	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Jp	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
UK	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Results from applying Johansen's method to the cointegration hypothesis are presented in summarised form in Table 10.4 onwards. Results from Microfit 3.0 also generate the number of cointegrating vectors, estimates for Π, α and β, and both the maximal eigenvalue and trace statistic likelihood ratio (LR) statistics. A brief summary of the principal results is given in table 10.4 only.

Table 10.4 Cointegration results for the real exchange rate and Lilus

Sample Period	1950 -1990			1950- 1970			1970 - 1990		
Country	*Op 4*	*Op 3*	*Op2*	*Op 4*	*Op 3*	*Op 2*	*Op 4*	*Op 3*	*Op 2*
Australia	no	no	no	**yes**	**yes**	**yes**	no	no	no
Germany	no	no	no	**yes**	**yes**	**yes**	no	no	no
Canada	no	no	no	**yes**	**yes**	**no**	yes	no	no
France	yes	yes	yes	**no**	**no**	**yes**	no	no	no
Italy	no	no	no	**yes**	**no**	**no**	yes	yes	yes
Japan	yes	yes	yes	**no**	**no**	**yes**	yes	yes	yes
United Kingdom	no	yes	yes	**no**	**no**	**no**	no	no	no

Key: Op 2 = Option 2 VAR(2) = non-trended case. No trend in x_t and no trend in DGP.

Op 3 = Option 3 VAR(2) = Linear deterministic trends in x_t but no trend in DGP.

Op 4 = Option 4 VAR(2) = Linear deterministic trends in x_t and DGP.

Results indicate that a cointegrating relationship exists between the real exchange rate and the relative efficiency measure (Lilus). This relationship does not hold for the entire sample. Further, it is found that the tests for the cointegrating relationship, examine the LR test based on the maximal eigenvalue and also the LR test based in the trace of the stochastic matrix. Essentially the critical values are different and therefore a result of cointegration does not mean that both LR tests are significant.

A cointegrating relationship holds for almost all countries in the sample for the period 1950 to 1970, and in some cases beyond. However, in the period 1970 to 1990, the relationship breaks down. Further, when the entire sample is used, the relationship is less likely to occur. A second set of tests is run using the nominal exchange rate against Lilus. These results appear in table 10.5. Again similar results are obtained.

Table 10.5 Cointegration results for the Nominal exchange rate and Lilus

Sample Period	1950 -90			1950- 70			1970 - 90		
Country	***Op 4***	***Op3***	***Op2***	***Op 4***	***Op3***	***Op2***	***Op 4***	***Op3***	***Op2***
Australia	no	no	no	yes	yes	yes	no	no	no
Germany	no	no	no	yes	yes	yes	no	no	no
Canada	no	no	no	yes	yes	no	yes	yes	no
France	yes	no	yes	no	no	no	no	no	no
Italy	no	no	no	yes	yes	yes	yes	yes	yes
Japan	yes	yes	yes	yes	yes	yes	yes	yes	yes
United Kingdom	no	no	yes	yes	no	no	no	no	no

In the cases where the hypothesis of no cointegration is rejected, (a yes), there were mixed results regarding the number of cointegrating relations. These cases are discussed further in Chapter 11.1.

Chapter 10.4

Applying a Moving Average Process to Results

The second half of the sample suffers from increased volatility, both in terms of shocks and a collapse of exchange rate regimes. Increased volatility of the real exchange rate is noted. Given the results for the 1970 to 1990 period and as the long run real exchange rate is the primary focus of the study, it would seem appropriate to use a moving average on the real exchange rate for this period. Three different moving averages are applied. This improves the results for the 1970 to 1990 period for all economies, with one exception. In the case of Japan, the results worsen.

Cointegration results between the moving average real exchange rate and Lilus are shown in tables 10.6 to 10.8. The moving average improves the consistency of results for the cointegration relationships. Again for the entire sample, the hypothesis that the real exchange rate is related to a relative labour efficiency measure is not supported universally.

Table 10.6 Cointegration results for a three year moving average of the real exchange rate (RXR(3)) and Lilus

Sample Period	1953 -1990			1953- 1970			1970 - 1990		
Country	*Op 4*	*Op 3*	*Op2*	*Op 4*	*Op 3*	*Op 2*	*Op 4*	*Op 3*	*Op 2*
Australia	no	no	no	**yes**	**yes**	**yes**	no	no	no
Germany	no	no	no	**yes**	**yes**	**yes**	yes	yes	yes
Canada	no	no	yes	**yes**	**yes**	**yes**	yes	yes	yes
France	no	no	no	**no**	**no**	**no**	no	no	no
Italy	no	no	no	**yes**	**yes**	**yes**	yes	yes	yes
Japan	no	no	yes	**no**	**no**	**no**	yes	yes	yes
United Kingdom	no	no	no	**yes**	**yes**	**yes**	yes	yes	yes

Table 10.7 Cointegration results for a four year moving average of the real exchange rate (RXR(4)) and Lilus

Sample Period	1954 -1990			1954- 1970			1970 - 1990		
Country	*Op 4*	*Op 3*	*Op2*	*Op 4*	*Op 3*	*Op 2*	*Op 4*	*Op 3*	*Op 2*
Australia	no	no	no	**yes**	**yes**	**yes**	no	no	no
Germany	no	no	no	**no**	**no**	**no**	yes	yes	yes
Canada	no	no	no	**yes**	**yes**	**yes**	yes	yes	yes
France	no	no	yes	**no**	**no**	**yes**	yes	yes	yes
Italy	no	no	no	**yes**	**yes**	**yes**	yes	yes	yes
Japan	yes	yes	yes	**no**	**no**	**no***	yes	yes	yes
United Kingdom	yes	no *	yes	**yes**	**yes**	**yes**	yes	yes	yes

* marginal failure to reject null of no cointegration.

Table 10.8 Cointegration results for a five year moving average of the real exchange rate (RXR(5)) and Lilus

Sample Period	1955 -1990			1955- 1970			1970 - 1990		
Country	*Op 4*	*Op 3*	*Op2*	*Op 4*	*Op 3*	*Op 2*	*Op 4*	*Op 3*	*Op 2*
Australia	no	no	no	**yes**	**yes**	**yes**	no	no	no
Germany	no	no	no*	**yes**	**yes**	**no***	yes	yes	yes
Canada	no	no	no	**yes**	**yes**	**yes**	yes	yes	yes
France	no	no	no	**no**	**no**	**yes**	yes	yes	yes
Italy	no	no	no	**yes**	**yes**	**yes**	yes	yes	yes
Japan	yes	yes	yes	**no**	**no**	**yes**	yes	yes	yes
United Kingdom	no	no	yes	**yes**	**yes**	**yes**	yes	yes	yes

* marginal failure to reject null of no cointegration.

The deterioration in the cointegration results between the moving average of the Japanese real exchange rate and Lilus, is probably due to a large error or deviation within the real exchange rate for one period. This appears to have been caused by fluctuations in the relative prices and the nominal exchange rate, the moving average is allowing that observation to be transmitted to other periods. This conclusion is further supported by ADF results for the nominal exchange rate. The ADF (1), ADF (2) and the ADF(3), all reject the unit root for the period 1950 to 1970. This is especially true of the ADF(2) test. (See Appendix A).

Tables 10.9 to 10.11 show the results for the cointegration tests between a moving average of the nominal exchange rate and Lilus.

Table 10.9 Three year moving average of nominal exchange rate (RXR3) and Lilus

Sample Period	1953 -1990			1953- 1970			1970 - 1990		
Country	***Op 4***	***Op 3***	***Op2***	***Op 4***	***Op 3***	***Op 2***	***Op 4***	***Op 3***	***Op 2***
Australia	no	no	no	no	no	no	no	no	no
Germany	no	no	no	yes	yes	yes	yes	yes	yes
Canada	no	no	no	yes	yes	yes	yes	yes	yes
France	no	no	no	no	no	no	yes*	no	no
Italy	no	no	no	no	no	no	yes	yes	yes
Japan	yes	yes	yes	yes	yes	yes	yes	yes*	yes
United Kingdom	no	no	no	yes	yes	yes	yes	yes*	yes*

* marginal failure to reject null of no cointegration.

Table 10.10 Four year moving average of nominal exchange rate (RXR4) and Lilus

Sample Period	1953 -1990			1953- 1970			1970 - 1990		
Country	***Op 4***	***Op 3***	***Op2***	***Op 4***	***Op 3***	***Op 2***	***Op 4***	***Op 3***	***Op 2***
Australia	no	no	no	no	no	no	no	no	no
Germany	no	no	yes	no	no	yes	yes	yes	yes
Canada	no	no	no	yes	yes	yes	yes	yes	yes
France	no	no	yes*	no	no	yes	yes	yes*	yes*
Italy	no	no	no	yes	yes	yes	yes	yes	yes
Japan	yes	yes	yes	yes	yes	yes	yes*	no	yes
United Kingdom	yes*	no	yes	yes	no	yes	yes	yes*	no

* marginal failure to reject null of no cointegration.

Table 10.11 Five year moving average of nominal exchange rate (RXR5) and Lilus

Sample Period	1953 -1990			1953- 1970			1970 - 1990		
Country	***Op 4***	***Op 3***	***Op2***	***Op 4***	***Op 3***	***Op 2***	***Op 4***	***Op 3***	***Op 2***
Australia	yes	yes	yes	yes	no	yes*	yes	yes	yes
Germany	yes	no	yes	no	no	no	yes	yes	yes
Canada	no	no	no	no	no	no	yes	yes	yes
France	yes	no	yes	no	no	no	yes	yes	yes
Italy	yes	yes*	yes*	no	no	no	yes	yes	yes
Japan	yes	yes	yes	no	no	no	yes	yes	yes
United Kingdom	yes	yes	yes	no	no	yes	yes	yes	yes

* marginal failure to reject null of no cointegration.

When a moving average of the nominal exchange rate is used results are broadly similar, with a few exceptions. Although not shown here, the failure to find a cointegrating relation between the exchange rate and Lilus, is sensitive to the sample period chosen. In some cases, dropping an early observation (that is one from the early 1950s), was enough to lead to a change in the cointegration conclusions. For this reason the test was reapplied for new sample period.

Chapter 10.5

Cointegration Test for 1960 to 1990

Post World War II estimation of capital stocks is likely to be more inaccurate than in other periods. The US $ was a reserve currency. Coupled with the exchange rate regime of the time, countries set out to build stocks of dollars. These factors are likely to have affected the relationship between Lilus and the RXR or XR. For this reason it is decided to test the hypothesis for the period 1960 to 1990. However, when the relative residual term is re-tested for stationarity using an ADF test, results indicate that for Italy and the UK, Lilus is in fact stationary. (see Appendix A). In the case of the UK, this stationary result does not hold for the trended ADF test. (See Appendix A). The unit root test for the real exchange rate and the nominal exchange rate is also ambiguous. It may be the case that the UK exchange rate is in fact stationary. Both Italy and the

United Kingdom are excluded from this sample. In the case of Germany, the conclusion regarding non-stationarity requires an ADF(2) to accept the unit root. The ADF test for the trended case is more clear cut and accepts the unit root hypothesis.

Results for the cointegration tests are shown in tables 10.12 and 10.13. It was decided to use moving averages of both the nominal and real exchange rate. Results are much more consistent than for the period 1950 to 1990. Unfortunately the United Kingdom and Italy are removed from the sample.

Table 10.12 Cointegration results for moving average of real exchange rates and Lilus.

Sample Period	**1960 -1990** RXR(3) vs. Lilus			**1960 -1990** RXR(4) vs. Lilus			**1960 -1990** RXR(5) vs. Lilus		
Country	***Op 4***	***Op 3***	***Op2***	***Op 4***	***Op 3***	***Op 2***	***Op 4***	***Op 3***	***Op 2***
Australia	no	no	no	yes*	no	no	yes	yes*	yes*
Germany	yes	yes	yes	yes	yes	yes	yes	yes	yes
Canada	yes	yes	yes	yes	yes	yes	yes	yes	yes
France	yes	yes	yes	yes	yes	yes	yes	yes	yes
Italy	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Japan	yes	yes	yes	yes	yes	yes	yes	yes	yes
United Kingdom	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

(where an * indicates that hypothesis rejected at 90% confidence level)

Table 10.13 Cointegration results for moving average of exchange rates and Lilus.

Sample Period	1960 -1990 XR(3) vs. Lilus			1960 -1990 XR(4) vs. Lilus			1960 -1990 XR(5) vs. Lilus		
Country	*Op 4*	*Op 3*	*Op2*	*Op 4*	*Op 3*	*Op 2*	*Op 4*	*Op 3*	*Op 2*
Australia	no	no	no	yes*	no	no	yes	yes	yes
Germany	yes	yes	yes	yes	yes	yes	yes	yes	yes
Canada	yes	yes	yes	yes	yes	yes	yes	yes	yes
France	yes	yes	yes	yes	yes	yes	yes	yes	yes
Italy	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Japan	yes	yes	yes	yes	yes	yes	yes	yes	yes
United Kingdom	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

(where an * indicates that hypothesis rejected at 90% confidence level; n/a is not available)

From this analysis, stronger support is found for the hypothesis that the real and or nominal exchange rate are related to a relative labour efficiency measure.

What remains then is an interpretation of these results. This is dealt with in Chapter 11.

CHAPTER 11

CONCLUSIONS AND RECOMMENDATIONS

Chapter 11.0

Analysis of Results:

The cointegration results using the Johansen procedure are not supported for the full sample period 1950 to 1990. However, due to the post World War II readjustment it is deemed appropriate to use the period 1960 to 1990. Following World War II, the US dollar became responsible for global monetary stabilisation. (Cohen, 1995). The dollar shortage of the 1950s and the attempts by governments to stockpile US dollars to settle balance of payments problems would imply that the link between US efficiency and the real exchange rate was being affected. (Period of US hegemony). The period of dollar deficits began in the 1950s and ended in about 1958. According to Cohen (1995) this period was referred to as one of beneficial disequilibrium.

> So from 1947 until about 1960 the United States stepped in and assumed unilateral management of the international monetary system, appearing to use Bretton Woods as a veil of legitimacy for the liquidity provided by the outflow of American dollars. (Isaak, 1991, p.50).

Cointegration results from the 1960 to 1990 period support the hypothesis that there is a cointegrating relationship between the real and/or nominal exchange rate (once adjustment is made for variability of the real and nominal exchange rate) and the relative efficiency term. This result holds for all economies in the sample, although in the case of Australia, a five year moving average is required.

For the 1950 to 1970 period, the real exchange rate and the relative labour residual measure are also cointegrated. It would be expected that if the hypothesis did hold, it would be for this period but with the warning that post World War II adjustment in the 1950s period would tarnish conclusions drawn from results. 1950 to 1970 is believed to have been one of historically high TFP growth. This TFP growth later slowed in the post 1970 period. (Denison, 1979). In the case of the post 1970 period, a moving average is necessary to overcome the increased volatility of the real exchange rate. The moving average does improve results and cointegration is generally supported for that period.

It is only in the case of Japan, that cointegration holds consistently for the entire sample, 1950 to 1990. Cointegration holds for France, Japan and the United Kingdom using the non-trended option - that is with no trend in DGP and no trend in x_t, where x_t is a vector of non-stationary variables. (See equation [7.3.2]). Again in the case of France and the United Kingdom, this result does not hold within sub-samples and this weakens the conclusion.

Two changes in the estimation procedure have improved the results. Firstly, applying a moving average to the real and nominal exchange rate has reduced the variability of these measures. This is particularly useful in the post 1970s period. The decision to limit the estimation to the period 1960 to 1990, proved beneficial and the consistency of results was improved.

Italy and the United Kingdom are removed from the sample because when the period 1960 to 1990 is used, the unit root tests fail to consistently establish nonstationarity. Whether this is due to a real change in the nature of Lilus is another matter. In the case of the United Kingdom, the behaviour of the exchange rate (real and nominal), is the reason why it becomes excluded from the sample, rather than the behaviour of Lilus. (As mentioned earlier, the unit root is found when using an ADF test with trend). In the case of Italy, both the trended and non-trended ADF's reject the null hypothesis of a unit root. This rejection holds across different order ADF's. (See Appendix A). For the UK the result is less conclusive.

Chapter 11.1

Caveats

It should be noted that the cointegration results tend to be sensitive to the specification chosen. That is, the number of cointegrating vectors identified changes. r may be 1 or

2. This also changes across samples. Only in the case of the Japanese real exchange rate and the Japanese Lilus measure for the period 1970 to 1990, does r =2, for all specifications (options). However, when the nominal exchange rate is used for the same period, r =2 occurs in the case of option 4, but not for options 2 and 3. (Options as specified previously). When a moving average of the nominal exchange rate is used, r =1, for the period 1970 to 1990. This holds for all three moving averages used. In the case of other countries, generally r = 2 in cases where Option 4 is used. See Table 11.1 and 11.2.

Table 11.1 Number of cointegrating vectors in sample 1960 to 1990. Real exchange rate and Lilus.

Sample Period	**1960 -1990** RXR(3) vs. Lilus			**1960 -1990** RXR(4) vs. Lilus			**1960 -1990** RXR(5) vs. Lilus		
Country	***Op 4***	***Op 3***	***Op2***	***Op 4***	***Op 3***	***Op 2***	***Op 4***	***Op 3***	***Op 2***
Australia	no	no	no	**yes*(1)**	no	no	**yes(1)**	**yes*(1)**	**yes*(1)**
Germany	yes(2)	**yes(1)**	**yes(1)**	yes(2)	**yes(1)**	**yes(1)**	yes(2)	**yes*(1)**	**yes*(1)**
Canada	yes(2)	**yes(1)**	**yes(1)**	yes(2)	**yes(1)**	**yes(1)**	yes(2)	yes(2)	**yes(1)**
France	yes(2)	**yes(1)**	yes(2)	yes(2)	**yes(1)**	yes(2)	yes(2)	**yes(1)**	**yes(1)**
Italy	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Japan	yes(2)	**yes(1)**	**yes(1)**	yes(2)	**yes(1)**	**yes(1)**	**yes(1)**	**yes(1)**	**yes(1)**
United Kingdom	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

(where an * indicates that hypothesis rejected at 90% confidence level)

(Number of cointegrating vectors in Brackets. Only accept that r =2 at 95% confidence level)

Table 11.2 Number of cointegrating vectors in sample 1960 to 1990.

Nominal exchange rate and Lilus.

Sample Period	**1960 -1990** XR(3) vs. Lilus			**1960 -1990** XR(4) vs. Lilus			**1960 -1990** XR(5) vs. Lilus		
Country	***Op 4***	***Op 3***	***Op2***	***Op 4***	***Op 3***	***Op 2***	***Op 4***	***Op 3***	***Op 2***
Australia	no	no	no	yes*(1)	no	no	yes(1)	yes(1)	yes(1)
Germany	yes(2)	yes(1)	yes(1)	yes(2)	yes(1)	yes(1)	yes(2)	yes(1)	yes(1)
Canada	yes(2)	yes(1)	yes(1)	yes(2)	yes(1)	yes(1)	yes(2)	yes (1)	yes(1)
France	yes(2)	yes(2)	yes(2)	yes(2)	yes(2)	yes(2)	yes(2)	yes(1)	yes(2)
Italy	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Japan	yes(1)	yes(1)	yes(1)	yes(1)	yes(1)	yes(1)	yes(2)	yes(1)	yes(1)
United Kingdom	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

(where an * indicates that hypothesis rejected at 90% confidence level)

(Number of cointegrating vectors in Brackets. Only accept that r =2 at 95% confidence level)

This result may be due to how RXR was calculated. Alternatively, prices may be entering in both sides of the cointegration equation. The conclusion that the number of cointegrating vectors is in fact 2 is not consistent . However, it is noted. Since we are dealing with two relative measures, the appearance of a second cointegrating vector could be due to these relative measures. Does it refer to some relationship between the two relative labour residuals? Alternatively, does it reflect a possible relationship between the exchange rate relative to the nominal exchange rate?

The conclusion regarding whether r is one or two, depends on whether we include a linear deterministic trend in the non-stationary vector used in Microfit. (Difference between options 3 and 4, and option 2). Even when r =2 for all three options, this is not consistent across different samples. (That is the case when the real and nominal exchange rates are used and not moving averages). Lim (1992) encounters a similar problem with establishing the correct number of cointegrating vectors when dealing with real exchange rates.

Only in the case of France does the number of cointegrating vectors seem to be 2, however this is not always the case. This result holds for both moving averages of the nominal and real exchange rate. The second cointegrating vector is unlikely to be due to how the real exchange rate is calculated. If $r = 2$, then the alternative is that the second cointegrating vector is due to some relationship between the labour residual in France relative to the US relative residual term.

Chapter 11.2

Discussion of Findings:

The results from the cointegration analysis support the hypothesis that the real exchange rate contains information regarding the productive capacity of an economy and its relative performance. In this analysis, the relative performance of the economies within the G7 and Australia does affect the bilateral real exchange rate value with the United States, in the long run.

The conclusion is consistent with the literature reviewed. Convergence of laggard nations to the leader economy should result in a change in the real exchange rate for those economies. Convergence has occurred within the OECD if not the World sample as a whole. This implies that national wealth holdings or wealth generating ability have increased and this augments the relative purchasing powers of the converging economies. This fact should be reflected by a change in the real exchange rate value. Such a conclusion is supported by Ostry (1989). We do not maintain that the real exchange rate will approach parity. Convergence appears to be an asymptotic process. For various reasons the leader economy does not have to lose its position within the World hierarchy. This conclusion is based on the belief that convergence is occurring due to the backlog of technology. As this backlog is reduced, so too will the speed of convergence. This is consistent with the literature on convergence, one tenet being that the more backward the economy the greater the speed of catch-up. The nature of technological dissemination further supports this judgement. There is no single all embracing type of technology. 'Learning by doing' allows the leader economy to achieve and maintain a comparative advantage, an advantage that does not have to be eroded over time.

As noted above, wealth is the single most important determinant of real exchange rate values. (Ostry, 1989; Turnovsky, 1991). Although monetary models incorporate relative income growth, it is likely that monetary phenomena and the magnitude of capital account transactions, swamp the information contained within economic fundamentals. While this may be the case in the short to medium term, in the long run, monetary shocks should not be a significant determinant of the real exchange rate. Long run monetary neutrality is supported in the literature and this is an expected conclusion. (Kim and Enders, 1991). Monetary disturbances are shown to be stationary and should not affect non-stationary time series. Only real disturbances should impact on the real exchange rate. Increases in wealth and changes in terms of trade are two such real factors. (Amano and Van Norden, 1995). Terms of trade shifts are interpreted as changes in relative performance or changes in relative wealth. Terms of trade changes should then be related to the real exchange rate. While this is supported in some studies, it is not a World-wide conclusion. The relative residual measure in this study incorporates an extensive information set. Changes in relative efficiency provide a comprehensive measure which should impact on the real exchange rate.

Convergence is not a global phenomenon. It is concluded from a literature review that this is due, not to the attributes of technology, but to the characteristics of economies. There is a great deal of difficulty in identifying the components of an intangible idea such as social capability. Aspects such as human skills, innovative ability and country specific characteristics are difficult to measure and the proxies used are controversial. This is particularly true of attempts made to find proxies for the return on human capital and measurement of effective units of labour. The relative labour residual (Lilus) is calculated in such a fashion that it incorporates this social capability idea by default. While a direct measure would be preferable, Lilus is nevertheless useful.

The relative labour residual measure provides a way of identifying superior performance in economies. The measure is calculated by grouping the contribution from labour (based on a social capability idea) with residual growth (growth not measured by conventional inputs). It is not adjusted for capacity utilisation effects or secular effects as suggested by Morrison (1992). It is believed that these effects are only transitory. In the case of capacity utilisation, a superior economy should be able to maximise these rates and is rewarded for doing so by increasing relative efficiency. The existence of secular effects within the measure is interpreted as a symptom of labour immobility and an inability to marry skills with labour demand. A superior economy should be able to overcome the misalignment between labour demand and labour skill supply and this is another aspect of that country's social capability.

In attempting to correctly gauge the contributions of labour and capital to income, the method adopted here overcomes certain difficulties. By choosing economies in the same stage of development, it is intended to minimise cross country disparities in terms of economic measurement. (Summers and Heston, 1991; Ohkawa, 1993). By fixing the contribution from capital for all economies in the sample, we force the contribution from labour, social capability and residual growth through Lilus. This method is justified on the basis that capital goods are internationally mobile and that technology may be embodied within capital goods. Therefore capital goods in one economy cannot be continually superior to another. Since interest rates tend to be equalised over time given capital mobility, capital alone should not be the reason for sustained income differentials. Some other nontraded factor must be responsible for differential growth rates. This factor is measured using the relative labour residual.

The relationship between Lilus and the real exchange rate is based on a cointegrating approach. By avoiding differencing data we retain more of the long run information contained in the data and increase the chance of identifying a long run connection in the data. This approach is consistent with the theoretical framework since we are concerned with establishing a long run relationship.

Johansen's methodology provides a means of establishing whether a cointegrating vector(s) exists between the two variables. As mentioned earlier, Johansen's method is superior to the residual based approach. Within Johansen's approach, results indicate that there is at least one cointegrating vector between the two data series. This result is interesting in that it links the relative performance of two economies with their bilateral (real) exchange rate. The literature on convergence predicts that two economies may converge over time and therefore the expectation is that the (real) exchange rate will change to reflect this fact.

Chapter 11.3

Comparison with Other Exchange Rate Theories

Most long run models of exchange rates emphasise the role played by economic fundamentals in determining the value of currency. The idea that sound economic fundamentals will translate into a 'strong' currency is widely believed, but is difficult to prove. Isolating accurate measures of efficiency have proven difficult. In the model presented here I have attempted to isolate an efficiency measure. By measuring the contribution of conventional inputs first, I have isolated a measure that contains the contributions of both labour and residual growth. The difficulties associated with correctly estimating the contributions of labour to growth are widely known. This problem has been overcome by using a labour residual measure as the 'catch for all term'. A cointegrating relationship is established between the real exchange rate (nominal exchange rate) and the economic fundamentals inherent within an economy. In this respect, the model presented here supports the fact that superior economic fundamentals do affect the long run value of the exchange rate. Lim (1992) suggests that the fundamental determinants of the real exchange rate include variables such as productivity, terms of trade and real domestic and foreign interest rates. What is suggested here is that superior efficiency should lead to favourable changes in the real exchange rate. This appears to be happening for some of the economies in the sample.

Various monetary models that arose from the volatility of the post 1970s period, emphasise the importance of money in explaining exchange rate movements. The belief that these monetary flows are transitory is supported elsewhere. In the model presented here, monetary phenomena are believed to be stationary and thus should not be cointegrated with the long run value of the exchange rate. The model presented here assumes that monetary flows have no long term effect on the exchange rate measures.

Only economic fundamentals are cointegrated with the real exchange rate. The model presented here does not see monetary flows having the ability to affect long run exchange rate values. However Grilli and Kaminsky (1991) claim that the stability of the monetary regime may impact on the fluctuations of the real exchange rate. This is not examined in the model I presented, yet there is a logical progression to the argument. While monetary shocks are transitory, the monetary environment may impact on the real exchange rate. I interpret this more as a reflection of the institutional factors within the economy rather than the power of monetary phenomena to affect the long path of the real exchange rate.

Hooper and Morton (1982) extend the model suggested by Dornbusch-Frankel in an attempt to explain the large and sustained changes in the real exchange rate. Their model emphasises the importance of changes in the current account. However their model also puts great weighting on the importance of expectations. I have not considered the effect of expectations on the real exchange rate. The belief is that changes in the current account are temporary otherwise we see a change in the wealth of the nation. Should this happen then the exchange rate should depreciate to reflect the loss of earnings potential within that nation.

Faruqee (1995) examines the long run determinants of the real exchange rate from a stock flow perspective. The empirical analysis in that paper estimates the long run relationship between the real exchange rate, net foreign assets, and other factors affecting trade flows. Using data from the United States and Japan for the Post World War II period, the author uses a cointegration technique that supports the idea that structural factors underlying each country's net trade and net foreign asset positions determines the long run path for the real value of the two currencies. Faruqee (1995) warns against simply examining terms of trade effects and linking changes in same with the real exchange rate. The reason for changes in the terms of trade are more important. The reason for changes in prices is important is determining whether the change in the real exchange rate is permanent or transitory. A distinction is made between relative price movements that represent lasting changes in the level of competitiveness and short term fluctuations in that they reflect transitory departures from a given PPP level. The distinction is important and reflects the fact that price signal interpretation is dependent on the underlying cause for extrapolation.

It is difficult to establish that the exchange rate is stationary in the long run. Yet some authors such as Kim (1990) find support for PPP. Again cointegration techniques are being applied. 'Estimated error correction models suggest that deviations from PPP significantly affect exchange rates in all cases where cointegration is confirmed.' (Kim, 1990, p. 501). The use of low frequency data and longer time series are aiding those authors seeking to find support for PPP. While the model here does find that the exchange rate is nonstationary for the period 1950 to 1990, this result is believed to be time dependent. It is interesting to note that superior efficiency is cointegrated with the exchange rate. One of the predictions of the PPP model is that higher inflation will lead to a depreciation of that country's currency. If inflation is being caused by inefficiency within the economy, for example if inflation is due to the failure to correctly allocate resources in the economy, then the prediction of a depreciation may also reflect inefficiency within the economy. The prediction from PPP and the prediction from the model presented here are consistent.

Strauss (1995) notes that for Canada, the United States and the United Kingdom a cointegrating relationship is found between real exchange rates and both relative prices and productivity, but not between relative prices and productivity. This implies that productivity differentials affect real exchange rates, but not through the relative price channel. The dual nature of the economy and its effect on the real exchange rate was not examined in detail here. It is an interesting avenue for future exploration.

What information in contained within price measures? Do prices reflect changes in the quality of capital and labour? If so, changes in prices are correctly measuring changes in the quality of inputs. If this is the case then inflation actually reflects positive changes in quality. Certainly it would mean that PPP and the predictions from that model are inconsistent. I think it more likely that changes in wealth and the ability to produce wealth is the reason for changes in the exchange rate. The reasons behind changes in prices are more important than the changes in prices themselves.

The focus of the model presented here was not on prices. The effect of prices was removed, although this assumes that labour, capital and income are being measure in the same manner. The assumption that capital goods are traded and therefore the price of capital should equalise across economies seems reasonable. Capital should not be the reason for long run differential growth patterns. The disparity of labour costs across economies is noteworthy and led to the use of a labour residual measure. The residual based approach presented here overcomes some of the difficulties associated with using price measures in international comparisons. Again price signals are symptoms of underlying phenomena. The interpretation of price signals is hazardous and hence predictions about changes in exchange rate values must also be so.

Chapter 11.4

Convergence Phenomenon:

A great deal of the literature examined dealt with economic growth and convergence. Convergence in the post World War II period occurred for a variety of reasons. The existence of a backlog of technology, openness to trade and investment in social capability are principal factors behind convergence.

The notion of asymptotic catch-up is encouraging for those economies with the correct institutional framework and infrastructure. However, failure to invest in human capital and the correct technology can impede convergence.

One important conclusion drawn from the literature reviewed is the importance of correctly measuring factor input growth and its contribution to economic growth. Correctly calculating labour's contribution to the growth process is difficult but necessary. The relative residual term (Lilus) calculated here shows signs that convergence is occurring. An attempt to measure the rate of this convergence may prove a useful research avenue for the future. If convergence is occurring at different speeds then it implies that some country specific factors are responsible for convergence. If convergence is occurring at some common rate, then this would require explanation. It might indicate that disembodied technology is the engine behind convergence and not social capability.

Chapter 11.5

Further Research Recommendation:

Due to data limitations several other options have not been pursued. While this reason could be extended to embrace all the limitations of the analysis some of this restrictions are noteworthy.

It would be desirable to estimate the above relationship using a real effective exchange rate and a combination of weighted average labour residual measures. Such an exposition might reveal additional relationships or provide greater consistency in the results. A real effective exchange rate would require the construction of an effective labour residual. The choice of weighting system would be an area of contention. Again the choice of base country is noted. However, if one continues to couch the hypothesis in a convergence background, the US would remain the base economy. A more comprehensive analysis would be provided by analysing the model presented here using multilateral exchange rates against a multilateral relative labour residual.

The estimation procedure and software have been replaced by more advanced testing procedures. This could prove beneficial in allowing greater tests on the data and scrutinising the values generated for α, β and Π. Tests here and restrictions on these values would allow a more rigorous and perhaps more insightful view of the actual workings between relative efficiency and the real exchange rate.

Further, I am aware that a more in depth analysis of the residuals generated when the Johansen procedure is applied is necessary. This is constrained by software problems, but again could prove a useful avenue of research. The residuals generated by the error correction model may contain information regarding the ECM system.

Chapter 11.6

Final Conclusion

Given the above, the work is still interesting in its conclusions. There does appear to be a long run equilibrating relationship between the exchange rate of a nation and its relative performance within the World economy. The exchange rate, both real and nominal, appear to be a reflection of the productive ability of an economy, in both a physical and intangible sense. The work therefore succeeds in establishing a relationship between the real exchange rate and/or nominal exchange rate and a relative labour residual term.

Economic fundamentals do determine the value of the real exchange rate in the long run. The direction of causation runs from the former to the latter. Superior efficiency as measured by a relative labour residual term, are cointegrated with the real exchange rate of an economy.

The fact that convergence is occurring is interesting. Relative differences in income in one economy versus the leader economy appear to be diminishing over time. The expectation then is that exchange rates should converge asymptotically for converging economies. Such a prediction could promote the use of a unified currency for some trading blocks. On the other hand, failure to converge in income terms would lead to increased pressure on a single currency area.

The result may provide a useful springboard from which to extend the analysis and gain more insight into the actual causal relationship between the two variables. Further analysis of social capability is required.

The exchange rate does appear to contain information about a nation and its trading partners. Relative economic performance does affect long term currency values.

End

APPENDIX A

UNIT ROOT RESULTS

Unit Root Results

- **Lilus** is the Labour residual in country i divided by that in the base economy.
- **XR** is the exchange rate in country i relative that in the base economy.
- **RXR** is the real exchange rate calculated by adjusting the nominal exhange rate (XR) by changes in the relative prices in the economies. This price level is taken from the Penn World Tables (P).

Australian Data:

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-2.3626(-2.9358)	-4.2934(-3.5247)
ADF(1)	1952 1990	39	-1.0546(-2.9378)	-4.6928(-3.5279)
ADF(2)	1953 1990	38	-.45623(-2.9400)	-3.2216(-3.5313)
ADF(3)	1954 1990	37	-.48249(-2.9422)	-1.8175(-3.5348)
ADF(4)	1955 1990	36	-1.0600(-2.9446)	-3.1932(-3.5386)
ADF(5)	1956 1990	35	-.95134(-2.9472)	-3.8714(-3.5426)
ADF(6)	1957 1990	34	-1.3979(-2.9499)	-3.3384(-3.5468)
ADF(7)	1958 1990	33	-1.1579(-2.9528)	-2.5237(-3.5514)
ADF(8)	1959 1990	32	-1.7281(-2.9558)	-3.6510(-3.5562)
ADF(9)	1960 1990	31	-1.6497(-2.9591)	-2.3085(-3.5615)
ADF(10)	1961 1990	30	-1.5748(-2.9627)	-2.2120(-3.5671)
ADF(11)	1962 1990	29	-1.6550(-2.9665)	-1.7589(-3.5731)
ADF(12)	1963 1990	28	-1.5197(-2.9706)	-1.6148(-3.5796)

95% critical values in brackets.

Unit root tests for variable XR

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-.48596(-2.9358)	-1.3157(-3.5247)
ADF(1)	1952 1990	39	-1.2007(-2.9378)	-1.9595(-3.5279)
ADF(2)	1953 1990	38	-.99313(-2.9400)	-1.7593(-3.5313)
ADF(3)	1954 1990	37	-.67631(-2.9422)	-1.4003(-3.5348)
ADF(4)	1955 1990	36	-.22366(-2.9446)	-.75065(-3.5386)
ADF(5)	1956 1990	35	.18190(-2.9472)	.16374(-3.5426)
ADF(6)	1957 1990	34	-.20985(-2.9499)	-.10985(-3.5468)
ADF(7)	1958 1990	33	-.71311(-2.9528)	-.33734(-3.5514)
ADF(8)	1959 1990	32	-2.4606(-2.9558)	-1.9846(-3.5562)
ADF(9)	1960 1990	31	-2.0954(-2.9591)	-1.6659(-3.5615)
ADF(10)	1961 1990	30	-4.0148(-2.9627)	-3.4644(-3.5671)
ADF(11)	1962 1990	29	-3.8565(-2.9665)	-3.4008(-3.5731)
ADF(12)	1963 1990	28	-1.4886(-2.9706)	-1.1937(-3.5796)

95% critical values in brackets.

Unit root tests for variable RXR

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-1.7336(-2.9358)	-1.6476(-3.5247)
ADF(1)	1952 1990	39	-2.3502(-2.9378)	-2.2748(-3.5279)
ADF(2)	1953 1990	38	-2.1114(-2.9400)	-2.0496(-3.5313)
ADF(3)	1954 1990	37	-1.8286(-2.9422)	-1.6485(-3.5348)
ADF(4)	1955 1990	36	-1.6715(-2.9446)	-1.2675(-3.5386)
ADF(5)	1956 1990	35	-1.4237(-2.9472)	-.63130(-3.5426)
ADF(6)	1957 1990	34	-1.5457(-2.9499)	-.92338(-3.5468)
ADF(7)	1958 1990	33	-1.7617(-2.9528)	-1.1853(-3.5514)
ADF(8)	1959 1990	32	-2.5504(-2.9558)	-2.6020(-3.5562)
ADF(9)	1960 1990	31	-2.1091(-2.9591)	-2.3702(-3.5615)
ADF(10)	1961 1990	30	-2.5586(-2.9627)	-3.4705(-3.5671)
ADF(11)	1962 1990	29	-1.9218(-2.9665)	-3.7820(-3.5731)
ADF(12)	1963 1990	28	-1.5270(-2.9706)	-1.4290(-3.5796)

95% critical values in brackets.

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-2.6310(-3.0199)	-2.8140(-3.6592)
ADF(1)	1952 1970	19	-1.6287(-3.0294)	-3.3260(-3.6746)
ADF(2)	1953 1970	18	-.82291(-3.0401)	-2.5961(-3.6921)
ADF(3)	1954 1970	17	-.33412(-3.0522)	-1.5040(-3.7119)
ADF(4)	1955 1970	16	-1.9060(-3.0660)	-2.1321(-3.7347)
ADF(5)	1956 1970	15	-2.5276(-3.0819)	-3.4001(-3.7612)
ADF(6)	1957 1970	14	-3.4542(-3.1004)	-2.2977(-3.7921)
ADF(7)	1958 1970	13	-1.8890(-3.1223)	.023069(-3.8288)
ADF(8)	1959 1970	12	-2.7039(-3.1485)	.028784(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

95% critical values in brackets.

Unit root tests for variable XR

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-5.2270(-3.0199)	-5.2735(-3.6592)
ADF(1)	1952 1970	19	-4.5525(-3.0294)	-5.0172(-3.6746)
ADF(2)	1953 1970	18	-2.4806(-3.0401)	-2.8752(-3.6921)
ADF(3)	1954 1970	17	-1.3470(-3.0522)	-1.6178(-3.7119)
ADF(4)	1955 1970	16	-1.2512(-3.0660)	-1.4153(-3.7347)
ADF(5)	1956 1970	15	-.79090(-3.0819)	-.94037(-3.7612)
ADF(6)	1957 1970	14	-.52415(-3.1004)	-.58678(-3.7921)
ADF(7)	1958 1970	13	-.68979(-3.1223)	-.37748(-3.8288)
ADF(8)	1959 1970	12	-1.1108(-3.1485)	-.52943(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

95% critical values in brackets.

Unit root tests for variable RXR

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-2.7461(-3.0199)	-3.7080(-3.6592)
ADF(1)	1952 1970	19	-3.1876(-3.0294)	-6.1658(-3.6746)
ADF(2)	1953 1970	18	-1.5472(-3.0401)	-1.3894(-3.6921)
ADF(3)	1954 1970	17	-2.4810(-3.0522)	-3.1237(-3.7119)
ADF(4)	1955 1970	16	-1.1398(-3.0660)	-3.3657(-3.7347)
ADF(5)	1956 1970	15	-.70790(-3.0819)	-1.3458(-3.7612)
ADF(6)	1957 1970	14	-.68878(-3.1004)	-.97991(-3.7921)
ADF(7)	1958 1970	13	-1.2391(-3.1223)	-2.0440(-3.8288)
ADF(8)	1959 1970	12	-1.3910(-3.1485)	-1.9816(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

95% critical values in brackets.

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-.81401(-3.0115)	-3.0307(-3.6454)
ADF(1)	1970 1990	21	-.91331(-3.0115)	-4.1843(-3.6454)
ADF(2)	1970 1990	21	-.51097(-3.0115)	-3.7266(-3.6454)
ADF(3)	1970 1990	21	-.18115(-3.0115)	-3.2225(-3.6454)
ADF(4)	1970 1990	21	-.38158(-3.0115)	-3.4023(-3.6454)
ADF(5)	1970 1990	21	-.21298(-3.0115)	-3.5009(-3.6454)
ADF(6)	1970 1990	21	.052261(-3.0115)	-2.9396(-3.6454)
ADF(7)	1970 1990	21	-.0030104(-3.0115)	-3.9763(-3.6454)
ADF(8)	1970 1990	21	.11627(-3.0115)	-5.1041(-3.6454)
ADF(9)	1970 1990	21	.17504(-3.0115)	-3.3802(-3.6454)
ADF(10)	1970 1990	21	.010394(-3.0115)	-2.6571(-3.6454)

ADF(11)	1970 1990	21	-.051153(-3.0115)	-1.9643(-3.6454)
ADF(12)	1970 1990	21	-.080553(-3.0115)	-2.8252(-3.6454)

****

95% critical values in brackets.

Unit root tests for variable XR

****

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-.55932(-3.0115)	-1.9055(-3.6454)
ADF(1)	1970 1990	21	-1.0173(-3.0115)	-2.5303(-3.6454)
ADF(2)	1970 1990	21	-.85633(-3.0115)	-2.3894(-3.6454)
ADF(3)	1970 1990	21	-.59639(-3.0115)	-2.1046(-3.6454)
ADF(4)	1970 1990	21	-.20031(-3.0115)	-1.5756(-3.6454)
ADF(5)	1970 1990	21	.21406(-3.0115)	-.57809(-3.6454)
ADF(6)	1970 1990	21	-.054658(-3.0115)	-.54512(-3.6454)
ADF(7)	1970 1990	21	-.38134(-3.0115)	-.26136(-3.6454)
ADF(8)	1970 1990	21	-1.6307(-3.0115)	-1.2415(-3.6454)
ADF(9)	1970 1990	21	-1.3966(-3.0115)	-1.0436(-3.6454)
ADF(10)	1970 1990	21	-2.7624(-3.0115)	-2.3893(-3.6454)
ADF(11)	1970 1990	21	-2.7123(-3.0115)	-2.6285(-3.6454)
ADF(12)	1970 1990	21	-1.0268(-3.0115)	-1.0669(-3.6454)

****

95% critical values in brackets.

Unit root tests for variable RXR

****

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-1.1452(-3.0115)	-1.8629(-3.6454)
ADF(1)	1970 1990	21	-1.6728(-3.0115)	-2.4505(-3.6454)
ADF(2)	1970 1990	21	-1.5926(-3.0115)	-2.3963(-3.6454)
ADF(3)	1970 1990	21	-1.2482(-3.0115)	-1.9984(-3.6454)
ADF(4)	1970 1990	21	-1.1120(-3.0115)	-1.5729(-3.6454)
ADF(5)	1970 1990	21	-1.0863(-3.0115)	-.71999(-3.6454)
ADF(6)	1970 1990	21	-1.3155(-3.0115)	-.83301(-3.6454)
ADF(7)	1970 1990	21	-1.5347(-3.0115)	-.71019(-3.6454)
ADF(8)	1970 1990	21	-2.7536(-3.0115)	-1.8858(-3.6454)
ADF(9)	1970 1990	21	-2.3726(-3.0115)	-1.5577(-3.6454)
ADF(10)	1970 1990	21	-3.0068(-3.0115)	-2.4512(-3.6454)
ADF(11)	1970 1990	21	-2.5724(-3.0115)	-2.5254(-3.6454)
ADF(12)	1970 1990	21	-1.5663(-3.0115)	-.54844(-3.6454)

****

95% critical values in brackets.

German Data:

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-.43214(-2.9358)	-2.3313(-3.5247)
ADF(1)	1952 1990	39	-1.0401(-2.9378)	-3.1575(-3.5279)
ADF(2)	1953 1990	38	-1.4394(-2.9400)	-2.8159(-3.5313)
ADF(3)	1954 1990	37	-1.3365(-2.9422)	-3.0424(-3.5348)
ADF(4)	1955 1990	36	-2.0959(-2.9446)	-2.5423(-3.5386)
ADF(5)	1956 1990	35	-1.7193(-2.9472)	-2.3397(-3.5426)
ADF(6)	1957 1990	34	-2.0631(-2.9499)	-2.9056(-3.5468)
ADF(7)	1958 1990	33	-1.4773(-2.9528)	-1.1904(-3.5514)
ADF(8)	1959 1990	32	-1.6838(-2.9558)	-1.4777(-3.5562)
ADF(9)	1960 1990	31	-1.6527(-2.9591)	-1.3059(-3.5615)
ADF(10)	1961 1990	30	-2.6664(-2.9627)	-1.9348(-3.5671)
ADF(11)	1962 1990	29	-2.6260(-2.9665)	-1.5968(-3.5731)
ADF(12)	1963 1990	28	-2.4286(-2.9706)	-1.7686(-3.5796)

95% critical values in brackets.

Unit root tests for variable XR

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	.041170(-2.9358)	-1.8896(-3.5247)
ADF(1)	1952 1990	39	-.48643(-2.9378)	-2.7443(-3.5279)
ADF(2)	1953 1990	38	-.13796(-2.9400)	-2.2889(-3.5313)
ADF(3)	1954 1990	37	-.22793(-2.9422)	-2.4334(-3.5348)
ADF(4)	1955 1990	36	-.31867(-2.9446)	-2.6913(-3.5386)
ADF(5)	1956 1990	35	-.27186(-2.9472)	-2.2267(-3.5426)
ADF(6)	1957 1990	34	-.29243(-2.9499)	-2.2148(-3.5468)
ADF(7)	1958 1990	33	-.54911(-2.9528)	-2.6043(-3.5514)
ADF(8)	1959 1990	32	-.60017(-2.9558)	-2.7754(-3.5562)
ADF(9)	1960 1990	31	-.35942(-2.9591)	-2.4797(-3.5615)
ADF(10)	1961 1990	30	.78599(-2.9627)	-1.7390(-3.5671)
ADF(11)	1962 1990	29	1.4474(-2.9665)	-1.8405(-3.5731)
ADF(12)	1963 1990	28	1.5055(-2.9706)	-1.8558(-3.5796)

95% critical values in brackets.

Unit root tests for variable RXR

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-.42416(-2.9358)	-1.8359(-3.5247)
ADF(1)	1952 1990	39	-.80093(-2.9378)	-2.7976(-3.5279)
ADF(2)	1953 1990	38	-.57166(-2.9400)	-2.3617(-3.5313)
ADF(3)	1954 1990	37	-.69451(-2.9422)	-2.4655(-3.5348)
ADF(4)	1955 1990	36	-.72727(-2.9446)	-2.5257(-3.5386)
ADF(5)	1956 1990	35	-.73438(-2.9472)	-1.9705(-3.5426)
ADF(6)	1957 1990	34	-.81278(-2.9499)	-2.0796(-3.5468)
ADF(7)	1958 1990	33	-.99614(-2.9528)	-2.3785(-3.5514)
ADF(8)	1959 1990	32	-1.1115(-2.9558)	-2.6167(-3.5562)
ADF(9)	1960 1990	31	-1.1102(-2.9591)	-2.3310(-3.5615)
ADF(10)	1961 1990	30	-.60771(-2.9627)	-1.7780(-3.5671)
ADF(11)	1962 1990	29	-.061901(-2.9665)	-1.9575(-3.5731)
ADF(12)	1963 1990	28	-.17132(-2.9706)	-1.9105(-3.5796)

95% critical values in brackets.

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-.65308(-3.0199)	-1.8163(-3.6592)
ADF(1)	1952 1970	19	-1.6215(-3.0294)	-2.7090(-3.6746)
ADF(2)	1953 1970	18	-2.6967(-3.0401)	-2.6821(-3.6921)
ADF(3)	1954 1970	17	-2.2271(-3.0522)	-2.6723(-3.7119)
ADF(4)	1955 1970	16	-3.5468(-3.0660)	-2.3962(-3.7347)
ADF(5)	1956 1970	15	-2.4293(-3.0819)	-1.9108(-3.7612)
ADF(6)	1957 1970	14	-3.7867(-3.1004)	-3.2572(-3.7921)
ADF(7)	1958 1970	13	-1.5731(-3.1223)	-1.6999(-3.8288)

ADF(8)	1959 1970	12	-1.7322(-3.1485)	-2.0766(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

95% critical values in brackets.

Unit root tests for variable XR

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	1.2660(-3.0199)	-.76579(-3.6592)
ADF(1)	1952 1970	19	.84331(-3.0294)	-1.3011(-3.6746)
ADF(2)	1953 1970	18	.93417(-3.0401)	-1.2495(-3.6921)
ADF(3)	1954 1970	17	.96280(-3.0522)	-1.2281(-3.7119)
ADF(4)	1955 1970	16	1.0275(-3.0660)	-1.1958(-3.7347)
ADF(5)	1956 1970	15	1.1221(-3.0819)	-1.1131(-3.7612)
ADF(6)	1957 1970	14	1.3059(-3.1004)	-.95990(-3.7921)
ADF(7)	1958 1970	13	1.7337(-3.1223)	-.79216(-3.8288)
ADF(8)	1959 1970	12	2.1781(-3.1485)	-1.0577(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

95% critical values in brackets.

Unit root tests for variable RXR

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	.42568(-3.0199)	-1.4378(-3.6592)
ADF(1)	1952 1970	19	.17899(-3.0294)	-2.1715(-3.6746)
ADF(2)	1953 1970	18	.42328(-3.0401)	-1.9177(-3.6921)
ADF(3)	1954 1970	17	.40625(-3.0522)	-1.8021(-3.7119)
ADF(4)	1955 1970	16	.47104(-3.0660)	-1.7591(-3.7347)
ADF(5)	1956 1970	15	.60110(-3.0819)	-1.8223(-3.7612)
ADF(6)	1957 1970	14	.75598(-3.1004)	-1.5653(-3.7921)
ADF(7)	1958 1970	13	1.2713(-3.1223)	-.98022(-3.8288)
ADF(8)	1959 1970	12	1.7056(-3.1485)	-.83175(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

95% critical values in brackets.

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-1.3073(-3.0115)	-2.2213(-3.6454)
ADF(1)	1970 1990	21	-1.5747(-3.0115)	-3.2652(-3.6454)
ADF(2)	1970 1990	21	-1.1172(-3.0115)	-2.8696(-3.6454)
ADF(3)	1970 1990	21	-1.0106(-3.0115)	-3.1795(-3.6454)
ADF(4)	1970 1990	21	-.69214(-3.0115)	-2.6937(-3.6454)
ADF(5)	1970 1990	21	-.49121(-3.0115)	-2.5690(-3.6454)
ADF(6)	1970 1990	21	-.38497(-3.0115)	-2.6986(-3.6454)
ADF(7)	1970 1990	21	-.91857(-3.0115)	-1.8567(-3.6454)
ADF(8)	1970 1990	21	-.90482(-3.0115)	-1.7878(-3.6454)
ADF(9)	1970 1990	21	-1.0158(-3.0115)	-1.6045(-3.6454)
ADF(10)	1970 1990	21	-.33045(-3.0115)	-1.9233(-3.6454)
ADF(11)	1970 1990	21	-.77977(-3.0115)	-1.7869(-3.6454)
ADF(12)	1970 1990	21	-.65358(-3.0115)	-2.2064(-3.6454)

95% critical values in brackets.

Unit root tests for variable XR

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-2.0238(-3.0115)	-1.9588(-3.6454)
ADF(1)	1970 1990	21	-2.1363(-3.0115)	-2.6011(-3.6454)
ADF(2)	1970 1990	21	-1.8233(-3.0115)	-2.1592(-3.6454)

ADF(3)	1970 1990	21	-1.7930(-3.0115)	-2.2536(-3.6454)
ADF(4)	1970 1990	21	-1.7626(-3.0115)	-2.4610(-3.6454)
ADF(5)	1970 1990	21	-1.8523(-3.0115)	-1.6402(-3.6454)
ADF(6)	1970 1990	21	-1.7871(-3.0115)	-1.4941(-3.6454)
ADF(7)	1970 1990	21	-1.8202(-3.0115)	-2.1602(-3.6454)
ADF(8)	1970 1990	21	-1.7394(-3.0115)	-3.0176(-3.6454)
ADF(9)	1970 1990	21	-1.5556(-3.0115)	-3.9550(-3.6454)
ADF(10)	1970 1990	21	-.68630(-3.0115)	-3.7942(-3.6454)
ADF(11)	1970 1990	21	-.13169(-3.0115)	-3.3745(-3.6454)
ADF(12)	1970 1990	21	.47086(-3.0115)	-2.4490(-3.6454)

95% critical values in brackets.

Unit root tests for variable RXR

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-2.5699(-3.0115)	-2.2322(-3.6454)
ADF(1)	1970 1990	21	-2.7795(-3.0115)	-2.7648(-3.6454)
ADF(2)	1970 1990	21	-2.4607(-3.0115)	-2.3900(-3.6454)
ADF(3)	1970 1990	21	-2.4841(-3.0115)	-2.5159(-3.6454)
ADF(4)	1970 1990	21	-2.4298(-3.0115)	-2.5702(-3.6454)
ADF(5)	1970 1990	21	-2.4241(-3.0115)	-1.6187(-3.6454)
ADF(6)	1970 1990	21	-2.3434(-3.0115)	-1.6097(-3.6454)
ADF(7)	1970 1990	21	-2.4029(-3.0115)	-2.1811(-3.6454)
ADF(8)	1970 1990	21	-2.3557(-3.0115)	-2.9817(-3.6454)
ADF(9)	1970 1990	21	-2.3377(-3.0115)	-2.7220(-3.6454)
ADF(10)	1970 1990	21	-2.1254(-3.0115)	-1.8558(-3.6454)
ADF(11)	1970 1990	21	-2.1329(-3.0115)	-.96550(-3.6454)
ADF(12)	1970 1990	21	-2.0613(-3.0115)	-.44385(-3.6454)

95% critical values in brackets.

Canadian Data:

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-.14408(-2.9358)	-.11761(-3.5247)
ADF(1)	1952 1990	39	-.53078(-2.9378)	-.35878(-3.5279)
ADF(2)	1953 1990	38	-.73740(-2.9400)	-.56743(-3.5313)
ADF(3)	1954 1990	37	-.47598(-2.9422)	-.10078(-3.5348)
ADF(4)	1955 1990	36	-1.3262(-2.9446)	-.84635(-3.5386)
ADF(5)	1956 1990	35	-1.2486(-2.9472)	-.88176(-3.5426)
ADF(6)	1957 1990	34	-2.3354(-2.9499)	-2.2462(-3.5468)
ADF(7)	1958 1990	33	-1.6851(-2.9528)	-.76484(-3.5514)
ADF(8)	1959 1990	32	-1.7881(-2.9558)	-1.2627(-3.5562)
ADF(9)	1960 1990	31	-1.9852(-2.9591)	-.57404(-3.5615)
ADF(10)	1961 1990	30	-2.1555(-2.9627)	-.63827(-3.5671)
ADF(11)	1962 1990	29	-1.7926(-2.9665)	-.47616(-3.5731)
ADF(12)	1963 1990	28	-1.6642(-2.9706)	-.59007(-3.5796)

95% critical values in brackets.

Unit root tests for variable XR

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-.93006(-2.9358)	-2.1087(-3.5247)
ADF(1)	1952 1990	39	-1.7146(-2.9378)	-2.8449(-3.5279)
ADF(2)	1953 1990	38	-1.7138(-2.9400)	-2.3188(-3.5313)
ADF(3)	1954 1990	37	-1.3397(-2.9422)	-2.4189(-3.5348)
ADF(4)	1955 1990	36	-1.6680(-2.9446)	-2.4875(-3.5386)
ADF(5)	1956 1990	35	-1.6555(-2.9472)	-2.6254(-3.5426)
ADF(6)	1957 1990	34	-1.6747(-2.9499)	-2.7428(-3.5468)
ADF(7)	1958 1990	33	-2.0126(-2.9528)	-3.0458(-3.5514)
ADF(8)	1959 1990	32	-1.5386(-2.9558)	-3.1558(-3.5562)
ADF(9)	1960 1990	31	-.88656(-2.9591)	-2.5016(-3.5615)
ADF(10)	1961 1990	30	-.045781(-2.9627)	-1.7114(-3.5671)
ADF(11)	1962 1990	29	.17395(-2.9665)	-1.7455(-3.5731)
ADF(12)	1963 1990	28	.35983(-2.9706)	-1.5267(-3.5796)

95% critical values in brackets.

Unit root tests for variable RXR

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-1.2427(-2.9358)	-2.1741(-3.5247)
ADF(1)	1952 1990	39	-2.1994(-2.9378)	-3.0229(-3.5279)
ADF(2)	1953 1990	38	-1.8229(-2.9400)	-2.3170(-3.5313)
ADF(3)	1954 1990	37	-1.4034(-2.9422)	-2.3441(-3.5348)
ADF(4)	1955 1990	36	-1.7277(-2.9446)	-2.2701(-3.5386)
ADF(5)	1956 1990	35	-1.9089(-2.9472)	-2.5070(-3.5426)
ADF(6)	1957 1990	34	-2.2602(-2.9499)	-2.8552(-3.5468)
ADF(7)	1958 1990	33	-2.6446(-2.9528)	-3.2961(-3.5514)
ADF(8)	1959 1990	32	-2.0347(-2.9558)	-3.3942(-3.5562)
ADF(9)	1960 1990	31	-1.2089(-2.9591)	-2.5203(-3.5615)
ADF(10)	1961 1990	30	-.33895(-2.9627)	-1.7783(-3.5671)
ADF(11)	1962 1990	29	-.17901(-2.9665)	-1.7750(-3.5731)
ADF(12)	1963 1990	28	.13508(-2.9706)	-1.5929(-3.5796)

95% critical values in brackets.

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-2.3952(-3.0199)	-2.2306(-3.6592)
ADF(1)	1952 1970	19	-1.7777(-3.0294)	-1.6032(-3.6746)
ADF(2)	1953 1970	18	-2.1195(-3.0401)	-1.6246(-3.6921)
ADF(3)	1954 1970	17	-1.2251(-3.0522)	-.76635(-3.7119)
ADF(4)	1955 1970	16	-1.2257(-3.0660)	-.93976(-3.7347)
ADF(5)	1956 1970	15	-.82641(-3.0819)	-.15705(-3.7612)
ADF(6)	1957 1970	14	-2.0964(-3.1004)	.48247(-3.7921)
ADF(7)	1958 1970	13	-.32525(-3.1223)	.59481(-3.8288)

ADF(8)	1959 1970	12	-.66409(-3.1485)	-.36173(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

95% critical values in brackets.

Unit root tests for variable XR

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-1.4439(-3.0199)	-2.9533(-3.6592)
ADF(1)	1952 1970	19	-1.7598(-3.0294)	-2.8672(-3.6746)
ADF(2)	1953 1970	18	-1.5404(-3.0401)	-1.2262(-3.6921)
ADF(3)	1954 1970	17	-1.4530(-3.0522)	-1.7385(-3.7119)
ADF(4)	1955 1970	16	-1.3252(-3.0660)	-1.3352(-3.7347)
ADF(5)	1956 1970	15	-1.8835(-3.0819)	-1.9029(-3.7612)
ADF(6)	1957 1970	14	-1.6559(-3.1004)	-1.4390(-3.7921)
ADF(7)	1958 1970	13	-2.9833(-3.1223)	-.59422(-3.8288)
ADF(8)	1959 1970	12	-4.9418(-3.1485)	-1.9701(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

95% critical values in brackets.

Unit root tests for variable RXR

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-1.9867(-3.0199)	-3.2321(-3.6592)
ADF(1)	1952 1970	19	-2.0417(-3.0294)	-2.6848(-3.6746)
ADF(2)	1953 1970	18	-1.6033(-3.0401)	-1.3002(-3.6921)
ADF(3)	1954 1970	17	-1.5207(-3.0522)	-1.7940(-3.7119)
ADF(4)	1955 1970	16	-1.3335(-3.0660)	-1.1969(-3.7347)
ADF(5)	1956 1970	15	-1.8742(-3.0819)	-1.5990(-3.7612)
ADF(6)	1957 1970	14	-1.7273(-3.1004)	-1.2421(-3.7921)
ADF(7)	1958 1970	13	-2.6140(-3.1223)	-.39153(-3.8288)
ADF(8)	1959 1970	12	-6.4165(-3.1485)	-2.4919(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

95% critical values in brackets.

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	1.0504(-3.0115)	-2.2399(-3.6454)
ADF(1)	1970 1990	21	-.38499(-3.0115)	-2.1782(-3.6454)
ADF(2)	1970 1990	21	.27436(-3.0115)	-1.8173(-3.6454)
ADF(3)	1970 1990	21	-.12149(-3.0115)	-1.7673(-3.6454)
ADF(4)	1970 1990	21	-.97872(-3.0115)	-2.0696(-3.6454)
ADF(5)	1970 1990	21	-1.1511(-3.0115)	-2.1805(-3.6454)
ADF(6)	1970 1990	21	-.50288(-3.0115)	-1.2599(-3.6454)
ADF(7)	1970 1990	21	-.53758(-3.0115)	-.87317(-3.6454)
ADF(8)	1970 1990	21	-.87243(-3.0115)	-.70827(-3.6454)
ADF(9)	1970 1990	21	-.38540(-3.0115)	.26307(-3.6454)
ADF(10)	1970 1990	21	-.69296(-3.0115)	.37641(-3.6454)
ADF(11)	1970 1990	21	-1.4204(-3.0115)	-.34255(-3.6454)
ADF(12)	1970 1990	21	-1.5420(-3.0115)	-.31286(-3.6454)

95% critical values in brackets.

Unit root tests for variable XR

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-.88826(-3.0115)	-.99393(-3.6454)
ADF(1)	1970 1990	21	-1.4557(-3.0115)	-2.4136(-3.6454)
ADF(2)	1970 1990	21	-1.3327(-3.0115)	-2.4651(-3.6454)

ADF(3)	1970 1990	21	-1.1173(-3.0115)	-2.3008(-3.6454)
ADF(4)	1970 1990	21	-1.4857(-3.0115)	-2.4311(-3.6454)
ADF(5)	1970 1990	21	-1.3492(-3.0115)	-2.2810(-3.6454)
ADF(6)	1970 1990	21	-1.4826(-3.0115)	-2.3345(-3.6454)
ADF(7)	1970 1990	21	-1.9399(-3.0115)	-3.1652(-3.6454)
ADF(8)	1970 1990	21	-1.5328(-3.0115)	-3.2007(-3.6454)
ADF(9)	1970 1990	21	-1.1413(-3.0115)	-3.4171(-3.6454)
ADF(10)	1970 1990	21	-.61976(-3.0115)	-2.7403(-3.6454)
ADF(11)	1970 1990	21	-.29985(-3.0115)	-2.6291(-3.6454)
ADF(12)	1970 1990	21	-.029582(-3.0115)	-2.9633(-3.6454)

95% critical values in brackets.

Unit root tests for variable RXR

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-.95434(-3.0115)	-1.0619(-3.6454)
ADF(1)	1970 1990	21	-1.7138(-3.0115)	-2.7658(-3.6454)
ADF(2)	1970 1990	21	-1.3433(-3.0115)	-2.4118(-3.6454)
ADF(3)	1970 1990	21	-1.0732(-3.0115)	-2.1893(-3.6454)
ADF(4)	1970 1990	21	-1.4509(-3.0115)	-2.2621(-3.6454)
ADF(5)	1970 1990	21	-1.4590(-3.0115)	-2.1632(-3.6454)
ADF(6)	1970 1990	21	-2.0159(-3.0115)	-2.5170(-3.6454)
ADF(7)	1970 1990	21	-2.6504(-3.0115)	-3.5222(-3.6454)
ADF(8)	1970 1990	21	-1.9129(-3.0115)	-3.0687(-3.6454)
ADF(9)	1970 1990	21	-1.4219(-3.0115)	-2.9648(-3.6454)
ADF(10)	1970 1990	21	-.87406(-3.0115)	-2.4184(-3.6454)
ADF(11)	1970 1990	21	-.68613(-3.0115)	-2.6222(-3.6454)
ADF(12)	1970 1990	21	-.30860(-3.0115)	-3.1914(-3.6454)

95% critical values in brackets.

French Data:

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-1.8430(-2.9358)	-1.5941(-3.5247)
ADF(1)	1952 1990	39	-1.3084(-2.9378)	-1.0035(-3.5279)
ADF(2)	1953 1990	38	-1.1973(-2.9400)	-1.2092(-3.5313)
ADF(3)	1954 1990	37	-1.0992(-2.9422)	-.83328(-3.5348)
ADF(4)	1955 1990	36	-1.4532(-2.9446)	-1.4154(-3.5386)
ADF(5)	1956 1990	35	-1.2849(-2.9472)	-.54137(-3.5426)
ADF(6)	1957 1990	34	-2.0157(-2.9499)	-.75001(-3.5468)
ADF(7)	1958 1990	33	-2.3041(-2.9528)	-.57774(-3.5514)
ADF(8)	1959 1990	32	-2.4977(-2.9558)	-.61575(-3.5562)
ADF(9)	1960 1990	31	-2.0268(-2.9591)	-.14630(-3.5615)
ADF(10)	1961 1990	30	-2.7831(-2.9627)	-.36361(-3.5671)
ADF(11)	1962 1990	29	-3.0103(-2.9665)	-.15393(-3.5731)
ADF(12)	1963 1990	28	-3.2227(-2.9706)	-.56186(-3.5796)

95% critical values in brackets.

Unit root tests for variable XR

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-1.6803(-2.9358)	-1.8798(-3.5247)
ADF(1)	1952 1990	39	-2.5537(-2.9378)	-3.2814(-3.5279)
ADF(2)	1953 1990	38	-2.1499(-2.9400)	-2.7066(-3.5313)
ADF(3)	1954 1990	37	-2.0813(-2.9422)	-2.6939(-3.5348)
ADF(4)	1955 1990	36	-2.2621(-2.9446)	-3.1196(-3.5386)
ADF(5)	1956 1990	35	-1.5418(-2.9472)	-2.5125(-3.5426)
ADF(6)	1957 1990	34	-1.5563(-2.9499)	-2.6758(-3.5468)
ADF(7)	1958 1990	33	-1.9304(-2.9528)	-3.7234(-3.5514)
ADF(8)	1959 1990	32	-1.4771(-2.9558)	-3.6966(-3.5562)
ADF(9)	1960 1990	31	-.61683(-2.9591)	-1.9954(-3.5615)
ADF(10)	1961 1990	30	-.85265(-2.9627)	-1.6198(-3.5671)
ADF(11)	1962 1990	29	-.92923(-2.9665)	-2.2976(-3.5731)
ADF(12)	1963 1990	28	-.94158(-2.9706)	-1.7338(-3.5796)

95% critical values in brackets.

Unit root tests for variable RXR

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-2.0872(-2.9358)	-2.0479(-3.5247)
ADF(1)	1952 1990	39	-3.3924(-2.9378)	-3.4710(-3.5279)
ADF(2)	1953 1990	38	-2.7911(-2.9400)	-2.7829(-3.5313)
ADF(3)	1954 1990	37	-2.7674(-2.9422)	-2.8202(-3.5348)
ADF(4)	1955 1990	36	-3.0574(-2.9446)	-3.2004(-3.5386)
ADF(5)	1956 1990	35	-2.2968(-2.9472)	-2.5257(-3.5426)
ADF(6)	1957 1990	34	-2.5728(-2.9499)	-2.7741(-3.5468)
ADF(7)	1958 1990	33	-3.1005(-2.9528)	-3.3574(-3.5514)
ADF(8)	1959 1990	32	-3.0037(-2.9558)	-3.4236(-3.5562)
ADF(9)	1960 1990	31	-1.6359(-2.9591)	-1.9806(-3.5615)
ADF(10)	1961 1990	30	-1.5612(-2.9627)	-1.6779(-3.5671)
ADF(11)	1962 1990	29	-1.9747(-2.9665)	-2.1667(-3.5731)
ADF(12)	1963 1990	28	-1.5658(-2.9706)	-1.4771(-3.5796)

95% critical values in brackets.

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-.92544(-3.0199)	-1.7928(-3.6592)
ADF(1)	1952 1970	19	-.17611(-3.0294)	-1.5661(-3.6746)
ADF(2)	1953 1970	18	-.45985(-3.0401)	-2.3408(-3.6921)
ADF(3)	1954 1970	17	-.18090(-3.0522)	-2.3011(-3.7119)
ADF(4)	1955 1970	16	-1.5631(-3.0660)	-3.7333(-3.7347)
ADF(5)	1956 1970	15	.029835(-3.0819)	-2.0046(-3.7612)
ADF(6)	1957 1970	14	-1.5073(-3.1004)	-1.9445(-3.7921)
ADF(7)	1958 1970	13	-2.4695(-3.1223)	-2.6107(-3.8288)
ADF(8)	1959 1970	12	-4.3680(-3.1485)	-1.7463(-3.8731)

ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

95% critical values in brackets.

Unit root tests for variable XR

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-.24847(-3.0199)	-1.5522(-3.6592)
ADF(1)	1952 1970	19	-.78573(-3.0294)	-2.9758(-3.6746)
ADF(2)	1953 1970	18	-.59812(-3.0401)	-2.1042(-3.6921)
ADF(3)	1954 1970	17	-.78204(-3.0522)	-2.4619(-3.7119)
ADF(4)	1955 1970	16	-.82259(-3.0660)	-2.1873(-3.7347)
ADF(5)	1956 1970	15	-1.0058(-3.0819)	-2.1705(-3.7612)
ADF(6)	1957 1970	14	-1.3576(-3.1004)	-2.0123(-3.7921)
ADF(7)	1958 1970	13	-2.0549(-3.1223)	-2.5117(-3.8288)
ADF(8)	1959 1970	12	-1.3178(-3.1485)	-7.0597(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

95% critical values in brackets.

Unit root tests for variable RXR

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-.21753(-3.0199)	-1.6717(-3.6592)
ADF(1)	1952 1970	19	-1.0965(-3.0294)	-2.9142(-3.6746)
ADF(2)	1953 1970	18	-.80426(-3.0401)	-2.2481(-3.6921)
ADF(3)	1954 1970	17	-.82423(-3.0522)	-2.6278(-3.7119)
ADF(4)	1955 1970	16	-.81805(-3.0660)	-2.4837(-3.7347)
ADF(5)	1956 1970	15	-.91479(-3.0819)	-2.8269(-3.7612)
ADF(6)	1957 1970	14	-1.0048(-3.1004)	-2.5852(-3.7921)
ADF(7)	1958 1970	13	-1.2981(-3.1223)	-2.4272(-3.8288)
ADF(8)	1959 1970	12	-1.0983(-3.1485)	-4.8035(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

95% critical values in brackets.

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-1.1867(-3.0115)	-1.9817(-3.6454)
ADF(1)	1970 1990	21	-1.2079(-3.0115)	-2.7662(-3.6454)
ADF(2)	1970 1990	21	-1.0930(-3.0115)	-1.7716(-3.6454)
ADF(3)	1970 1990	21	-1.0563(-3.0115)	-2.0341(-3.6454)
ADF(4)	1970 1990	21	-1.1078(-3.0115)	-1.5132(-3.6454)
ADF(5)	1970 1990	21	-1.2577(-3.0115)	-1.1505(-3.6454)
ADF(6)	1970 1990	21	-1.8326(-3.0115)	-.88495(-3.6454)
ADF(7)	1970 1990	21	-2.0361(-3.0115)	-.85103(-3.6454)
ADF(8)	1970 1990	21	-1.7675(-3.0115)	-.82459(-3.6454)
ADF(9)	1970 1990	21	-2.2038(-3.0115)	-1.1518(-3.6454)
ADF(10)	1970 1990	21	-2.1112(-3.0115)	-1.2277(-3.6454)
ADF(11)	1970 1990	21	-2.5630(-3.0115)	-2.5779(-3.6454)
ADF(12)	1970 1990	21	-1.4249(-3.0115)	-2.2038(-3.6454)

95% critical values in brackets.

Unit root tests for variable XR

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-1.3350(-3.0115)	-1.3225(-3.6454)
ADF(1)	1970 1990	21	-2.1439(-3.0115)	-2.3555(-3.6454)
ADF(2)	1970 1990	21	-1.7617(-3.0115)	-1.9858(-3.6454)
ADF(3)	1970 1990	21	-1.6655(-3.0115)	-2.0113(-3.6454)

ADF(4)	1970 1990	21	-1.8453(-3.0115)	-2.3924(-3.6454)
ADF(5)	1970 1990	21	-1.2164(-3.0115)	-1.8959(-3.6454)
ADF(6)	1970 1990	21	-1.3658(-3.0115)	-1.8727(-3.6454)
ADF(7)	1970 1990	21	-2.5863(-3.0115)	-3.0582(-3.6454)
ADF(8)	1970 1990	21	-3.4051(-3.0115)	-4.4036(-3.6454)
ADF(9)	1970 1990	21	-1.3143(-3.0115)	-2.3667(-3.6454)
ADF(10)	1970 1990	21	.23632(-3.0115)	-.72225(-3.6454)
ADF(11)	1970 1990	21	.062427(-3.0115)	-1.6151(-3.6454)
ADF(12)	1970 1990	21	-.18451(-3.0115)	-1.4452(-3.6454)

****

95% critical values in brackets.

Unit root tests for variable RXR

****

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-1.5318(-3.0115)	-1.4673(-3.6454)
ADF(1)	1970 1990	21	-2.5232(-3.0115)	-2.4966(-3.6454)
ADF(2)	1970 1990	21	-2.0399(-3.0115)	-2.0141(-3.6454)
ADF(3)	1970 1990	21	-2.0278(-3.0115)	-2.0601(-3.6454)
ADF(4)	1970 1990	21	-2.2741(-3.0115)	-2.4048(-3.6454)
ADF(5)	1970 1990	21	-1.6397(-3.0115)	-1.7772(-3.6454)
ADF(6)	1970 1990	21	-2.0324(-3.0115)	-1.9483(-3.6454)
ADF(7)	1970 1990	21	-2.9345(-3.0115)	-2.7527(-3.6454)
ADF(8)	1970 1990	21	-3.7859(-3.0115)	-3.8027(-3.6454)
ADF(9)	1970 1990	21	-2.2927(-3.0115)	-2.2350(-3.6454)
ADF(10)	1970 1990	21	-1.6393(-3.0115)	-1.2551(-3.6454)
ADF(11)	1970 1990	21	-2.0473(-3.0115)	-2.2183(-3.6454)
ADF(12)	1970 1990	21	-1.2630(-3.0115)	-1.6569(-3.6454)

****

95% critical values in brackets.

Italian Data:

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-1.6435(-2.9358)	-1.9367(-3.5247)
ADF(1)	1952 1990	39	-1.5344(-2.9378)	-2.1348(-3.5279)
ADF(2)	1953 1990	38	-1.4581(-2.9400)	-1.9799(-3.5313)
ADF(3)	1954 1990	37	-1.5456(-2.9422)	-1.9330(-3.5348)
ADF(4)	1955 1990	36	-2.0048(-2.9446)	-1.8602(-3.5386)
ADF(5)	1956 1990	35	-1.5339(-2.9472)	-1.1825(-3.5426)
ADF(6)	1957 1990	34	-1.5592(-2.9499)	-1.3945(-3.5468)
ADF(7)	1958 1990	33	-1.5082(-2.9528)	-1.4131(-3.5514)
ADF(8)	1959 1990	32	-2.2448(-2.9558)	-1.5809(-3.5562)
ADF(9)	1960 1990	31	-1.8487(-2.9591)	-1.3653(-3.5615)
ADF(10)	1961 1990	30	-2.6880(-2.9627)	-1.5161(-3.5671)
ADF(11)	1962 1990	29	-3.3422(-2.9665)	-1.8780(-3.5731)
ADF(12)	1963 1990	28	-3.0346(-2.9706)	-2.1866(-3.5796)

95% critical values in brackets.

Unit root tests for variable XR

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-.84271(-2.9358)	-1.6852(-3.5247)
ADF(1)	1952 1990	39	-1.5217(-2.9378)	-2.4143(-3.5279)
ADF(2)	1953 1990	38	-1.1499(-2.9400)	-1.9825(-3.5313)
ADF(3)	1954 1990	37	-1.3291(-2.9422)	-2.2248(-3.5348)
ADF(4)	1955 1990	36	-1.4520(-2.9446)	-2.3744(-3.5386)
ADF(5)	1956 1990	35	.65345(-2.9472)	-.59685(-3.5426)
ADF(6)	1957 1990	34	.0047488(-2.9499)	-.68581(-3.5468)
ADF(7)	1958 1990	33	-1.3413(-2.9528)	-1.6590(-3.5514)
ADF(8)	1959 1990	32	-4.2173(-2.9558)	-4.3443(-3.5562)
ADF(9)	1960 1990	31	-6.1496(-2.9591)	-6.0293(-3.5615)
ADF(10)	1961 1990	30	-2.3849(-2.9627)	-2.4683(-3.5671)
ADF(11)	1962 1990	29	-3.8975(-2.9665)	-4.6405(-3.5731)
ADF(12)	1963 1990	28	-2.1707(-2.9706)	-2.9823(-3.5796)

95% critical values in brackets.

Unit root tests for variable RXR

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-1.8624(-2.9358)	-1.9740(-3.5247)
ADF(1)	1952 1990	39	-2.5918(-2.9378)	-2.8418(-3.5279)
ADF(2)	1953 1990	38	-2.0893(-2.9400)	-2.3243(-3.5313)
ADF(3)	1954 1990	37	-2.2323(-2.9422)	-2.5924(-3.5348)
ADF(4)	1955 1990	36	-2.2220(-2.9446)	-2.6678(-3.5386)
ADF(5)	1956 1990	35	.15741(-2.9472)	-.53563(-3.5426)
ADF(6)	1957 1990	34	-.19088(-2.9499)	-.38518(-3.5468)
ADF(7)	1958 1990	33	-.91834(-2.9528)	-.74625(-3.5514)
ADF(8)	1959 1990	32	-3.3152(-2.9558)	-2.9688(-3.5562)
ADF(9)	1960 1990	31	-3.5492(-2.9591)	-4.1209(-3.5615)
ADF(10)	1961 1990	30	-1.6292(-2.9627)	-1.3042(-3.5671)
ADF(11)	1962 1990	29	-2.2017(-2.9665)	-2.1619(-3.5731)
ADF(12)	1963 1990	28	-1.6765(-2.9706)	-1.3907(-3.5796)

95% critical values in brackets.

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-1.0358(-3.0199)	-1.4362(-3.6592)
ADF(1)	1952 1970	19	-1.1050(-3.0294)	-2.0692(-3.6746)
ADF(2)	1953 1970	18	-1.1998(-3.0401)	-2.6055(-3.6921)
ADF(3)	1954 1970	17	-1.1129(-3.0522)	-2.3937(-3.7119)
ADF(4)	1955 1970	16	-1.4463(-3.0660)	-2.0527(-3.7347)
ADF(5)	1956 1970	15	-.14975(-3.0819)	-1.7556(-3.7612)
ADF(6)	1957 1970	14	.10081(-3.1004)	-1.4595(-3.7921)
ADF(7)	1958 1970	13	-.40496(-3.1223)	-1.9597(-3.8288)

statistic	sample	observations	without trend	with trend
ADF(8)	1959 1970	12	-.75578(-3.1485)	-.61762(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

95% critical values in brackets.

Unit root tests for variable XR

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-10.5749(-3.0199)	-9.6819(-3.6592)
ADF(1)	1952 1970	19	-4.9265(-3.0294)	-4.9356(-3.6746)
ADF(2)	1953 1970	18	-2.6076(-3.0401)	-2.5876(-3.6921)
ADF(3)	1954 1970	17	-2.2352(-3.0522)	-2.6737(-3.7119)
ADF(4)	1955 1970	16	-1.4738(-3.0660)	-1.4697(-3.7347)
ADF(5)	1956 1970	15	-1.4149(-3.0819)	-1.9531(-3.7612)
ADF(6)	1957 1970	14	-1.0237(-3.1004)	-.96242(-3.7921)
ADF(7)	1958 1970	13	-1.8297(-3.1223)	-.42683(-3.8288)
ADF(8)	1959 1970	12	-2.4372(-3.1485)	-.080072(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

95% critical values in brackets.

Unit root tests for variable RXR

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-.98077(-3.0199)	-.96555(-3.6592)
ADF(1)	1952 1970	19	-2.3428(-3.0294)	-3.5836(-3.6746)
ADF(2)	1953 1970	18	-1.6843(-3.0401)	-3.4149(-3.6921)
ADF(3)	1954 1970	17	-.60935(-3.0522)	-2.2897(-3.7119)
ADF(4)	1955 1970	16	-.39781(-3.0660)	-2.1217(-3.7347)
ADF(5)	1956 1970	15	.11480(-3.0819)	-2.8890(-3.7612)
ADF(6)	1957 1970	14	.032286(-3.1004)	-2.8249(-3.7921)
ADF(7)	1958 1970	13	.29633(-3.1223)	-1.3479(-3.8288)
ADF(8)	1959 1970	12	-.21599(-3.1485)	-2.1321(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

95% critical values in brackets.

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-2.2703(-3.0115)	-2.6079(-3.6454)
ADF(1)	1970 1990	21	-2.3979(-3.0115)	-2.9225(-3.6454)
ADF(2)	1970 1990	21	-1.8472(-3.0115)	-2.4161(-3.6454)
ADF(3)	1970 1990	21	-2.1636(-3.0115)	-2.8548(-3.6454)
ADF(4)	1970 1990	21	-1.5573(-3.0115)	-2.2902(-3.6454)
ADF(5)	1970 1990	21	-.76719(-3.0115)	-1.4971(-3.6454)
ADF(6)	1970 1990	21	-.85415(-3.0115)	-1.7633(-3.6454)
ADF(7)	1970 1990	21	-.66252(-3.0115)	-1.5492(-3.6454)
ADF(8)	1970 1990	21	-.70807(-3.0115)	-1.4785(-3.6454)
ADF(9)	1970 1990	21	-.73709(-3.0115)	-1.3713(-3.6454)
ADF(10)	1970 1990	21	-.87261(-3.0115)	-1.2985(-3.6454)
ADF(11)	1970 1990	21	-.99254(-3.0115)	-1.2514(-3.6454)
ADF(12)	1970 1990	21	-.86082(-3.0115)	-1.2204(-3.6454)

95% critical values in brackets.

Unit root tests for variable XR

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-1.1259(-3.0115)	-1.0801(-3.6454)
ADF(1)	1970 1990	21	-1.5220(-3.0115)	-1.9894(-3.6454)
ADF(2)	1970 1990	21	-1.2435(-3.0115)	-1.5558(-3.6454)

ADF(3)	1970 1990	21	-1.3362(-3.0115)	-2.1022(-3.6454)
ADF(4)	1970 1990	21	-1.3878(-3.0115)	-2.4918(-3.6454)
ADF(5)	1970 1990	21	.19475(-3.0115)	-1.7352(-3.6454)
ADF(6)	1970 1990	21	-.078726(-3.0115)	-1.5673(-3.6454)
ADF(7)	1970 1990	21	-.95839(-3.0115)	-1.8046(-3.6454)
ADF(8)	1970 1990	21	-2.9845(-3.0115)	-3.3416(-3.6454)
ADF(9)	1970 1990	21	-4.3920(-3.0115)	-4.1134(-3.6454)
ADF(10)	1970 1990	21	-1.7567(-3.0115)	-1.7349(-3.6454)
ADF(11)	1970 1990	21	-3.0159(-3.0115)	-3.7679(-3.6454)
ADF(12)	1970 1990	21	-1.7488(-3.0115)	-2.8772(-3.6454)

****

95% critical values in brackets.

Unit root tests for variable RXR

****

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-1.4516(-3.0115)	-1.2646(-3.6454)
ADF(1)	1970 1990	21	-1.9873(-3.0115)	-2.0758(-3.6454)
ADF(2)	1970 1990	21	-1.6256(-3.0115)	-1.6567(-3.6454)
ADF(3)	1970 1990	21	-1.7366(-3.0115)	-2.2005(-3.6454)
ADF(4)	1970 1990	21	-1.7273(-3.0115)	-2.7337(-3.6454)
ADF(5)	1970 1990	21	.081368(-3.0115)	-1.5381(-3.6454)
ADF(6)	1970 1990	21	.046015(-3.0115)	-1.2753(-3.6454)
ADF(7)	1970 1990	21	-.40392(-3.0115)	-1.2322(-3.6454)
ADF(8)	1970 1990	21	-2.2908(-3.0115)	-2.3669(-3.6454)
ADF(9)	1970 1990	21	-3.4267(-3.0115)	-3.0775(-3.6454)
ADF(10)	1970 1990	21	-1.7905(-3.0115)	-.78998(-3.6454)
ADF(11)	1970 1990	21	-2.0344(-3.0115)	-1.2213(-3.6454)
ADF(12)	1970 1990	21	-1.5622(-3.0115)	-.56549(-3.6454)

****

95% critical values in brackets.

Japanese Data:

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-3.2124(-2.9358)	-.90484(-3.5247)
ADF(1)	1952 1990	39	-2.5467(-2.9378)	.40334(-3.5279)
ADF(2)	1953 1990	38	-1.9463(-2.9400)	-.24709(-3.5313)
ADF(3)	1954 1990	37	-2.2240(-2.9422)	-.024510(-3.5348)
ADF(4)	1955 1990	36	-2.6355(-2.9446)	-.35710(-3.5386)
ADF(5)	1956 1990	35	-2.9661(-2.9472)	.92554(-3.5426)
ADF(6)	1957 1990	34	-1.8636(-2.9499)	.83517(-3.5468)
ADF(7)	1958 1990	33	-2.0515(-2.9528)	.93593(-3.5514)
ADF(8)	1959 1990	32	-2.8588(-2.9558)	.30254(-3.5562)
ADF(9)	1960 1990	31	-2.7805(-2.9591)	1.7509(-3.5615)
ADF(10)	1961 1990	30	-2.5760(-2.9627)	1.4467(-3.5671)
ADF(11)	1962 1990	29	-3.0760(-2.9665)	1.8387(-3.5731)
ADF(12)	1963 1990	28	-1.7761(-2.9706)	1.2913(-3.5796)

95% critical values in brackets.

Unit root tests for variable XR

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	.34829(-2.9358)	-1.8651(-3.5247)
ADF(1)	1952 1990	39	-.11905(-2.9378)	-2.3205(-3.5279)
ADF(2)	1953 1990	38	.33987(-2.9400)	-1.9309(-3.5313)
ADF(3)	1954 1990	37	.62358(-2.9422)	-1.7180(-3.5348)
ADF(4)	1955 1990	36	1.8589(-2.9446)	-.94668(-3.5386)
ADF(5)	1956 1990	35	1.0929(-2.9472)	-1.1715(-3.5426)
ADF(6)	1957 1990	34	1.9111(-2.9499)	-.80026(-3.5468)
ADF(7)	1958 1990	33	1.4225(-2.9528)	-.88630(-3.5514)
ADF(8)	1959 1990	32	1.1703(-2.9558)	-.98182(-3.5562)
ADF(9)	1960 1990	31	.88333(-2.9591)	-1.1674(-3.5615)
ADF(10)	1961 1990	30	2.1401(-2.9627)	-.40157(-3.5671)
ADF(11)	1962 1990	29	3.3646(-2.9665)	.31706(-3.5731)
ADF(12)	1963 1990	28	2.4235(-2.9706)	.39346(-3.5796)

95% critical values in brackets.

Unit root tests for variable RXR

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-.94617(-2.9358)	-2.3007(-3.5247)
ADF(1)	1952 1990	39	-.62470(-2.9378)	-3.1242(-3.5279)
ADF(2)	1953 1990	38	-.73992(-2.9400)	-2.6851(-3.5313)
ADF(3)	1954 1990	37	-.41519(-2.9422)	-2.5131(-3.5348)
ADF(4)	1955 1990	36	-.24462(-2.9446)	-1.8451(-3.5386)
ADF(5)	1956 1990	35	-.084617(-2.9472)	-2.9431(-3.5426)
ADF(6)	1957 1990	34	-.26629(-2.9499)	-2.3184(-3.5468)
ADF(7)	1958 1990	33	-.096427(-2.9528)	-2.2953(-3.5514)
ADF(8)	1959 1990	32	-.41017(-2.9558)	-2.9730(-3.5562)
ADF(9)	1960 1990	31	-.37129(-2.9591)	-2.4076(-3.5615)
ADF(10)	1961 1990	30	-.14695(-2.9627)	-2.3713(-3.5671)
ADF(11)	1962 1990	29	.26350(-2.9665)	-1.6830(-3.5731)
ADF(12)	1963 1990	28	.080330(-2.9706)	-1.8355(-3.5796)

95% critical values in brackets.

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-1.6150(-3.0199)	-2.5020(-3.6592)
ADF(1)	1952 1970	19	-.72774(-3.0294)	-1.3116(-3.6746)
ADF(2)	1953 1970	18	-.74924(-3.0401)	-2.4339(-3.6921)
ADF(3)	1954 1970	17	-.84122(-3.0522)	-2.1448(-3.7119)
ADF(4)	1955 1970	16	-1.3440(-3.0660)	-3.5613(-3.7347)
ADF(5)	1956 1970	15	-.20308(-3.0819)	-1.6828(-3.7612)
ADF(6)	1957 1970	14	.97896(-3.1004)	-2.3468(-3.7921)
ADF(7)	1958 1970	13	1.4851(-3.1223)	-2.3617(-3.8288)

ADF(8)	1959 1970	12	-.26841(-3.1485)	-141.7699(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

****

95% critical values in brackets.

Unit root tests for variable XR

****

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-2.6344(-3.0199)	-2.1714(-3.6592)
ADF(1)	1952 1970	19	-4.0893(-3.0294)	-3.3180(-3.6746)
ADF(2)	1953 1970	18	-21.1568(-3.0401)	-17.5894(-3.6921)
ADF(3)	1954 1970	17	-4.8550(-3.0522)	-4.7497(-3.7119)
ADF(4)	1955 1970	16	-3.2551(-3.0660)	-3.1527(-3.7347)
ADF(5)	1956 1970	15	-3.2794(-3.0819)	-2.2222(-3.7612)
ADF(6)	1957 1970	14	-2.9127(-3.1004)	-2.3974(-3.7921)
ADF(7)	1958 1970	13	-1.9348(-3.1223)	-1.4152(-3.8288)
ADF(8)	1959 1970	12	-3.7782(-3.1485)	-2.6601(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

****

95% critical values in brackets.

Unit root tests for variable RXR

****

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-2.2708(-3.0199)	-3.1695(-3.6592)
ADF(1)	1952 1970	19	-.88768(-3.0294)	-1.6104(-3.6746)
ADF(2)	1953 1970	18	-1.2072(-3.0401)	-2.8574(-3.6921)
ADF(3)	1954 1970	17	-.56119(-3.0522)	-2.7226(-3.7119)
ADF(4)	1955 1970	16	-.34599(-3.0660)	-2.7425(-3.7347)
ADF(5)	1956 1970	15	-.58402(-3.0819)	-2.2983(-3.7612)
ADF(6)	1957 1970	14	.072220(-3.1004)	-3.8817(-3.7921)
ADF(7)	1958 1970	13	-.26209(-3.1223)	-1.8792(-3.8288)
ADF(8)	1959 1970	12	-6.2053(-3.1485)	-4.9738(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

****

95% critical values in brackets.

Unit root tests for variable LILUS

****

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-3.6664(-3.0115)	-1.3265(-3.6454)
ADF(1)	1970 1990	21	-3.1818(-3.0115)	-1.3605(-3.6454)
ADF(2)	1970 1990	21	-2.9982(-3.0115)	-1.4591(-3.6454)
ADF(3)	1970 1990	21	-2.9958(-3.0115)	-1.7655(-3.6454)
ADF(4)	1970 1990	21	-3.0902(-3.0115)	-.95313(-3.6454)
ADF(5)	1970 1990	21	-3.0432(-3.0115)	-.78636(-3.6454)
ADF(6)	1970 1990	21	-2.5460(-3.0115)	-.76980(-3.6454)
ADF(7)	1970 1990	21	-2.2957(-3.0115)	-.67233(-3.6454)
ADF(8)	1970 1990	21	-3.0204(-3.0115)	.23318(-3.6454)
ADF(9)	1970 1990	21	-2.3172(-3.0115)	.48371(-3.6454)
ADF(10)	1970 1990	21	-2.0634(-3.0115)	.23051(-3.6454)
ADF(11)	1970 1990	21	-1.9764(-3.0115)	.78972(-3.6454)
ADF(12)	1970 1990	21	-1.7224(-3.0115)	.62991(-3.6454)

****

95% critical values in brackets.

Unit root tests for variable XR

****

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-1.0828(-3.0115)	-2.3137(-3.6454)
ADF(1)	1970 1990	21	-1.2290(-3.0115)	-3.2878(-3.6454)
ADF(2)	1970 1990	21	-.87855(-3.0115)	-3.1823(-3.6454)

ADF(3)	1970 1990	21	-.62227(-3.0115)	-3.4182(-3.6454)
ADF(4)	1970 1990	21	.087559(-3.0115)	-1.9847(-3.6454)
ADF(5)	1970 1990	21	-.016465(-3.0115)	-3.2267(-3.6454)
ADF(6)	1970 1990	21	.48856(-3.0115)	-2.0835(-3.6454)
ADF(7)	1970 1990	21	.45558(-3.0115)	-2.1843(-3.6454)
ADF(8)	1970 1990	21	.40687(-3.0115)	-2.2658(-3.6454)
ADF(9)	1970 1990	21	.28550(-3.0115)	-2.5371(-3.6454)
ADF(10)	1970 1990	21	1.1931(-3.0115)	-1.5191(-3.6454)
ADF(11)	1970 1990	21	2.1771(-3.0115)	-.80090(-3.6454)
ADF(12)	1970 1990	21	1.6654(-3.0115)	-.57377(-3.6454)

****

95% critical values in brackets.

Unit root tests for variable RXR

****

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-1.9151(-3.0115)	-1.9832(-3.6454)
ADF(1)	1970 1990	21	-2.0104(-3.0115)	-2.6477(-3.6454)
ADF(2)	1970 1990	21	-1.7693(-3.0115)	-2.2100(-3.6454)
ADF(3)	1970 1990	21	-1.6535(-3.0115)	-2.0224(-3.6454)
ADF(4)	1970 1990	21	-1.5360(-3.0115)	-1.4577(-3.6454)
ADF(5)	1970 1990	21	-1.3254(-3.0115)	-2.4936(-3.6454)
ADF(6)	1970 1990	21	-1.2215(-3.0115)	-1.5579(-3.6454)
ADF(7)	1970 1990	21	-1.0041(-3.0115)	-2.8714(-3.6454)
ADF(8)	1970 1990	21	-.83686(-3.0115)	-2.8067(-3.6454)
ADF(9)	1970 1990	21	-.89940(-3.0115)	-3.0565(-3.6454)
ADF(10)	1970 1990	21	-.82387(-3.0115)	-2.4539(-3.6454)
ADF(11)	1970 1990	21	-.66230(-3.0115)	-1.8497(-3.6454)
ADF(12)	1970 1990	21	-.57489(-3.0115)	-2.1228(-3.6454)

****

95% critical values in brackets.

United Kingdom Data:

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-2.0591(-2.9358)	-.81920(-3.5247)
ADF(1)	1952 1990	39	-1.4524(-2.9378)	-.60830(-3.5279)
ADF(2)	1953 1990	38	-1.4228(-2.9400)	-.14036(-3.5313)
ADF(3)	1954 1990	37	-1.3519(-2.9422)	-.39898(-3.5348)
ADF(4)	1955 1990	36	-2.6938(-2.9446)	-1.7214(-3.5386)
ADF(5)	1956 1990	35	-2.2964(-2.9472)	-1.5045(-3.5426)
ADF(6)	1957 1990	34	-2.7715(-2.9499)	-1.8805(-3.5468)
ADF(7)	1958 1990	33	-2.2483(-2.9528)	-1.5132(-3.5514)
ADF(8)	1959 1990	32	-3.3620(-2.9558)	-.74978(-3.5562)
ADF(9)	1960 1990	31	-2.2786(-2.9591)	-.29878(-3.5615)
ADF(10)	1961 1990	30	-3.8051(-2.9627)	-.89369(-3.5671)
ADF(11)	1962 1990	29	-4.0923(-2.9665)	-.90245(-3.5731)
ADF(12)	1963 1990	28	-3.3955(-2.9706)	-1.3507(-3.5796)

95% critical values in brackets.

Unit root tests for variable XR

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-1.0495(-2.9358)	-2.1136(-3.5247)
ADF(1)	1952 1990	39	-1.9003(-2.9378)	-3.7013(-3.5279)
ADF(2)	1953 1990	38	-1.4511(-2.9400)	-3.0890(-3.5313)
ADF(3)	1954 1990	37	-.87590(-2.9422)	-2.3908(-3.5348)
ADF(4)	1955 1990	36	-.66313(-2.9446)	-2.2432(-3.5386)
ADF(5)	1956 1990	35	.085614(-2.9472)	-1.8498(-3.5426)
ADF(6)	1957 1990	34	.64064(-2.9499)	-1.4972(-3.5468)
ADF(7)	1958 1990	33	.62418(-2.9528)	-1.2233(-3.5514)
ADF(8)	1959 1990	32	-1.7252(-2.9558)	-2.0680(-3.5562)
ADF(9)	1960 1990	31	-.39328(-2.9591)	-.49456(-3.5615)
ADF(10)	1961 1990	30	-.060080(-2.9627)	-.2130E-3(-3.5671)
ADF(11)	1962 1990	29	-.75117(-2.9665)	-.52794(-3.5731)
ADF(12)	1963 1990	28	-1.2029(-2.9706)	-1.0851(-3.5796)

95% critical values in brackets.

Unit root tests for variable RXR

statistic	sample	observations	without trend	with trend
DF	1951 1990	40	-2.1259(-2.9358)	-2.3298(-3.5247)
ADF(1)	1952 1990	39	-3.8048(-2.9378)	-4.4988(-3.5279)
ADF(2)	1953 1990	38	-3.0840(-2.9400)	-4.0296(-3.5313)
ADF(3)	1954 1990	37	-2.3026(-2.9422)	-3.3475(-3.5348)
ADF(4)	1955 1990	36	-1.9923(-2.9446)	-3.2390(-3.5386)
ADF(5)	1956 1990	35	-1.0386(-2.9472)	-2.4908(-3.5426)
ADF(6)	1957 1990	34	-.10853(-2.9499)	-1.7232(-3.5468)
ADF(7)	1958 1990	33	.25268(-2.9528)	-1.3472(-3.5514)
ADF(8)	1959 1990	32	-1.2679(-2.9558)	-2.5307(-3.5562)
ADF(9)	1960 1990	31	-.40160(-2.9591)	-1.8708(-3.5615)
ADF(10)	1961 1990	30	.19061(-2.9627)	-2.2221(-3.5671)
ADF(11)	1962 1990	29	-.011431(-2.9665)	-2.0645(-3.5731)
ADF(12)	1963 1990	28	-.0084873(-2.9706)	-1.9110(-3.5796)

95% critical values in brackets.

Unit root tests for variable LILUS

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-.23875(-3.0199)	-1.6157(-3.6592)
ADF(1)	1952 1970	19	.25620(-3.0294)	-1.9988(-3.6746)
ADF(2)	1953 1970	18	.76189(-3.0401)	-2.3608(-3.6921)
ADF(3)	1954 1970	17	.65269(-3.0522)	-2.9741(-3.7119)
ADF(4)	1955 1970	16	-2.5505(-3.0660)	-1.9702(-3.7347)
ADF(5)	1956 1970	15	-1.6767(-3.0819)	-1.6957(-3.7612)
ADF(6)	1957 1970	14	-2.0895(-3.1004)	-1.9075(-3.7921)
ADF(7)	1958 1970	13	-2.3240(-3.1223)	-6.3237(-3.8288)

ADF(8)	1959 1970	12	-.60030(-3.1485)	-2.8698(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

****

95% critical values in brackets.

Unit root tests for variable XR

****

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-.12943(-3.0199)	-1.0759(-3.6592)
ADF(1)	1952 1970	19	-.26060(-3.0294)	-1.0113(-3.6746)
ADF(2)	1953 1970	18	.093621(-3.0401)	.26456(-3.6921)
ADF(3)	1954 1970	17	.98327(-3.0522)	1.2348(-3.7119)
ADF(4)	1955 1970	16	.66426(-3.0660)	1.0908(-3.7347)
ADF(5)	1956 1970	15	.42753(-3.0819)	1.0812(-3.7612)
ADF(6)	1957 1970	14	.77527(-3.1004)	2.2244(-3.7921)
ADF(7)	1958 1970	13	.12867(-3.1223)	1.1580(-3.8288)
ADF(8)	1959 1970	12	-.11823(-3.1485)	1.9982(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

****

95% critical values in brackets.

Unit root tests for variable RXR

****

statistic	sample	observations	without trend	with trend
DF	1951 1970	20	-1.3555(-3.0199)	-1.0972(-3.6592)
ADF(1)	1952 1970	19	-1.7547(-3.0294)	-1.2338(-3.6746)
ADF(2)	1953 1970	18	-1.9588(-3.0401)	-1.1677(-3.6921)
ADF(3)	1954 1970	17	-1.9212(-3.0522)	-.77188(-3.7119)
ADF(4)	1955 1970	16	-2.4096(-3.0660)	-1.3398(-3.7347)
ADF(5)	1956 1970	15	-1.8051(-3.0819)	-.94076(-3.7612)
ADF(6)	1957 1970	14	-1.7146(-3.1004)	-1.3333(-3.7921)
ADF(7)	1958 1970	13	-2.3461(-3.1223)	-.79544(-3.8288)
ADF(8)	1959 1970	12	-3.5274(-3.1485)	-27.3169(-3.8731)
ADF(9)	1960 1970	11	*NONE*(-3.1803)	*NONE*(-3.9272)
ADF(10)	1961 1970	10	*NONE*(-3.2197)	*NONE*(-3.9949)
ADF(11)	1962 1970	9	*NONE*(-3.2698)	*NONE*(-4.0816)
ADF(12)	1963 1970	8	*NONE*(-3.3353)	*NONE*(-4.1961)

****

95% critical values in brackets.

Unit root tests for variable LILUS

****

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-1.5020(-3.0115)	-2.1258(-3.6454)
ADF(1)	1970 1990	21	-1.4881(-3.0115)	-1.8655(-3.6454)
ADF(2)	1970 1990	21	-2.1300(-3.0115)	-.76630(-3.6454)
ADF(3)	1970 1990	21	-2.0962(-3.0115)	-.48586(-3.6454)
ADF(4)	1970 1990	21	-2.4478(-3.0115)	-.25162(-3.6454)
ADF(5)	1970 1990	21	-1.9601(-3.0115)	-.21992(-3.6454)
ADF(6)	1970 1990	21	-1.8124(-3.0115)	-.24689(-3.6454)
ADF(7)	1970 1990	21	-1.8788(-3.0115)	-.27589(-3.6454)
ADF(8)	1970 1990	21	-3.0979(-3.0115)	-.85726(-3.6454)
ADF(9)	1970 1990	21	-1.7911(-3.0115)	-.61951(-3.6454)
ADF(10)	1970 1990	21	-1.7204(-3.0115)	-.81123(-3.6454)
ADF(11)	1970 1990	21	-2.0015(-3.0115)	-1.4132(-3.6454)
ADF(12)	1970 1990	21	-.96729(-3.0115)	-1.0056(-3.6454)

****

95% critical values in brackets.

Unit root tests for variable XR

****

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-1.3675(-3.0115)	-1.3753(-3.6454)
ADF(1)	1970 1990	21	-2.1839(-3.0115)	-3.1358(-3.6454)
ADF(2)	1970 1990	21	-1.7691(-3.0115)	-3.0552(-3.6454)

ADF(3)	1970 1990	21	-1.3416(-3.0115)	-2.5224(-3.6454)
ADF(4)	1970 1990	21	-1.1811(-3.0115)	-2.8186(-3.6454)
ADF(5)	1970 1990	21	-.63739(-3.0115)	-2.4578(-3.6454)
ADF(6)	1970 1990	21	-.052316(-3.0115)	-2.0321(-3.6454)
ADF(7)	1970 1990	21	.39383(-3.0115)	-1.7381(-3.6454)
ADF(8)	1970 1990	21	-1.1920(-3.0115)	-2.4818(-3.6454)
ADF(9)	1970 1990	21	.75662(-3.0115)	-.91419(-3.6454)
ADF(10)	1970 1990	21	1.6232(-3.0115)	-1.3472(-3.6454)
ADF(11)	1970 1990	21	.78927(-3.0115)	-1.6718(-3.6454)
ADF(12)	1970 1990	21	.55157(-3.0115)	-2.1626(-3.6454)

****

95% critical values in brackets.

Unit root tests for variable RXR

****

statistic	sample	observations	without trend	with trend
DF	1970 1990	21	-1.6398(-3.0115)	-1.5543(-3.6454)
ADF(1)	1970 1990	21	-3.2409(-3.0115)	-3.3382(-3.6454)
ADF(2)	1970 1990	21	-2.6951(-3.0115)	-3.0549(-3.6454)
ADF(3)	1970 1990	21	-2.1182(-3.0115)	-2.6378(-3.6454)
ADF(4)	1970 1990	21	-1.9197(-3.0115)	-2.8091(-3.6454)
ADF(5)	1970 1990	21	-1.2395(-3.0115)	-2.3363(-3.6454)
ADF(6)	1970 1990	21	-.48750(-3.0115)	-1.6520(-3.6454)
ADF(7)	1970 1990	21	-.087837(-3.0115)	-1.2953(-3.6454)
ADF(8)	1970 1990	21	-1.1006(-3.0115)	-4.6930(-3.6454)
ADF(9)	1970 1990	21	-.49098(-3.0115)	-4.6026(-3.6454)
ADF(10)	1970 1990	21	-.0059007(-3.0115)	-2.1913(-3.6454)
ADF(11)	1970 1990	21	-.26624(-3.0115)	-2.3182(-3.6454)
ADF(12)	1970 1990	21	-.19412(-3.0115)	-2.3474(-3.6454)

****

95% critical values in brackets.

Unit Root Results for the Sample Period 1960 and 1990.

Australia

Unit root tests for variable LILUS

****

statistic	sample	observations	without trend	with trend
DF	1961 1990	30	-2.1339(-2.9627)	-3.2167(-3.5671)
ADF(1)	1962 1990	29	-1.4156(-2.9665)	-3.1894(-3.5731)
ADF(2)	1963 1990	28	-1.4712(-2.9706)	-3.0054(-3.5796)
ADF(3)	1964 1990	27	-1.6929(-2.9750)	-3.0380(-3.5867)
ADF(4)	1965 1990	26	-1.2540(-2.9798)	-3.8824(-3.5943)
ADF(5)	1966 1990	25	-.26362(-2.9850)	-3.0127(-3.6027)
ADF(6)	1967 1990	24	-.27425(-2.9907)	-2.6810(-3.6119)
ADF(7)	1968 1990	23	.25410(-2.9970)	-3.8296(-3.6219)
ADF(8)	1969 1990	22	.20563(-3.0039)	-4.9364(-3.6331)
ADF(9)	1970 1990	21	.17504(-3.0115)	-3.3802(-3.6454)
ADF(10)	1971 1990	20	-.65046(-3.0199)	-1.6739(-3.6592)
ADF(11)	1972 1990	19	-.61828(-3.0294)	-1.4875(-3.6746)
ADF(12)	1973 1990	18	-.79924(-3.0401)	-2.3288(-3.6921)

****

95% critical values in brackets.

Germany

Unit root tests for variable LILUS

****

statistic	sample	observations	without trend	with trend
DF	1961 1990	30	-4.1011(-2.9627)	-2.7647(-3.5671)
ADF(1)	1962 1990	29	-3.3453(-2.9665)	-3.5310(-3.5731)
ADF(2)	1963 1990	28	-2.9817(-2.9706)	-3.0794(-3.5796)
ADF(3)	1964 1990	27	-2.3371(-2.9750)	-3.0043(-3.5867)
ADF(4)	1965 1990	26	-2.4195(-2.9798)	-3.7864(-3.5943)
ADF(5)	1966 1990	25	-1.9024(-2.9850)	-4.2360(-3.6027)
ADF(6)	1967 1990	24	-1.3722(-2.9907)	-4.1599(-3.6119)
ADF(7)	1968 1990	23	-1.5424(-2.9970)	-2.2967(-3.6219)
ADF(8)	1969 1990	22	-1.1261(-3.0039)	-1.8448(-3.6331)
ADF(9)	1970 1990	21	-1.0158(-3.0115)	-1.6045(-3.6454)
ADF(10)	1971 1990	20	-.62931(-3.0199)	-3.2317(-3.6592)
ADF(11)	1972 1990	19	-.44566(-3.0294)	-2.9781(-3.6746)
ADF(12)	1973 1990	18	.11930(-3.0401)	-2.9118(-3.6921)

ADF(2)	1963 1990	28	-2.3952(-2.9706)	-1.3122(-3.5796)
ADF(3)	1964 1990	27	-1.8481(-2.9750)	-1.1621(-3.5867)
ADF(4)	1965 1990	26	-2.9066(-2.9798)	-.61174(-3.5943)
ADF(5)	1966 1990	25	-2.5135(-2.9850)	.19577(-3.6027)
ADF(6)	1967 1990	24	-1.9703(-2.9907)	.25705(-3.6119)
ADF(7)	1968 1990	23	-1.8312(-2.9970)	.0061130(-3.6219)
ADF(8)	1969 1990	22	-2.8448(-3.0039)	.53361(-3.6331)
ADF(9)	1970 1990	21	-2.3172(-3.0115)	.48371(-3.6454)
ADF(10)	1971 1990	20	-4.4384(-3.0199)	-.78325(-3.6592)
ADF(11)	1972 1990	19	-1.5403(-3.0294)	-.50693(-3.6746)
ADF(12)	1973 1990	18	-1.6662(-3.0401)	-2.0605(-3.6921)

****

95% critical values in brackets.

United Kingdom

Unit root tests for variable LILUS

****

statistic	sample	observations	without trend	with trend
DF	1961 1990	30	-4.5253(-2.9627)	-2.4340(-3.5671)
ADF(1)	1962 1990	29	-4.8279(-2.9665)	-3.2916(-3.5731)
ADF(2)	1963 1990	28	-4.6843(-2.9706)	-2.7219(-3.5796)
ADF(3)	1964 1990	27	-3.9353(-2.9750)	-3.3638(-3.5867)
ADF(4)	1965 1990	26	-3.5698(-2.9798)	-3.2647(-3.5943)
ADF(5)	1966 1990	25	-2.8923(-2.9850)	-2.8852(-3.6027)
ADF(6)	1967 1990	24	-2.0925(-2.9907)	-1.8685(-3.6119)
ADF(7)	1968 1990	23	-1.9821(-2.9970)	-1.4749(-3.6219)
ADF(8)	1969 1990	22	-3.2605(-3.0039)	-1.5129(-3.6331)
ADF(9)	1970 1990	21	-1.7911(-3.0115)	-.61951(-3.6454)
ADF(10)	1971 1990	20	-1.7126(-3.0199)	-.57651(-3.6592)
ADF(11)	1972 1990	19	-2.0765(-3.0294)	-1.0208(-3.6746)
ADF(12)	1973 1990	18	-.72697(-3.0401)	.035976(-3.6921)

****

95% critical values in brackets.

APPENDIX B

RELATIVE LABOUR RESIDUAL VALUES

Relative Labour Residual Values

	Aus	Bd	Cn	Fr
date	labi/labus	labi/labus	labi/labus	labi/labus
1950	0.798347365	0.933610773	0.887402829	1.60254941
1951	0.708349569	0.929848747	0.869850378	1.523490382
1952	0.678722462	0.968506198	0.90339391	1.509386739
1953	0.715846041	0.979301029	0.885393055	1.466953234
1954	0.762453154	1.042096559	0.871779565	1.503036189
1955	0.73620416	1.05558125	0.873725811	1.444620671
1956	0.728845493	1.066075728	0.913130506	1.484398124
1957	0.719012085	1.068774847	0.890375862	1.486857039
1958	0.76465051	1.083465246	0.896836388	1.478280021
1959	0.7491086	1.065617096	0.865534999	1.415127662
1960	0.730022475	1.078717828	0.857260715	1.4197574
1961	0.702632201	1.054211373	0.856216243	1.399976216
1962	0.697081853	1.012071694	0.868043693	1.364078614
1963	0.699447618	0.969990093	0.874256836	1.327114722
1964	0.689119764	0.948946	0.876187733	1.285704732
1965	0.650306691	0.922444517	0.875817334	1.229914721
1966	0.647896855	0.886158667	0.880170246	1.191435611
1967	0.643697524	0.855238895	0.876856583	1.178360225
1968	0.658171694	0.858941475	0.882183696	1.143703335
1969	0.661438706	0.885056424	0.897061301	1.150406397
1970	0.681666247	0.911880698	0.912606166	1.175182489
1971	0.679272701	0.890637935	0.924635512	1.152910804
1972	0.66442431	0.870753891	0.92336821	1.113190708
1973	0.652127502	0.862630423	0.940628768	1.089910484
1974	0.661194474	0.867522153	0.972599146	1.100376361
1975	0.671196189	0.856373878	0.982716991	1.080390317
1976	0.648864663	0.856400752	0.972558174	1.051019678
1977	0.623190193	0.843588669	0.949702991	1.026327343
1978	0.620001501	0.827553808	0.935077459	1.002343004
1979	0.621114161	0.844787973	0.938975197	1.008028047
1980	0.634613257	0.851788443	0.932614861	1.012962223
1981	0.620189141	0.832110452	0.917930261	0.992501811
1982	0.620704223	0.845124852	0.891788539	1.031467832
1983	0.625390568	0.824600453	0.872104466	0.994359938
1984	0.612300862	0.796685906	0.859613648	0.944689632
1985	0.611273234	0.791129029	0.860269383	0.933639629
1986	0.606049295	0.791662307	0.851854355	0.932001451
1987	0.611550372	0.784382162	0.843175241	0.923000014
1988	0.60458421	0.784751618	0.827389954	0.917370442
1989	0.604502307	0.793088324	0.813523526	0.924676631
1990	0.598270652	0.816397131	0.795678456	0.935540445

Relative Labour Residual Values

It	Jp	Uk
labi/labus	labi/labus	labi/labus
1.997729639	3.787544188	1.301130996
1.962389508	3.483680306	1.241976051
1.946350624	3.479630292	1.20667046
1.954911312	3.358644984	1.209438214
2.007377087	3.393535097	1.26612281
1.941623932	3.233413754	1.216622331
1.931383456	3.174513861	1.209269583
1.909548961	3.061968216	1.199724178
1.943800093	3.076747183	1.198618695
1.895683394	2.941446754	1.166597126
1.938316927	2.948119511	1.162794242
1.944895947	2.899350078	1.140593861
1.871693481	2.714036644	1.074652274
1.81421481	2.573197018	1.056274582
1.712824798	2.475913881	1.031775669
1.65072575	2.29334954	0.983502322
1.646294524	2.236475111	0.941174728
1.692846173	2.229831905	0.923760545
1.695838829	2.20494986	0.907206407
1.708645562	2.186548632	0.888219573
1.755770397	2.183766569	0.894819723
1.69511493	2.021239371	0.873185118
1.636348877	1.924636594	0.855466084
1.650045606	1.834292428	0.871350009
1.722449149	1.736714844	0.856864006
1.66675991	1.711342351	0.849448602
1.675186037	1.625367445	0.825492925
1.649681222	1.572260348	0.808776765
1.628177163	1.518373023	0.800831412
1.689318349	1.521562078	0.810455423
1.742711436	1.528003552	0.79513636
1.706572741	1.501022271	0.772748792
1.74160466	1.539779883	0.80588511
1.688962335	1.486883184	0.805378694
1.627923157	1.423691704	0.771247171
1.619886266	1.420121691	0.774507018
1.618826324	1.391771746	0.784088824
1.617884918	1.374208242	0.794028088
1.616320632	1.365651165	0.791482108
1.624732423	1.355775594	0.781618132
1.642539045	1.374933383	0.773234737
Aus = Australia		
Bd = Germany		
Cn = Canada		
Fr = France		
It = Italy		
Jp = Japan		
Uk = United Kingdom		

APPENDIX C

NOTE ON COINTEGRATION RESULTS

Results from Cointegration Analysis:

Note that the cointegration investigation is based on the hypothesis that relative labour residual measure is cointegrated with the real exchange rate or the nominal exchange rate. The real exchange rate is used in preference to the nominal exchange rate. Where the non-stationarity of the dependent variable is in doubt, the nominal exchange rate is used.

Both a ML and a Trace statistic are calculated for Π. (See Equation [7.3.1]). The first two tests assume that there is a linear deterministic trend in the variable in x_t. One based on analysis with a trend in DGP (Option 4) and one for the no trend in DGP case (Option 3). The results essentially differ with regard to the critical values used. A third test is run, the non-trended case- and this is based on a regression with no trend in DGP and assuming that there are no deterministic trends in the variables in x_t.

Alternative VAR lengths are allowed for. From the literature reviewed the longest VAR length (VAR(p)) is believed to be 2. Hence results are presented with p=2.

The results are quite extensive, especially when different sample periods are applied.

APPENDIX D

CALCULATION OF VARIABLES

Real and Nominal exchanges Rates as calculated per equation [10.1.1]

FRRXR	ITXR	ITRXR	JPXR	JPRXR	XRUK	UKRXR
4.394624	625.8	1028.262	361.1	823.3014	0.3572	0.558474
4.090697	625.1	1034.934	361.2	747.8261	0.3571	0.557533
3.753754	625	1032.716	361.1	749.6367	0.3571	0.536992
3.75134	625	1019.576	360	714.4275	0.3572	0.531389
3.734927	625	1002.567	360	687.8105	0.3571	0.525302
3.705272	625	974.8869	360	683.2416	0.3571	0.50927
3.674927	625	969.4432	360	675.6757	0.3572	0.497354
3.838641	625	985.0276	360	664.2066	0.3572	0.498465
4.737555	624.9	990.1759	360.1	691.8348	0.357	0.495352
6.234373	625	1004.339	359.9	683.3112	0.3571	0.496662
6.179747	625.1	1005.954	360	659.945	0.357	0.496938
6.033977	625.1	985.8067	360	616.4384	0.3572	0.486383
5.866904	625	949.7037	359.9	604.0618	0.3571	0.478494
5.607816	625.1	893.7661	360	585.0804	0.3571	0.472917
5.506357	625	853.7085	360	567.1078	0.3572	0.463054
5.438423	625.1	833.4667	360	547.1956	0.3571	0.448449
5.479467	625	847.113	360	538.358	0.3571	0.446152
5.488496	625.2	850.728	359.9	527.9448	0.3614	0.459563
5.502787	624.9	874.2306	360	522.1932	0.4167	0.610192
6.028081	625	886.1477	360	521.7391	0.4167	0.603214
6.938164	625	900.5764	360	522.724	0.4167	0.595967
6.825514	619.9	863.611	349.3	490.6588	0.4109	0.557455
5.552501	583.2	750.4826	303.2	367.738	0.4004	0.516845
4.258286	583	694.6265	271.7	275.8376	0.4082	0.521328
4.752221	650.3	781.7045	292.1	288.3799	0.4278	0.533283
3.669835	652.8	746.313	296.8	303.6628	0.452	0.524666
4.335874	832.3	1084.147	296.6	298.2703	0.5565	0.728976
4.466867	882.4	1094.382	268.5	245.3175	0.5733	0.727261
3.701911	848.7	955.4205	210.4	156.2338	0.5215	0.586548
3.255031	830.9	864.1706	219.1	175.6313	0.4722	0.460503
3.116519	856.4	840.7618	226.7	195.1618	0.4303	0.360597
4.997242	1137	1349.075	220.5	195.8085	0.4976	0.472106
6.95229	1353	1748.062	249.1	260.2926	0.5724	0.615616
8.81754	1519	1991.348	237.5	241.2882	0.6597	0.806085
11.11549	1757	2465.965	237.5	244.1908	0.7518	1.033971
11.56817	1909	2777.131	238.5	252.381	0.7792	1.089485
6.841169	1491	1641.167	168.5	130.5291	0.6822	0.822126
5.188158	1296	1214.393	144.6	99.96543	0.6119	0.653739
5.142882	1302	1192.854	128.2	81.54698	0.5622	0.542141
5.921663	1372	1294.95	138	95.93326	0.6112	0.626615
4.383705	1198	965.5061	144.8	107.5301	0.5632	0.521675
4.749958	1241	1015.631	134.7	95.64723	0.567	0.517572
4.195261	1232	973.6052	126.7	85.28541	0.5698	0.515283

Real and Nominal exchanges Rates as calculated per equation [10.1.1]

FRRXR	ITXR	ITRXR	JPXR	JPRXR	XRUK	UKRXR
4.394624	625.8	1028.262	361.1	823.3014	0.3572	0.558474
4.090697	625.1	1034.934	361.2	747.8261	0.3571	0.557533
3.753754	625	1032.716	361.1	749.6367	0.3571	0.536992
3.75134	625	1019.576	360	714.4275	0.3572	0.531389
3.734927	625	1002.567	360	687.8105	0.3571	0.525302
3.705272	625	974.8869	360	683.2416	0.3571	0.50927
3.674927	625	969.4432	360	675.6757	0.3572	0.497354
3.838641	625	985.0276	360	664.2066	0.3572	0.498465
4.737555	624.9	990.1759	360.1	691.8348	0.357	0.495352
6.234373	625	1004.339	359.9	683.3112	0.3571	0.496662
6.179747	625.1	1005.954	360	659.945	0.357	0.496938
6.033977	625.1	985.8067	360	616.4384	0.3572	0.486383
5.866904	625	949.7037	359.9	604.0618	0.3571	0.478494
5.607816	625.1	893.7661	360	585.0804	0.3571	0.472917
5.506357	625	853.7085	360	567.1078	0.3572	0.463054
5.438423	625.1	833.4667	360	547.1956	0.3571	0.448449
5.479467	625	847.113	360	538.358	0.3571	0.446152
5.488496	625.2	850.728	359.9	527.9448	0.3614	0.459563
5.502787	624.9	874.2306	360	522.1932	0.4167	0.610192
6.028081	625	886.1477	360	521.7391	0.4167	0.603214
6.938164	625	900.5764	360	522.724	0.4167	0.595967
6.825514	619.9	863.611	349.3	490.6588	0.4109	0.557455
5.552501	583.2	750.4826	303.2	367.738	0.4004	0.516845
4.258286	583	694.6265	271.7	275.8376	0.4082	0.521328
4.752221	650.3	781.7045	292.1	288.3799	0.4278	0.533283
3.669835	652.8	746.313	296.8	303.6628	0.452	0.524666
4.335874	832.3	1084.147	296.6	298.2703	0.5565	0.728976
4.466867	882.4	1094.382	268.5	245.3175	0.5733	0.727261
3.701911	848.7	955.4205	210.4	156.2338	0.5215	0.586548
3.255031	830.9	864.1706	219.1	175.6313	0.4722	0.460503
3.116519	856.4	840.7618	226.7	195.1618	0.4303	0.360597
4.997242	1137	1349.075	220.5	195.8085	0.4976	0.472106
6.95229	1353	1748.062	249.1	260.2926	0.5724	0.615616
8.81754	1519	1991.348	237.5	241.2882	0.6597	0.806085
11.11549	1757	2465.965	237.5	244.1908	0.7518	1.033971
11.56817	1909	2777.131	238.5	252.381	0.7792	1.089485
6.841169	1491	1641.167	168.5	130.5291	0.6822	0.822126
5.188158	1296	1214.393	144.6	99.96543	0.6119	0.653739
5.142882	1302	1192.854	128.2	81.54698	0.5622	0.542141
5.921663	1372	1294.95	138	95.93326	0.6112	0.626615
4.383705	1198	965.5061	144.8	107.5301	0.5632	0.521675
4.749958	1241	1015.631	134.7	95.64723	0.567	0.517572
4.195261	1232	973.6052	126.7	85.28541	0.5698	0.515283

Calculation of marginal products for the US and variable Lilus

	A	B	C
1			[redacted]
2	date	USAK	USK
3	1950	3,739,679,981,568	3,552,695,982,490
4	1951	3,904,397,901,824	3,709,178,006,733
5	1952	4,033,835,958,272	3,832,144,160,358
6	1953	4,171,138,072,576	3,962,581,168,947
7	1954	4,295,123,009,536	4,080,366,859,059
8	1955	4,476,748,955,648	4,252,911,507,866
9	1956	4,643,283,795,968	4,411,119,606,170
10	1957	4,782,291,943,424	4,543,177,346,253
11	1958	4,901,392,875,520	4,656,323,231,744
12	1959	5,061,377,261,568	4,808,308,398,490
13	1960	5,207,136,141,312	4,946,779,334,246
14	1961	5,351,811,842,048	5,084,221,249,946
15	1962	5,514,340,073,472	5,238,623,069,798
16	1963	5,697,641,119,744	5,412,759,063,767
17	1964	5,900,078,153,728	5,605,074,246,042
18	1965	6,134,723,248,128	5,827,987,085,722
19	1966	6,378,571,169,792	6,059,642,611,302
20	1967	6,607,817,146,368	6,277,426,289,050
21	1968	6,858,803,773,440	6,515,863,584,768
22	1969	7,109,146,050,560	6,753,688,748,032
23	1970	7,330,180,104,192	6,963,671,098,982
24	1971	7,571,568,066,560	7,192,989,663,232
25	1972	7,849,869,049,856	7,457,375,597,363
26	1973	8,153,203,212,288	7,745,543,051,674
27	1974	8,407,229,136,896	7,986,867,680,051
28	1975	8,588,866,093,056	8,159,422,788,403
29	1976	8,799,189,952,896	8,359,239,955,251
30	1977	9,063,954,907,136	8,610,757,161,779
31	1978	9,376,408,535,040	8,907,588,108,288
32	1979	9,692,525,887,488	9,207,899,593,114
33	1980	9,948,722,364,416	9,451,286,246,195
34	1981	10,193,759,895,552	9,684,971,900,774
35	1982	10,373,029,691,392	9,854,378,206,822
36	1983	10,596,659,494,912	10,066,826,520,166
37	1984	10,912,660,455,424	10,367,027,432,653
38	1985	11,267,109,552,128	10,703,754,074,522
39	1986	11,623,269,924,864	11,042,106,428,621
40	1987	11,988,220,510,208	11,388,809,484,698
41	1988	12,380,279,930,880	11,761,265,934,336
42	1989	12,779,799,969,792	12,140,809,971,302
43	1990	13,138,079,514,624	12,481,175,538,893
44			
45			

Calculation of marginal products for the US and variable Lilus

	A	D	E
1			
2	date	[redacted]	USAI
3	1950	[redacted]	311,697,211,392
4	1951	[redacted]	314,305,511,424
5	1952	[redacted]	285,613,686,784
6	1953	[redacted]	298,655,416,320
7	1954	[redacted]	290,830,385,152
8	1955	[redacted]	353,430,700,032
9	1956	[redacted]	345,605,603,328
10	1957	[redacted]	324,738,908,160
11	1958	[redacted]	310,393,012,224
12	1959	[redacted]	356,039,000,064
13	1960	[redacted]	348,214,001,664
14	1961	[redacted]	352,961,986,560
15	1962	[redacted]	376,600,002,560
16	1963	[redacted]	403,875,004,416
17	1964	[redacted]	430,342,012,928
18	1965	[redacted]	470,649,012,224
19	1966	[redacted]	489,236,987,904
20	1967	[redacted]	484,388,012,032
21	1968	[redacted]	515,299,999,744
22	1969	[redacted]	524,693,995,520
23	1970	[redacted]	505,400,000,512
24	1971	[redacted]	534,595,010,560
25	1972	[redacted]	581,164,007,424
26	1973	[redacted]	617,329,000,448
27	1974	[redacted]	580,154,097,664
28	1975	[redacted]	517,925,994,496
29	1976	[redacted]	553,888,972,800
30	1977	[redacted]	616,722,989,056
31	1978	[redacted]	675,010,969,600
32	1979	[redacted]	691,173,982,208
33	1980	[redacted]	643,897,098,240
34	1981	[redacted]	642,987,982,848
35	1982	[redacted]	587,022,991,360
36	1983	[redacted]	638,543,003,648
37	1984	[redacted]	739,865,985,024
38	1985	[redacted]	790,965,977,088
39	1986	[redacted]	806,842,007,552
40	1987	[redacted]	829,873,979,392
41	1988	[redacted]	871,594,983,424
42	1989	[redacted]	894,728,994,816
43	1990	[redacted]	869,472,993,280
44			
45			

Calculation of marginal products for the US and variable Lilus

	A	F	G	H	I	J	K
1				[redacted]			
2	date	USAPOP	[redacted]	[redacted]	[redacted]	workforce	eff workfor
3	1950	152,262,400	[redacted]		1.00	6.75E+08	6.75E+08
4	1951	154,872,304	[redacted]		1.00	7.44E+08	7.44E+08
5	1952	157,542,096	[redacted]		1.00	8.61E+08	8.61E+08
6	1953	160,172,000	[redacted]		1.00	8.73E+08	8.73E+08
7	1954	163,021,904	[redacted]		1.00	8.96E+08	8.96E+08
8	1955	165,921,696	[redacted]		1.00	8.05E+08	8.05E+08
9	1956	168,891,600	[redacted]		1.00	8.52E+08	8.52E+08
10	1957	171,971,392	[redacted]		1.00	9.37E+08	9.37E+08
11	1958	174,871,296	[redacted]		1.00	9.86E+08	9.86E+08
12	1959	177,821,104	[redacted]		1.00	9.26E+08	9.26E+08
13	1960	180,671,008	[redacted]	10	1.00	9.85E+08	9.85E+08
14	1961	183,691,008	[redacted]	10	1.00	1.02E+09	1.02E+09
15	1962	186,538,000	[redacted]	10	1.00	1.02E+09	1.02E+09
16	1963	189,242,000	[redacted]	10	1.00	1E+09	1E+09
17	1964	191,888,992	[redacted]	10	1.00	1.01E+09	1.01E+09
18	1965	194,303,008	[redacted]	9	1.00	9.92E+08	9.92E+08
19	1966	196,560,000	[redacted]	9	1.00	1.01E+09	1.01E+09
20	1967	198,712,000	[redacted]	9	1.00	1.06E+09	1.06E+09
21	1968	200,706,000	[redacted]	9	1.00	1.05E+09	1.05E+09
22	1969	202,676,992	[redacted]	9	1.00	1.07E+09	1.07E+09
23	1970	205,052,000	[redacted]	9	1.00	1.12E+09	1.12E+09
24	1971	207,660,992	[redacted]	9	1.00	1.11E+09	1.11E+09
25	1972	209,896,000	[redacted]	9	1.00	1.08E+09	1.08E+09
26	1973	211,908,992	[redacted]	9	1.00	1.08E+09	1.08E+09
27	1974	213,854,000	[redacted]	9	1.00	1.15E+09	1.15E+09
28	1975	215,972,992	[redacted]	9	1.00	1.29E+09	1.29E+09
29	1976	218,035,008	[redacted]	10	1.00	1.27E+09	1.27E+09
30	1977	220,239,008	[redacted]	10	1.00	1.21E+09	1.21E+09
31	1978	222,584,992	[redacted]	10	1.00	1.17E+09	1.17E+09
32	1979	225,055,008	[redacted]	10	1.00	1.18E+09	1.18E+09
33	1980	227,756,992	[redacted]	10	1.00	1.28E+09	1.28E+09
34	1981	230,138,000	[redacted]	10	1.00	1.33E+09	1.33E+09
35	1982	232,520,000	[redacted]	10	1.00	1.43E+09	1.43E+09
36	1983	234,799,008	[redacted]	10	1.00	1.38E+09	1.38E+09
37	1984	237,000,992	[redacted]	10	1.00	1.29E+09	1.29E+09
38	1985	239,279,008	[redacted]	10	1.00	1.26E+09	1.26E+09
39	1986	241,624,992	[redacted]	10	1.00	1.29E+09	1.29E+09
40	1987	243,942,000	[redacted]	10	1.00	1.31E+09	1.31E+09
41	1988	246,307,008	[redacted]		1.00	1.32E+09	1.32E+09
42	1989	248,762,000	[redacted]		1.00	1.33E+09	1.33E+09
43	1990	249,975,008	[redacted]		1.00	1.39E+09	1.39E+09
44							
45							

Calculation of marginal products for the US and variable Lilus

	A	L	M	N	O
1		0.11			
2	date	L^.?	K^.(1.-?)	Y*	Y-Y*=
3	1950	9.358428	147909701272	1.38E+12	(2,999,232,072)
4	1951	9.459565	153694077172	1.45E+12	55,971,964,372
5	1952	9.612679	158220676143	1.52E+12	39,820,346,833
6	1953	9.627067	163004867275	1.57E+12	57,931,173,909
7	1954	9.655338	167310153738	1.62E+12	(16,521,089,619)
8	1955	9.542023	173592456215	1.66E+12	58,416,733,637
9	1956	9.601495	179328147437	1.72E+12	21,296,665,290
10	1957	9.702187	184098446700	1.79E+12	(17,595,576,139)
11	1958	9.757261	188173462914	1.84E+12	(85,874,476,844)
12	1959	9.690498	193630229548	1.88E+12	(21,574,340,061)
13	1960	9.75625	198585282322	1.94E+12	(38,823,663,367)
14	1961	9.788769	203488444939	1.99E+12	(40,894,337,638)
15	1962	9.791043	208979297304	2.05E+12	8,103,721,842
16	1963	9.776492	215150638550	2.1E+12	38,947,378,549
17	1964	9.784293	221940938958	2.17E+12	96,119,682,529
18	1965	9.763465	229779635860	2.24E+12	158,800,458,197
19	1966	9.787839	237890905653	2.33E+12	196,599,286,434
20	1967	9.834621	245485386115	2.41E+12	168,234,367,709
21	1968	9.822732	253766953073	2.49E+12	197,570,093,491
22	1969	9.844324	261994109580	2.58E+12	188,196,105,301
23	1970	9.896538	269231606844	2.66E+12	100,057,083,259
24	1971	9.884012	277108213328	2.74E+12	115,479,023,800
25	1972	9.858542	286155142724	2.82E+12	177,781,508,041
26	1973	9.853949	295975774894	2.92E+12	225,339,895,249
27	1974	9.923344	304169087997	3.02E+12	100,183,473,373
28	1975	10.0475	310010853673	3.11E+12	(28,192,685,274)
29	1976	10.03641	316758621929	3.18E+12	57,961,503,371
30	1977	9.977068	325227150442	3.24E+12	136,152,604,644
31	1978	9.944392	335186495551	3.33E+12	220,697,943,364
32	1979	9.951994	345225535283	3.44E+12	188,488,556,785
33	1980	10.04216	353335208838	3.55E+12	73,056,332,361
34	1981	10.08006	361070181839	3.64E+12	63,841,710,146
35	1982	10.16381	366716128809	3.73E+12	(119,344,749,302)
36	1983	10.12346	373744147099	3.78E+12	(35,156,888,168)
37	1984	10.04717	383647418712	3.85E+12	162,342,228,471
38	1985	10.02491	394718197471	3.96E+12	211,521,052,637
39	1986	10.04837	405803900050	4.08E+12	223,686,222,324
40	1987	10.06609	417124512338	4.2E+12	254,067,461,916
41	1988	10.07159	429243890249	4.32E+12	331,748,194,697
42	1989	10.08399	441550538537	4.45E+12	331,943,125,775
43	1990	10.13147	452550852391	4.59E+12	243,755,668,996
44					
45					

Calculation of marginal products for the US and variable Lilus

	A	P	Q	R	S	T
1						
2	date	%Y*/Y	Y	K^.(1.-a)	L^MPL	labl/labus
3	1950	100%	1,381,203,050,496	147909701272	9.34	1.00
4	1951	96%	1,509,851,004,928	153694077172	9.82	1.00
5	1952	97%	1,560,744,951,808	158220676143	9.86	1.00
6	1953	96%	1,627,189,936,128	163004867275	9.98	1.00
7	1954	101%	1,598,914,953,216	167310153738	9.56	1.00
8	1955	97%	1,714,840,010,752	173592456215	9.88	1.00
9	1956	99%	1,743,114,993,664	179328147437	9.72	1.00
10	1957	101%	1,768,561,967,104	184098446700	9.61	1.00
11	1958	105%	1,750,183,051,264	188173462914	9.30	1.00
12	1959	101%	1,854,798,954,496	193630229548	9.58	1.00
13	1960	102%	1,898,624,057,344	198585282322	9.56	1.00
14	1961	102%	1,951,006,982,144	203488444939	9.59	1.00
15	1962	100%	2,054,228,934,656	208979297304	9.83	1.00
16	1963	98%	2,142,365,941,760	215150638550	9.96	1.00
17	1964	96%	2,267,654,914,048	221940938958	10.22	1.00
18	1965	93%	2,402,245,935,104	229779635860	10.45	1.00
19	1966	92%	2,525,037,068,288	237890905653	10.61	1.00
20	1967	93%	2,582,490,120,192	245485386115	10.52	1.00
21	1968	93%	2,690,254,897,152	253766953073	10.60	1.00
22	1969	93%	2,767,350,923,264	261994109580	10.56	1.00
23	1970	96%	2,764,517,933,056	269231606844	10.27	1.00
24	1971	96%	2,854,419,955,712	277108213328	10.30	1.00
25	1972	94%	2,998,853,959,680	286155142724	10.48	1.00
26	1973	93%	3,141,870,026,752	295975774894	10.62	1.00
27	1974	97%	3,118,558,085,120	304169087997	10.25	1.00
28	1975	101%	3,086,641,004,544	310010853673	9.96	1.00
29	1976	98%	3,237,079,941,120	316758621929	10.22	1.00
30	1977	96%	3,380,966,064,128	325227150442	10.40	1.00
31	1978	94%	3,553,923,956,736	335186495551	10.60	1.00
32	1979	95%	3,624,170,946,560	345225535283	10.50	1.00
33	1980	98%	3,621,305,974,784	353335208838	10.25	1.00
34	1981	98%	3,703,450,894,336	361070181839	10.26	1.00
35	1982	103%	3,607,887,085,568	366716128809	9.84	1.00
36	1983	101%	3,748,427,988,992	373744147099	10.03	1.00
37	1984	96%	4,016,914,038,784	383647418712	10.47	1.00
38	1985	95%	4,168,533,934,080	394718197471	10.56	1.00
39	1986	95%	4,301,352,075,264	405803900050	10.60	1.00
40	1987	94%	4,452,879,171,584	417124512338	10.68	1.00
41	1988	93%	4,654,917,746,688	429243890249	10.84	1.00
42	1989	93%	4,784,535,896,064	441550538537	10.84	1.00
43	1990	95%	**4,828,760,113,152**	452550852391	10.67	1.00
44						
45						

Calculation of marginal products for the US and variable Lilus

	A	U	V	W
1				
2	date	d(L^MPL)/dt	d(labi\labus)	
3	1950	#VALUE!	#VALUE!	
4	1951	5.20%	0%	
5	1952	0.41%	0%	
6	1953	1.20%	0%	
7	1954	-4.27%	0%	
8	1955	3.37%	0%	
9	1956	-1.60%	0%	
10	1957	-1.17%	0%	
11	1958	-3.18%	0%	
12	1959	2.99%	0%	
13	1960	-0.19%	0%	
14	1961	0.28%	0%	
15	1962	2.52%	0%	
16	1963	1.30%	0%	
17	1964	2.61%	0%	
18	1965	2.32%	0%	
19	1966	1.53%	0%	
20	1967	-0.89%	0%	
21	1968	0.77%	0%	
22	1969	-0.36%	0%	
23	1970	-2.79%	0%	
24	1971	0.32%	0%	
25	1972	1.74%	0%	
26	1973	1.29%	0%	
27	1974	-3.42%	0%	
28	1975	-2.89%	0%	
29	1976	2.64%	0%	
30	1977	1.73%	0%	
31	1978	1.99%	0%	
32	1979	-0.99%	0%	
33	1980	-2.37%	0%	
34	1981	0.08%	0%	
35	1982	-4.08%	0%	
36	1983	1.94%	0%	
37	1984	4.40%	0%	
38	1985	0.86%	0%	
39	1986	0.37%	0%	
40	1987	0.71%	0%	
41	1988	1.59%	0%	
42	1989	-0.08%	0%	
43	1990	-1.53%	0%	
44				
45				

Calculation of marginal products for the US and variable Lilus

Cell: C1
Note: Depreciation rate of 5% is used.

Cell: B2
Note: Capital Stock measure from Nehru and Dhareschwar (1993)

Cell: C2
Note: Depreciated Capital Stock. (Straight line Method applied).

Cell: D2
Note: Income level from Nehru and Dhareschwar (1993).

Cell: E2
Note: Investment rate in levels from. Compare to alternatives from Penn World Tables.

Cell: F2
Note: Population measures from Nehru and Dhareshwar (1993). Alternative measures from Penn World Tables.

Cell: G2
Note: PARTICIPATION RATE IS THE RGDPL DIVIDED BY RGDPW. (see appendix A1).

note that both are in 1985 prices.

Cell: H2
Note: Mean years in education. Possible aid to calculating effective units of labour. Not used in the calculation of the Labour Residual but included to test the robustness of the marginal product estimates.

Cell: I2
Note: Educational effect, calculated by multiplying the times years in education times the return from one year in education. Cell Dependent on the Return set. If one implies that return is being ignored.

Cell: J2
Note: Labour force calculated by multiplying the population measure times the participation rate in the economy.

Cell: K2
Note: effective units of labour is 9% (estimates from Psacharopoulos (1985)) times the average year spent in education for that economy.

Cell: L2
Note: Labour force measure to the power of the marginal product of labour.

Cell: M2
Note: Capital stock measure to the power of (1-the MPL).
That is K^(1-MPL)
Where MPL is the marginal product of labour.

Cell: N2
Note: Estimated Income Level.

Calculation of marginal products for the US and variable Lilus

Y*= L^MPL*K^(1-MPL).

Cell: O2
Note: Residual Growth Calculated by subtracting the predicted Income level (Y*) from the actual Income level (GDP).

Cell: P2
Note: This is the difference between predicted Income and Actual income generated using an estimate of labour equal to the population of the countries in question.

Cell: S2
Note: Labour Residual calculated from dividing Income by capital stock to the power of its marginal product, in this case one minus the marginal product of labour.

Cell: T2
Note: Compares the ratio of the levels of growth attributable to the labour measure. In this case it would be one.

Cell: U2
Note: First Difference of the Relative Residual term in the text this is Lilus, that is labour residual in country i divided by the labour residual in the US.

Cell: O3
Note: Residual Growth Calculated by subtracting the predicted Income level (Y*) from the actual Income level (Y).

APPENDIX E

NBER PENN WORLD TABLES VARIABLE LIST

NBER: PENN WORLD TABLES VARIABLE LIST:

POP	=	Population in 000's
RGDPCH	=	R GDP/capita in constant $ (Chain Index) (1985IP)
RGDPL	=	R GDP per capita (Laspeyres index) (1985IP)
C	=	R Consumption share of GDP [%] (1985IP)
I	=	R Investment share of GDP [%] (1985IP)
G	=	R Government share of GDP [%] (1985IP)
RGDPTT	=	R GDP/capita in constant $ adj. for terms of trade
Y	=	"CGDP relative to US [%] (US=100, CurrentIP)"
CGDP	=	R GDP per capita (CurrentIP)
CC	=	R Consumption share of GDP [%] (CurrentIP)
CI	=	R Investment share of GDP [%] (CurrentIP)
CG	=	R Government share of GDP [%] (CurrentIP)
P	=	Price level GDP [%] (PPP GDP/ $US exchange rate)
PC	=	Price level Consumption [%] ([PPP of C]/XR)
PI1	=	Price level Investment [%] ([PPP of I]/XR)
PG	=	Price level Government [%] ([PPP of G]/XR)
XR	=	Exchange Rate with U.S. dollar
RGDPEA	=	R GDP per Equivalent Adult (1985IP)
RGDPW	=	R GDP per Worker (1985 intl. prices)
KAPW	=	Non-residential Capital Stock per Worker (1985IP)
KDUR	=	Producer Durables (% of KAPW) (1985IP)
KNRES	=	Nonresidential construction (% of KAPW) (1985IP)
KOTHER	=	Other Construction (% of KAPW) (1985IP)
KRES	=	Residential construction (% of KAPW) (1985IP)
KTRANP	=	Transportation Equipment (% of KAPW) (1985IP)
OPEN	=	Openness (Exports+Imports)/Nominal GDP
RGNP	=	R Gross National Product (% of CGDP)
IPRI	=	Gross Domestic Private Investment (% GDI CurrentIP)
STLIV	=	Standard of Living Index (see text)

APPENDIX F

NEHRU'S ESTIMATION OF LABOUR STOCKS

Appendix F: Calculation of Labour Stock.

Nehru, Swanson and Dubey (1993) approach the stock measurement in the following manner. S_{gt} is the addition to the education stock as a result of one year of education in grade g in year t, then the cumulative investment in education that takes place in grades G = [g_1, g_2] between the years T = [t_1, t_2] is

$$H_{GT} = \sum_{G}\sum_{T} S_{gt} \qquad [4.4.1]$$

Where the summation operators act over the range of index sets G and T.

The human capital stock skill level is the product of the sum of time in education and the grades achieved, that is primary, secondary or tertiary. To obtain the net value of human capital stock, the paper sums the oldest members of the labour force, T-64+6, (where 6 is assumed to be the average beginning age for education), and the youngest is T-15+6.

The depreciation rate is determined by the mortality rate of the labour force. If we concentrate on only the primary school section, then:

$$\hat{E}_{PT} = \sum_{T-58}^{T-9}\sum_{g=1}^{6} \theta^{T}_{g,T-g-1} E^{*}_{g,T-g-1} \qquad [4.4.2]$$

Where θ is the proxy for the survival rate. Nehru, Swanson and Dubey (1993) assume that age is closely related to the grade achieved. E_g* is designed to capture this. It is possible to complicate [4.4.2] further by including the drop out rates (d). Expanding net enrolments E*, which is regarded as a function of the gross enrolment level, the retention rate (r), and the drop out rate, Nehru, Swanson and Dubey (1993) arrive at

$$\hat{E}_{PT} = \sum_{T-58}^{T-9}\sum_{g=1}^{6}\theta_{g,T-g-1}(1-r_{g,T-g-1})E_{g,T-g-1}(1-d_{g,T-g-1}), \quad [4.4.3]$$

It is assumed that $r_t = r$ for all t, and $d_{g,t} = d$, this becomes

$$\hat{E}_{PT} = \sum_{T-58}^{T-9}\sum_{g=1}^{6}\theta_{g,T-g-1}(1-r)E_{g,T-g-1}(1-d), \quad [4.4.4]$$

This is the equation used to calculate the estimate of the primary education stock. The same approach is used to calculate stocks for secondary and tertiary education levels.

BIBLIOGRAPHY

Abauf, A. and P. Jorion, 1990. 'Purchasing Power Parity in the Long Run', Journal of Finance, Vol. 45, (Mar) pp. 157-174.

Abramovitz, M. 1986. 'Catching-Up, Forging Ahead, and Falling Behind', Journal of Economic History, Vol. 46, (Jun) pp. 385-406.

Amable, B. 1993. 'Catch-Up and Convergence: A Model of Cumulative Growth', International Review of Applied Economics, Vol. 7, (1) pp. 1-25.

Amano, Robert A. and Simon van Norden, 1995. 'Terms of Trade and Real Exchange Rates: the Canadian Evidence', Journal of International Money and Finance, Vol. 14, (1) pp. 83-104.

Arize, Augustine C. 1994. 'Cointegration of a Long Run Relation Between The Real Effective Exchange Rate and the Trade Balance', International Economic Journal, Vol. 8, (3) pp. 1-9.

Asea, Patrick K. and Enrique G. Mendoza, 1994. 'The Balassa-Samuelson Model: A General Equilibrium Appraisal', Review of International Economics, Vol. 2, (Oct) pp. 244-267.

Bahmani-Oskooee, Mohsen, 1992. 'A Time Series Approach to Test the Productivity Bias Hypothesis in Purchasing Power Parity', Kyklos, Vol. 45, (2) pp. 227-236.

Baille, R. and D. Selover, 1987. 'Cointegration and Models of Exchange Rate Determination', International Journal of Forecasting, Vol.3, pp. 43-51.

Balassa, Bela, 1964. 'The Purchasing Power Parity Doctrine: A Reappraisal', Journal of the Political Economy, Vol. 72, (Dec) pp. 584-596.

Barro, Robert J. and Jong-Wha Lee, 1994. 'How Do National Policies Affect Long-Run Growth', International Comparisons of Educational Attainment Conference. World Bank: Washington D.C.

Barro, Robert J., N. G. Mankiw and. Sali-Martin, 1995. 'Capital Mobility in Neo-classical Models of Growth', American Economic Review. Vol. 85, (1) pp. 103-115.

Baumol, William, 1986. 'Productivity Growth, Convergence and Welfare', American Economic Review, Vol.76, pp. 1072-85.

Baxter, M. and M. J. Crucini, 1993. 'Explaining Savings-Investment Correlation's', American Economic Review, Vol.83, (Jun).

Bernanke, B. S. 1982. 'On Sources of Labour Productivity Variation in the US Manufacturing, 1947-1980', Review of Economics and Statistics. Vol. 62, (2) pp. 214-224.

Bernard, Andrew B. and Charles I. Jones, 1996. 'Productivity Across Industries and Countries: Time Series Theory and Evidence', The Review of Economics and Statistics, Vol. 77, (1) pp 135-46.

Blundell-Wignall A. and R. G. Gregory, 1990. 'Exchange Rate Policy in Advanced Commodity Exporting Countries: The Case of Australia and New Zealand', OECD Economics and Statistics Department, Working Paper No. 83.

Brander, James and Steve Dorwick, 1990. 'The Role of Fertility and Population in Economic Growth: New Results for Aggregate Cross-National Data', Centre For Economic Policy - Australia National University Canberra, Discussion Paper No. 232.

Brezis, E. S., Paul R. Krugman and D. Tsiddon, 1993. 'Leapfrogging in International Competition: A Theory of Cycles on National Technological Leadership', American Economic Review, Vol. 83, (5) pp. 1211-1219.

Bruno, Michael and William Easterly, 1995. 'Inflation Crises and Long-Run Growth', World Bank Policy Research Department, June.

Buiter, Willem H. and Kenneth M. Kletzer, 1992. 'Permanent International Productivity Growth Differentials in an Integrated Global Economy', Yale Economic Growth Centre, Discussion Paper No. 664.

Chan, Luke and Dean Mountain, 1983. 'Economies of Scale and the Tornqvist Discrete Measure of Productivity Growth', The Review of Economics and Statistics, Vol. 65, (4) pp. 663-667.

Chen, Baizhu and Kien C. Tran, 1994. 'Are We Sure that the Real Exchange Rate Follows a Random Walk? A Re-examination', International Economic Journal, Vol.8, (3) pp. 33-44.

Chenery, H., S. Robinson and M. Syrquin, 1986. Industrialisation and Growth - A Comparative Study, World Bank Publication, Oxford University Press, New York

Christiano, L. J. and M. Eichenbaum, 1989. 'Unit Roots in Real GNP: Do We Know, and Do We Care?', Federal Reserve Bank of Minneapolis, Working Paper No. 18.

Cochrane, J. H. 1988. 'How Big is the Random Walk in GNP?', Journal of the Political Economy, Vol.96, (5) pp. 893-920.

Corbae, D. and S. Oularis, 1988. 'Cointegration and Tests of Purchasing Power Parity', The Review of Economics and Statistics, Vol. 70, (3) pp. 508-511.

Cohen, Benjamin J. 1995, 'A Brief History of International Monetary Relations', in: Jeffry A. Frieden and David A. Lake (eds.) International Political Economy, Third Edition, Routledge, London.

Cumby, Robert C. and John Huizinga, 1991. 'The Predictability of Real Exchange Rate Changes in the Short and Long Run', Japan and the World Economy, Vol.3, pp. 17-38.

Davutyan, N. and J. Pippenger, 1985. 'Purchasing Power Parity Did Not Collapse During the 1970s', American Economic Review, Vol. 75, (Dec) pp. 1151-58.

Denison, E. F. 1967. Why Growth Rates Differ?, Brookings Institute, Washington.

Denison, Edward and William K. Chung, 1976. How Japans Economy Grew so Fast: The Sources of Post-War Expansion, Brookings Institute, Washington.

Denison, E. F. 1979. Accounting for Slower Economic Growth-The US in the 1970s, Brookings Institute, Washington.

Dickey, D. A. and W. A. Fuller, 1979. 'Distribution of the Estimators for Autoregressive Time-Series with a Unit Root', Journal of the American Statistical Association, Vol. 74, pp. 427-431.

Dickey, D. A. and W.A. Fuller, 1981. 'Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root', Econometrica, Vol. 49, (4) pp. 1057-1072.

Diebold, F., S. Husted and M. Rush, 1990. 'Real Exchange Rates Under the Gold Standard', Federal Reserve Bank of Minneapolis, Working Paper No. 32.

Dollar, David, 1993. 'Technological Differences as a Source of Comparative Advantage', American Economic Review, Vol. 83, (2) pp. 431-444.

Dosi, Giovanni and Silvia Fabiani, 1994. 'Convergence and Divergence in the Long Term Growth of Open Economies' in: G. Silverberg and L. Soete (eds.) The Economics of Growth and Technical Change, Elgar Publishing, Hants.

Dowrick, Steve and Duc-Tho Nguyen, 1989. 'OECD Comparative Economic Growth 1950-85: Catch-up and Convergence', American Economic Review, Vol. 79, (Dec) pp. 1010-1030.

Dowrick, Steve, 1992. 'Technological Catch-up and Diverging Economies: Patterns of Economic Growth, 1960-88', Economic Journal, Vol.102, pp. 600-610.

Eatwell, J., M. Milgate, P. Newman, and R. Palgrave, 1987. The New Palgrave: A Dictionary of Economics. Stockton Press, London.

Econometrics Toolkit, 1992. Version 3.0, Econometric Software Inc.

Enders, Walter, 1988. 'ARIMA and Cointegration of PPP Under Fixed and Flexible Exchange Rate Regimes', The Review of Economics and Statistics, Vol. 70, (3) pp. 504-508.

Engle, R. F. and C. W. J. Granger, 1987. 'Cointegration and Error Correction: Representation, Estimation and Testing', Econometrica, Vol.55, (2) pp. 251-276.

Engle, R. F. and B. S. Yoo, 1987. 'Forecasting and Testing in Cointegrated Systems', Journal of Econometrics, Vol.35, (1) pp. 143-159.

Fagerberg, J. 1994. 'Technology and International Differences in Growth Rates', Journal of Economic Literature, Vol. 32, (3) pp. 1114-1145.

Faruqee, Hamid 1995. 'Long Run Determinants of the Real Exchange Rate: A Stock-Flow Perspective.' International Monetary Fund Staff Papers. Vol. 42 No. 1 pp. 80-106.

Feldstein, Martin S. 1994. 'The Adam Smith Address: Competing in the World Economy: Trade Competition vs. Growth Competition', Business Economics, Vol. 29, (1) pp. 7-12.

Fischer, Stan, 1993. 'The Role of Macroeconomic Factors in Growth'. Journal of Monetary Economics, Vol.32, (3) pp. 485-512.

Flaig, G. and V. Steiner, 1993. 'Searching for the Productivity Slowdown: Some Surprising Findings from West German Manufacturing', The Review of Economics and Statistics, Vol. 75, (1) pp. 57-65.

Foster, Andrew D. and Mark R. Rosenweig, 1996. 'Technical Change and Human Capital Returns and Investments: Evidence from the Green Revolution', American Economic Review, Vol. 86, (4) pp. 931-953.

Freeman, C. 1984. Long Waves in the World Economy, Frances Pinter Publishers, London.

Gemmell, Norman, 1996. 'Evaluating the Impacts of Human Capital Stocks and Accumulation on Economic Growth: Some New Evidence', Oxford Bulletin of Economics and Statistics, Vol. 58, (1) pp. 9-28.

Gerschenkron, A. 1962. Economic Backwardness in Historical Perspective, Harvard University Press, Cambridge MA.

Granger, C. W. J. 1986. 'Developments in the Study of Cointegrated Economic Variables', Oxford Bulletin of Economics and Statistics, Vol. 48, (3) pp. 213-228.

Grier, K. and G. Tullock, 1989. 'An Empirical Analysis of Cross National Economic Growth 1951-80', Journal of Monetary Economics, Vol. 24, (2) pp. 259-276.

Grilli, Vittorio and Graciela Kaminsky, 1991. 'Nominal Exchange Rate Regimes and the Real Exchange Rate: Evidence from the United States and Great Britain, 1885-1986', Journal of Monetary Economics, Vol. 27, (2) pp. 191-212.

Grossman, Gene M. and Elhanan Helpman, 1990. 'Trade, Innovation and Growth', American Economic Review, Vol. 80, (May), pp. 86-91.

Gruen, David and Jenny Wilkinson, 1991. 'Australia's Real Exchange Rate: Is it Explained by the Terms of Trade or by Real Interest Differentials?', Reserve Bank of Australia, Research Discussion Paper 91/08.

Hakkio, C. 1986. 'Does the Exchange Rate Follow a Random Walk? A Monte Carlo Study of Four Tests for a Random Walk', Journal of International Money and Finance, Vol. 5, (2) pp. 221-229.

Hakkio, C. and M. Rush, 1991. 'Cointegration: How Short is the Long Run?', Journal of International Money and Finance, Vol.10, (4) pp. 571-581.

Hooper, P. and K. A. Larin, 1989. 'International Comparisons of Labour Costs in Manufacturing', Review of Income and Wealth, Vol. 35, (4) pp. 335-355.

Hooper, Peter and Morton, John, 1982. 'Fluctuations in the Dollar:A Model of Nominal and Real Exchange Determination.' Journal of International Money and Finance, Vol. 1 pp. 39-56.

Hsieh, David A. 1982. 'The Determination of the Real Exchange Rate -the Productivity Approach', Journal of International Economics, Vol.12, pp. 355-362.

Isaak, Robert A. 1991, International Political Economy: Managing World Economic Change, Prentice Hall, London.

Johnasen, S. 1988. 'Statistical Analysis of Cointegrating Vectors', Journal of Dynamics and Control, Vol. 12, pp. 231-254.

Johansen, S. 1989. 'Likelihood Based Inference on Cointegration: Theory and Application', Seminario Estivo de Econometricia, Centro Studi Sorelle, Bagni di Lucca, Italy.

Johansen, S. and K. Juselius, 1990. 'Some Structural Hypothesis in a Multivariate Cointegration Analysis of the Purchasing Power Parity and the Uncovered Interest Parity for the UK, Institute of Mathemathical Statistics, Unpublished Preprint.

Johnson, D. R. 1993. 'Unit Root, Cointegration, and Purchasing Power Parity: Canada and United States 1870-1991', The Exchange Rate and the Economy: Bank of Canada, Ottawa, Discussion Paper.

Jorgenson, D. W. and M. Kuroda, 1992. 'Productivity and International Competitiveness in Japan and the United States, 1960-1985', The Economic Studies Quarterly, Vol. 43, (4) pp. 313-325.

Kendrick, J. W. 1961, Productivity Trends in the U.S., NBER, Princeton University Press, New York.

Kendrick, J. W. 1991. Total Factor Productivity in Technology and Productivity: The Challenge of Economic Policy. OECD Report.

Kennedy, Peter, 1992. A Guide to Econometrics. 3rd.ed., Blackwell, Oxford.

Kim, Jin-Ock and Walter Enders, 1991. 'Real and Monetary Causes of Real Exchange Rate Movements in the Pacific Rim', Southern Economic Journal, Vol. 57, (4) pp. 1061-1071.

Kim, Yoonbai, 1990. 'Purchasing Power Parity in the Long Run: A Cointegration Approach', Journal of Money, Credit and Banking, Vol. 22, (4) pp. 491-50.

King, R. G. and R. Levine, 1994. 'Capital Fundamentalism, Economic Development, and Economic Growth', Carnegie-Rochester Conference Series on Public Policy, Vol. 40, North Holland, Amsterdam.

King, R. G. and S. T. Rebelo, 1993. 'Transitional Dynamics and Economic Growth in the Neo-classical Model', American Economic Review, Vol. 83, (Sept) pp. 908-931.

Kormendi, R. C. and P. G. Mequire, 1985. 'Macro-Economic Determinants of Growth: Cross-Country Evidence', Journal of Monetary Economics, Vol. 16, pp. 141-163.

Krugman, Paul, 1994. 'Competitiveness does it matter?', Fortune, Vol. 129, (5) pp 109-112.

Kwiatowski, D., P. Phillips, P. Schmidt and Y. Shin, 1992. 'Testing the Null Hypothesis of Stationarity against the Alternative of a Unit', Journal of Econometrics, Vol. 54, (Oct-Dec) pp. 159-178.

LaFrance, Robert and Simon Van Norden, 1995. 'Exchange Rate Fundamentals and the Canadian Dollar', Bank of Canada Review, Spring, pp. 17-33.

Lastrapes, William D. 1992. 'Sources of Fluctuations in Real and Nominal Exchange Rates', The Review of Economics and Statistics, Vol. 74, (Aug) pp. 530-539.

Lawrence, Robert Z. 1995. 'US Wage Trends in the 1980's: The Role of International Factors', Federal Reserve Bank of New York Policy Review, January pp. 18-25.

Levine, R. and D. Renelt, 1992. 'A Sensitivity Analysis of Cross Country Growth Regressions', American Economic Review, Vol. 82, (4) pp. 942-963.

Lichtenberg, Frank R. 1994. 'Testing the Convergence Hypothesis', The Review of Economics and Statistics, Vol. 76, (3) pp. 576-579.

Lim, G. C. 1992. 'Testing for the Fundamental Determinants of the Long Run Real Exchange Rate', Journal of Banking and Finance, Vol. 16, (3) pp. 625-642.

Lippert, Alston, F. Boucher and Janice Breuer, 1994. 'Purchasing Power Parity and Real Factors', Applied Economics, Vol. 26, (11) pp. 1029-1036.

Lipsey, Robert E. and Irving B. Kravis, 1988. 'Is the U. S. Losing the Economic Race?', U. S. Economic Long-Term Outlook, The Conference Board, New York.

Lucas, Robert E. 1988. 'On the Mechanics of Economic Development', Journal of Monetary Economics, Vol. 22, (July) pp. 3-42.

Lucas, Robert E. 1990. 'Why Does Not Capital Flow From Rich to Poor Countries', American Economic Review, Vol. 80, (May) pp. 92-96.

MacDonald, R. 1996. 'Panel Unit Root Tests and Real Exchange Rates', Economic Letters, Vol. 50, (Jan) pp. 7-11.

MacKinnon, J.G. 1990. 'Critical Values for Cointegration Tests', UC San Siego Discussion Paper, pp. 90-94.

MacKinnon, J. G. 1991. 'Critical Values for Cointegration Tests', in: R. F. Engel and C. W. Granger (ed's), Readings in Cointegration, Oxford University Press, Oxford.

Maddala, G. S. 1992. Introduction to Econometrics, 2nd Edition, MacMillian, New York.

Mankiw, Gregory N., D. Romer and David Weil, 1992. 'A Contribution to the Empirics of Economic Growth', Quarterly Journal of Economics, Vol. 107, (May) pp. 407-437.

Marston, Richard, 1989. 'Real Exchange Rates and Productivity Growth in the United States and Japan', National Bureau of Economic Research, Working Paper No. 1922.

Marston, Richard, 1990. 'Systematic Movements in Real Exchange Rates in the G-5: Evidence on the Integration of Internal and External Markets', National Bureau of Economic Research, Working Paper No. 3332.

Meese, R. and K. Rogoff, 1983. Exchange Rates and International Econometrics, University Press, Chicago.

Meese, R. and K. Rogoff, 1988. 'Was it Real? The Exchange Rate-Interest Differential Relation over the Modern Floating Period', Journal of Finance, Vol.43, (4) pp. 933-948.

Microfit, 1991. Version 3.0, Oxford University Press.

Morrison, C. J. 1992. 'Unravelling the Productivity Growth Slowdown in the United States, Canada and Japan', The Review of Economics and Statistics, Vol. 74, (3) pp. 381-93.

Mullen, John K. and Martin Williams, 1994. 'Convergence, Scale and the Relative Productivity Performance of Canadian-US Manufacturing Industries', Applied Economics, Vol. 26, (7) pp. 739-741.

Mussa, Michael, 1986. 'Nominal Exchange Rate Regimes and the Behaviour of Real Exchange Rates: Evidence and Implications', Carnegie-Rochester Conference Series on Public Policy, Vol. 25, North Holland, Amsterdam.

Neary, Peter, 1988. 'Determinants of the Equilibrium Real Exchange Rate', American Economic Review, Vol. 78, (Mar) pp. 210-215.

Nehru, V. and A. Dhareschwar, 1993. 'A New Database on Physical Capital: Sources, Methodology, and Results', Rivista de Analisis Economico, Vol. 8, (1) pp. 37-59.

Nehru, V., E. Swanson and A. Dubey, 1993. 'A New Database on Human Capital Stock: Sources, Methodology and Results', The World Bank, Working Paper No. 1124.

Nelson, C. R. and C. I. Plosser, 1982. 'Trends and Random Walks in Macroeconomic Time Series', Journal of Monetary Economics, Vol. 10, (Sept) pp. 139-162.

Nishimizu, Mieko and John M. Page Jr. 1986. 'Productivity Change and Dynamic Comparative Advantage', The Review of Economics and Statistics, Vol. 77, (2) pp. 241-247.

Ohkawa, Kazushi, 1993. Growth Mechanism of Developing Economies-Investment, Productivity, and Employment, International Centre for Economic Growth, Panama.

Ostry, Jonathan D. 1989. 'The Balance of Trade, Terms of Trade, and Real Exchange Rate: An Intertemporal Optimising Framework', International Monetary Fund - Staff Papers, Vol. 35, (4) pp. 541-573.

Parente, Stephen L. and Edward C. Prescott, 1994. 'Barriers to Technology Adoption and Development', Journal of Political Economy, Vol. 102, (2) pp. 298-321.

Park, S. R. and J. K. Kwon, 1995. 'Rapid Economic Growth with Increasing Returns to Scale and Little or no Productivity Growth', The Review of Economics and Statistics, Vol. 77, (2) pp. 332-351.

Pearce D. W. 1983. Dictionary of Modern Economics. MIT Press.

Perron, P. 1988. 'Trends and Random Walks in Macroeconomic Time Series: Further Evidence From a New Approach', Journal of Economic Dynamics and Control, Vol. 12, (2/3), pp. 297-332.

Phillips, P. 1987. 'Time Series Regression with a Unit Root', Econometrica, Vol.55, (2) pp. 277-301.

Phillips, P. and Pierre Perron, 1986. 'Testing For a Unit Root in Time Series Regression', Cowels Foundation, Discussion Paper No. 795.

Phillips, P. and P. Perron, 1988. 'Testing for unit root in Time Series Regression', Biometrika, Vol. 75, (Jun) pp. 335-346.

Psacharopoulos, George, 1985. 'Returns to Education: A Further International Update and Implications', Journal of Human Resources, Vol. 20, (4) pp. 583-604.

Rogers, John H. and Michael Jenkins, 1995. 'Haircuts or Hysteresis? Sources of Movements in Real Exchange Rates', Journal of International Economics, Vol. 38, (May), pp. 339-360.

Romer, Christina D. 1986. 'The Pre-war Business Cycle Reconsidered: New Estimates of Gross National Product, 1869-1918', National Bureau of Economic Research Working Paper No.1969.

Romer, Paul M. 1986. 'Increasing Returns and Long Run Growth', Journal of the Political Economy, Vol. 94, (Oct) pp. 1002-1037.

Romer, Paul M. 1987. 'Crazy Explanations for the Productivity Slowdown', in: S. Fisher's (editor) National Bureau of Economic Research Macroeconomic Annual, MIT Press, Cambridge MA.

Romer, Paul M. 1990. 'Are Nonconvexities Important For Understanding Growth?', American Economic Review, Vol. 80, (May) pp. 97-103.

Scarfe, B. L. 1977. Cycles, Growth, and Inflation: A Survey of Contemporary Macrodynamics, McGraw-Hill, New York.

Silverberg G. and L. Soete, 1994. (eds.) The Economics of Growth and Technical Change, Elgar Publishing, Hants.

Solow Robert, 1956. 'A Contribution to the Theory of Economic Growth' Quarterly Journal of Econoomics, LXX, pp. 65-94.

Solow, R. 1957. 'Technical Change and the Aggregate Production Function', Review of Economics and Statistics, Vol. 39, pp. 312-329.

Stein, Jerome L. 1990. 'The Real Exchange Rate', Journal of Banking and Finance, Vol.14, (5) pp. 1045-1078.

Stockman, A. C. 1980. 'A Theory of Exchange Rate Determination', Journal of Political Economy, Vol. 88, (Aug) pp. 673-698.

Stockman, A. C. 1987. 'The Equilibrium Approach to Exchange Rates', Economic Review: Federal Reserve Bank of Richmond, Vol. 73, (2) pp. 12-30.

Strauss, Jack, 1995. 'Real Exchange Rates, PPP and the Relative Price of Non-traded Goods', Southern Economic Journal, Vol. 61, (Apr) pp. 991-1005.

Stulz, Rene M. 1988. 'Capital Mobility and the Current Accounts', Journal of International Money and Finance, Vol. 7, (2) pp. 167-180.

Summers, Robert and Alan Heston, 1984. 'Improved International Comparisons of Real Product and its Composition: 1950-1980', Review of Income and Wealth, Vol. 30, pp 207-262.

Summers, Robert and Alan Heston, 1988. 'A New Set of International Comparisons of Real Product and Price Levels', Review of Income and Wealth, Vol. 34, pp. 1-25.

Summers, Robert and Alan Heston, 1991. "The Penn World Table (mark 5): An expanded set of International Comparisons 1950-88', Quarterly Journal of Economics, Vol. 106, (2) pp 327-368.

Taylor, Mark P. 1990. 'On Unit Roots and Real Exchange Rates: Empirical Evidence and Monte Carlo Analysis', Applied Economics, Vol. 22, (10) pp. 1311-1321.

Tinbergen, J. 1959. 'On the Theory of Trend Movements', In: L.H. Klassen, L.M. Koyck, and H.J. Witteveen (eds), J. Tinbergen Selected Essays, North Holland, Amsterdam.

Turnovsky, S. J. 1991. 'The Impact of the Terms of Trade Shocks on a Small Open Economy: A Stochastic Analysis', National Bureau of Economic Research, Working Paper No. 3916.

Verspagen, B. 1991. 'A New Empirical Approach to Catching Up or Falling Behind', Structural Change and Economic Dynamics, Vol. 2, pp 359-380.

Verspagen, B. 1994. 'Technology and Growth', in: G. Silverberg and L. Soete (eds.) The Economics of Growth and Technical Change, Elgar Publishing, Hants.

Whitt, J. 1992. 'The Long Run Behaviour of the Real Exchange Rate: A Reconsideration', Journal of Money, Credit, and Banking, Vol. 24, (1) pp. 72-82.

Williamson, J. G. 1991. 'Productivity and American Leadership: A Review Article', The Journal of Economic Literature, Vol. 29, (Mar) pp. 51-49.

Wolff, Edward N. 1991. 'Capital Formation and Productivity Convergence over the Long Term', American Economic Review, Vol. 81, (3) pp. 565-579.

Wolff, Edward N. 1994. 'Productivity Growth and Capital Intensity on the Sector and Industry Level, in: G. Silverberg and L. Soete (eds.), The Economics of Growth and Technical Change. Elgar Publishing, Hants.

Young, Alwyn, 1994. 'The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Experience', National Bureau of Economic Research, Working Paper 4680.

Zhou, Su, 1995. 'The Response of the Real Exchange Rate to Various Economic Shocks', Southern Economic Journal, Vol.61, (4) pp. 936-954.