Essays on International Trade and Economic Growth

By

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In compliance with the rules of Degree of Doctor of Philosophy of the Australian National University it is affirmed that, unless otherwise stated, the work that follows is my own.

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THESIS ABSTRACT

The fact that the rate of economic growth varies considerably between countries and that some countries, the East Asian NICs in particular, have experienced sustained growth over prolonged periods of time raises questions on the efficacy of growth predictions from the neoclassical model. Furthermore, the observation that there is significant correlation between policy stance and the rate of economic growth in cross-country growth regressions raises serious questions on the role of economic policy in growth. The first of the above is a theoretical issue while the latter is an empirical one but the two are inextricably linked. This thesis attempts to thread the two issues together so as to gain further insights into the role of policy in economic growth. The accommodation of a strictly positive long-run rate of growth within a theoretical framework has created an expanding literature on endogenous growth. The role of policy in growth has also generated an expanding volume of empirical research.

The first part of the thesis is devoted to theory where the neoclassical model is augmented with human capital to generate sustained growth. Markets for labour and physical capital are assumed to be competitive while human capital accumulates via an externality as learning-by-doing. The production function is therefore constant-returns-to-scale in physical capital and labour but increasing-returns-to-scale when human capital is included as an additional factor of production. Policy has a role in this framework given the existence of an externality. The second part of the thesis is devoted to empirics where we confront the theoretical constructs from the earlier section with data. We find support for hypotheses that rely on human capital explanations for observed productivity growth. The <u>thesis</u> is that policy has a role in growth.

CONTENTS

Chapter 1

INTRODUCTION

The traditional neoclassical prescription of laissez-faire in international trade has in the last decade faced two serious challenges.[1] The first is the recognition of imperfect competition which gives rise to the possibility of rent shifting between countries through pursuance of interventionist trade policies (Brander and Spencer 1984, Dixit 1988). An extensive survey of this literature is contained in the edited volume of Grossman (1992). The second challenge to the dominance of free trade ideas is the notion of the dynamics of comparative advantage based on the concept of human capital accumulation, either through explicit utility-maximising investment in skill acquisition or via an externality as learning-by-doing. The main proponents of the former are Lucas (1988), Romer (1990) and Grossman and Helpman (1991) and of the latter are Arrow (1962), Spence (1981) and Lucas (1988 and 1993). It is true that these two approaches are intimately related in that learning is a form of technology that has economies-of-scale advantages that accrue over time and with larger production runs. The implications of this aspect of technology for the analysis of trade and (endogenous) growth, the subject of this thesis, can not be over-emphasised.

Economists have long been aware of the importance of human capital accumulation as a factor responsible for endogenous technological change. Arrow (1962) and Uzawa (1965) were among the first to document the economic implications of this 'new' form of technology on production. Recent work on endogenous growth and the role of trade has rejuvenated

[1] Mussa (1993) and Falvey (1995) espouse the view that free trade is still the pragmatic policy option given the information constraint faced by policy makers.

interest in the subject. Lucas (1988) was among the first of this latter generation of economists to have looked at the issue in detail at a theoretical level. Model-based empirical work on the subject is scarce, the case study of the 16K RAM industry by Baldwin and Krugman (1988) being one of the first.

In a series of separate essays, this thesis explores the role of human capital accumulation, including learning by doing (LBD), research and development (R&D), and increases in use of specialised inputs in production, on growth of output under different trade regimes. Chapter 2 of the thesis is a literature review on the role of trade in growth. Chapters 3 to 7 constitute the substantive part of the thesis, each being an <u>independent essay</u> on a particular issue within the broad area of trade and growth. These essays separate naturally into two distinct but related groups, the first theoretical (Chapters 3 and 4) the second empirical (Chapters 5 to 7). Heeding the advice of Leamer (1992) that empirical testing should be based on an appropriate theoretical model, the essays in the latter part of the thesis draw on some of the theory in the earlier original chapters as well as the existing theory of trade and growth as surveyed in Chapter 2.

The main findings of this thesis can be summarised as follows: Chapter 3 develops a Ricardo-Viner generalisation of the Lucas (1988) 2-country growth model and generalises the Lucas result. It is shown that growth can be enhanced for a small country by consciously shifting resources to a "modern" or "high-tech" sector, but this finding is subject to a number of qualifications for large economies. Chapter 4 employs a North-South framework to show that technology diffusion is a strong determinant of wages in the South relative to that in the North. This chapter also analyses the impact of trade policy on technology diffusion and welfare in the two regions individually and collectively. One of the lessons from this chapter is that policy distortions can be more detrimental to welfare in the presence of diffusion than in the absence of diffusion. The first of the empirical chapters (Chapter 5) undertakes a cross-country study of the sources of TFP growth within the manufacturing sectors of twelve OECD countries. The empirics in this chapter employ panel data to provide support for hypotheses that rely on human capital accumulation as a source of TFP growth. Chapter 6 uses panel data from Australian manufacturing sectors dissaggregated at 3-digit ISIC to demonstrate that trade liberalization within the sector has had a significant positive impact on TFP growth. Chapter 7 deviates from the previous four chapters in that it considers the role of institutions in growth and particularly in the setting of two small developing economies. The paired case study of the growth experiences of Fiji and Mauritius in their post-independence era shows that pushing resources towards the manufacturing sector (the modern sector) is highly correlated with higher TFP growth. Again policy is shown to be responsible for the observed pattern of sectoral resource allocation. Chapter 8 presents the conclusions.

Chapter 2

Trade and Growth: A Survey

2.1 Introduction

Two "important" trends in the world economy, as noted by Grossman and Helpman (1991), are an increasing importance of technological innovations and an increasing interdependence between the economies in the world. These two phenomena, which are inter-related, are argued to have grown in importance over time (Romer 1990, 1993) and therefore are of considerable interest to policy makers and academic economists interested in the link between policy and economic growth (Rodrik 1990). This chapter offers a succinct review of the current state of research in the general area of trade and growth. The issues of trade and growth, both at the theoretical and empirical levels, constitute books in their own right.[1] This chapter-length review is brief and narrowed down to include areas of direct relevance to the analysis that follows in the subsequent chapters. Directions for sources of further references are provided via pointers to the bibliography.

The rest of the chapter is organised as follows. Section 2 looks at traditional models of growth. This section demonstrates that the neoclassical model does not admit a role for policy in long-run growth. Section 3 introduces some of the empirical research on the linkages between trade and growth. This section demonstrates the inability of the neoclassical model to explain the observed divergences in growth experiences of countries across the globe. Section 4 surveys the "new" growth theory and discusses the need for such theory in the context of explaining the linkages between trade and growth. Section 5 discusses the role of trade policy, trade liberalization in particular,

[1] The most recent book length publication on trade and growth at the theoretical level is Grossman and Helpman (1991). Barro and Sala-i-Martin (1995) is a book length publication on Economic Growth. Empirical work linking trade policy with growth is World Bank (1988).

on growth. The role of technology is also discussed in some detail in this section.

2.2 The Neoclassical Model of Growth and Policy Neutrality

The neoclassical production function for the single sector economy is characterised by

$Y = F(K, L)$ where $F_K > 0$, $F_L > 0$, and $F_{KK} < 0$, $F_{LL} < 0$ for K, $L > 0$ (2.1)

where Y, K and L are aggregate output, capital stock and labour, respectively, in the economy[2]. The restrictions on *F(.)* state that there are positive and diminishing marginal products of each factor of production for strictly positive quantities of the two factors. *F(.)* is also assumed to be linearly homogeneous as well as satisfying the Inada conditions.

$$F(\lambda K, \lambda L) = \lambda F(K, L) \text{ for } \lambda > 0 \qquad \text{(2.2a); and}$$

$$\lim_{K\to\infty}(F_K) = \lim_{L\to\infty}(F_L) = 0 \text{ and } \lim_{K\to 0}(F_K) = \lim_{L\to 0}(F_L) = \infty \qquad \text{(2.2b).}$$

Technological progress is assumed exogenous to the system and is therefore omitted from (2.1). The restriction in (2.2a) allows *F(.)* to be expressed in per capita form,

$$y = f(k) \qquad (2.3)$$

[2] We use the notation that capital letters denote aggregate quantities while small letters denote per-capita levels.

where $k=\frac{K}{L}$ and $y=\frac{Y}{L}$. It follows from (2.2a) and (2.2b) that $f(0)=0$, $f'(.)>0$ for $k\geq 0$ and $f''(.)<0$ for $k>0$. Dynamics are introduced into the system by specifying the evolution of k. Assuming a constant savings rate[3], the evolution of per-capita capital stock can be stated as

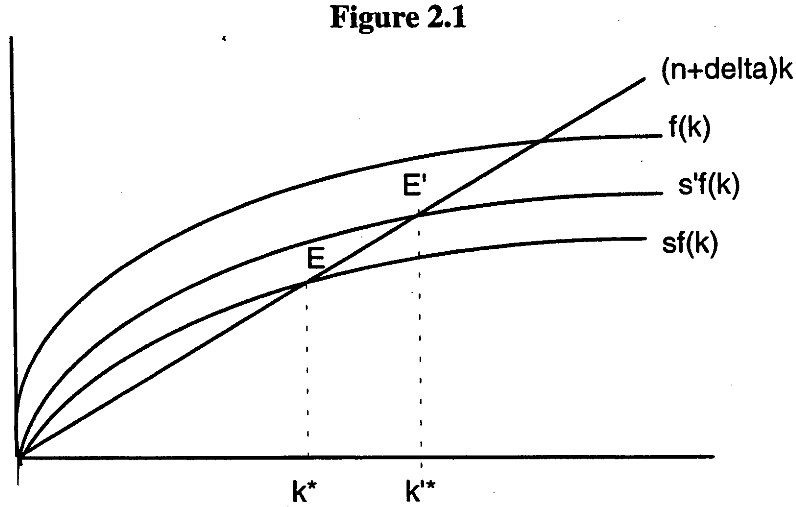
$$\dot{k}=sf(k)-(n+\delta)k \qquad (2.4)$$

where the parameters s, n and δ denote the rates of saving, population growth and depreciation, respectively. Equation (2.4) is the fundamental differential equation of the Solow-Swan model. Note that this equation is a function of k alone. The steady state level of k, k^*, is characterised by

$$sf(k^*)=(n+\delta)k^* \qquad (2.5)$$

and can be illustrated graphically as given in Figure 2.1 below.

Figure 2.1



[3] Savings rate can be made endogenous (see Chapter 2 in Barro and Sala-I-Martin 1995) but this only adds more equations to the system without adding further content to the role of policy in the model.

The model will converge to a constant k^* so that the steady state level of output is also constant from the specification of per-capita production given in equation (2.3) above. Consumption in this model is output less savings, hence in the steady state, per-capita consumption is also constant. The constancy of per-capita levels of output, capital stock and consumption implies that the gross amounts of the variables grow at the rate of growth of population. Changes in the value of any of the parameters in (2.5) results in a new steady state but the model does not admit any long-run growth in per capita variables. For example, an increase in the savings rate from s to s' results in the shift of $sf(k)$ to $s'f(k)$ giving rise to a new steady state level of per-capita capital stock, k'^* . Transitional dynamics will involve positive growth when the economy moves from equilibrium E to E', but following that, the growth rate of per-capita output returns to zero again. Positive long-run growth is admitted in the model by introducing exogenous technological progress. The existence of a steady state necessitates that the exogenous technological progress be labour augmenting.[4] This would imply a modification of the production function given in (2.1) to

$$Y = F(K, A(t)L) \qquad (2.1')$$

where A is a function of time (t) and denotes exogenous labour-augmenting technological progress. The long-run growth rate in the steady state is now equal to $\frac{\dot{A}}{A}$ (= λ), the rate of growth of this exogenous factor. The inclusion of exogenous labour-augmenting technological progress has enabled the neoclassical model to admit positive rates of growth but this growth is the result of factors exogenous to the system. Thus, long-run growth in the

[4] The proof of this proposition is in Barro and Sala-I-Martin (1995: Appendix to Chapter 2).

neoclassical framework - by assumption - is exogenous and therefore beyond the purview of the policy maker. This result has led to much dissatisfaction amongst policy makers who have adhered strongly to the view that policy has a significant role in growth. The recent experiences of the rapidly growing NICs has lent considerable support to this position. We now consider the evidence on the role of policy on growth.

2.3 Evidence on Role of Policy in Growth

One observed fact on growth is that it has wide variability both across different historical periods for a given country and for different countries for any given period. Furthermore, some countries have been successful in maintaining positive and non-declining rates of growth for prolonged periods of time (see data in Maddison 1991). These empirical facts are in conflict with the predictions of the neoclassical model.

Evidence has been corroborated by a number of researchers in support of the view that policy has a role in growth. For example Feder (1982) and Romer (1989) show a positive (partial) correlation between the fraction of output exported by a country and productivity growth. Dowrick and Nguyen (1988) using data on the OECD countries show a positive (partial) correlation between fraction of investment in output and GDP growth; Azariadis and Drazen (1990) and Romer (1989) show positive correlation between proxies for the stock of human capital and growth in real GDP; Barro (1991) shows a positive (partial) correlation between school enrolment rate and output growth; and Barro (1991) and Dowrick (1994) show a positive (negative) correlation between government investment (consumption) and GDP growth. World Bank (1988) presents empirical case studies in support of its claim that export orientation enhances economic growth.

The role of policy in growth is deduced from empirical studies, the volume of which has been on the rise in the recent past. Policy makers have acted as though their actions are significant in the determination of long-run growth (in the Australian context see the edited volume of Dwyer 1995). This view has been given a boost by the success of the newly industrialising economies (NIEs) of Hong Kong, Korea, Singapore and Taiwan who are often cited as having considerable overlap in their policy stance. This league is now being expanded to include Malaysia, Thailand and China. Academic economists and multilateral institutions, particularly the World Bank, who have had an active role in policy making have propelled the view that policy has a role in the determination of economic growth. The difficulty with this view is that it cannot be encapsulated within the neoclassical model. Hence researchers with a leaning towards the belief that policy influences growth have traditionally used empirics to support their propositions. This, over the last two decades, has culminated in an industry in data collection, the World Bank being active in both the collection of the economic data as well as in the funding of such collections by other agencies. Development economics with its preoccupation into the role of policy in long-run growth, tended to deviate away from the main stream (see Krugman 1993 for a survey).

The critics such as Leamer (1992) continue to point out that evidence gathered in support of a role for policy in growth is weak given that many of the regression equations estimated are ad-hoc and badly specified with none derived from rational optimising behaviour of economic agents. Within the mainstream, Arrow (1962) and Uzawa (1965) were amongst the pioneering works in "endogenising" technical change. The recent success of the NICs has provided the impetus for further theoretical research in the area. Since the mid-1980s much of the focus of the theoretical work in the area has involved endogenising growth. As a result, a number of theoretical models have been produced which support the "old" claims made by development economists (see Krugman 1993a for a survey).

2.4 The need for a "new" theory on growth

Development economists have correctly called the burst of recent activity within mainstream neoclassical economics on endogenous growth as a re-invention of the wheel. This section briefly reflects on the divorce of development economics from mainstream economics with respect to issues of growth and documents the current moves towards reconciliation via the emergence of endogenous growth theory.

As pointed out in section 2.2 above, growth in the neoclassical framework is due solely to technological progress, a factor exogenous to the system. The fact that increasing returns and perpetual growth had been inconsistent with diminishing returns and the Inada conditions of neoclassical theory made many mainstream economists suspicious of claims that policy has a role in long-run growth. Modern microeconomic theory, which is still neoclassical, now permits increasing returns but over <u>some</u> ranges of output only. Thus, neoclassical models permit increasing returns to scale, but only over limited ranges of output. It is therefore necessary to go beyond the neoclassical growth framework to find a model which accommodates increasing returns, permits long-run growth and allows policy to affect growth.

Endogenous Growth Theory

Endogenous growth differs from neoclassical growth theory in that, while the latter assumes economic growth to be exogenous to the system, the former considers 'economic growth as an endogenous outcome of the economic system' (Romer 1994: 3). Work in the area of endogenous growth is still continuing with none of the existing models considered as being adequate in explaining the growth process (see Romer 1994 for a survey on this issue). The pioneers attempted to incorporate long-run growth within the neoclassical structure by suspending one or more of the assumptions of the neoclassical model. For example Rebelo (1991) generates perpetual growth in his 'AK' model by assuming constant returns to scale to capital. Lucas (1988) does the same but by incorporating an externality from human capital accumulation which in turn generates increasing returns to scale in the three factors of production. Other approaches such as Grossman and Helpman (1991) attempt to model technology creation as due to active profit seeking activity. These models rely on the notion that innovation is accompanied by the creation of knowledge as a by-product which then adds to the existing stock of public knowledge. The increase in the stock of public knowledge in these models lowers the cost of future innovation, hence the externality from current innovation on future output. It is important to note that all the recent models of endogenous growth, including Romer (1986, 1990), Lucas (1988), Jones and Manuelli (1990), Rebelo (1991) and Grossman and Helpman (1991), modify the orthodox neoclassical model so as to admit long-run growth in per-capita income (see Hammond and Rodriguez-Clare 1993 for details of the relationship between the above models). These developments within endogenous growth theory have created a framework in which economic institutions and policies have long-run effects on growth rates.

Here, we consider two of the modifications of the neoclassical model which permit long-run growth in per capita output. The first involves suspension of the upper Inada condition to give the so called 'AK' model (Rebelo 1991), the second considers a two-sector model. The AK model includes a number of simplifications for reasons of tractability, but it serves well to demonstrate the effect of policy on growth in endogenous growth models in general. The AK model assumes a constant marginal product of capital, hence production can be represented by

$$Y = AK \qquad (2.6)$$

where A[5], a constant and denotes the marginal product of capital. The rest of the variables are as defined in section 2.2 above. Growth in the per-capita capital stock is now given by

$$\frac{\dot{k}}{k} = sA - (n+\delta) \qquad (2.7)$$

where the savings rate has been assumed to be constant for simplicity and no exogenous technological progress has been incorporated. Equation (2.7) shows that change in any one of the parameters s, n, or δ will affect the growth rate of k and therefore also on y and c. Fiscal policy, in the form of taxation and/or government expenditure, affects the savings rate and hence capital accumulation. This in turn affects long-run growth. Note that the economy represented by the AK model displays positive growth without exogenous technological progress. More importantly, the model admits a role for policy in growth. The AK model has two serious shortcomings, the first being that the model's prediction of an absence of convergence in growth rates between economies is inconsistent with empirical evidence (Barro 1991 and Dowrick and Nguyen 1988)[6] and second, the assumption of constant

[5] Note that 'A' here is a constant and different from exogenous technological progress notation used in section 2.2 above. The choice of this notation is conventional within this literature.

[6] We qualify this by the fact that the neoclassical model predicts conditional convergence, a prediction supported by a number of empirical studies. It is the rate of convergence predictions of the model that are at odds with the empirics (see Mankiw 1995 for a recent survey on this issue together with ways in which the neoclassical model can be augmented so as to give rise to predictions that are plausible with the empirics).

marginal product is not supported by data as shown by Young (1992). To rectify the first weakness, the AK model has been augmented by incorporating Cobb-Douglas technology (Hammond *et al* 1993). The modified production function is now given by

$$y = AK + BK^{\alpha}L^{\beta} \ , 0 < \alpha, \beta < 1 \qquad (2.8)$$

where A and B are positive constants. The augmented structure now admits convergence but the model still has, in the limit, constant marginal product of capital. Not withstanding the above problems with the AK formulation, the model demonstrates the common feature of all endogenous growth models where policy is relevant for long-run growth.

The above is a simple modification of the one-sector neoclassical model. A number of multi-sector models have been developed, Uzawa (1965) being amongst the first, that generate endogenous growth. Rebelo (1991) shows that growth is possible in a two-sector set up where output of one sector is produced using reproducible resources only. We illustrate this briefly and then use the framework to describe other models that use this two-sector framework. Let the two sectors be consumption (C) and investment (I). Production in the consumption sector is Cobb-Douglas and constant returns to scale (CRS),

$$C = K_c^{\alpha}L^{1-\alpha}, \quad 0 < \alpha < 1 \qquad (2.9),$$

while investment is produced with capital alone with CRS technology.

$$\dot{K} = aK_I, \ a > 0 \qquad (2.10)$$

where a dot over a variable represents its time derivative, subscripts denote the respective sectors, and $K_C + K_I = K$. If a constant fraction, σ, of total capital stock is used to produce the investment good then growth of consumption is constant and given by

$$\hat{C} = \alpha\hat{K}_C = \alpha\hat{K} = \alpha\sigma a \qquad (2.11)$$

Two-sector endogenous growth models employ the structure given in (2.9) and (2.10) to generate long-run growth. For example, Lucas (1988) uses this framework to generate long-run growth but interprets equation (2.10) as constituting human capital accumulation. Policy that impacts on resource allocation between sectors in the above framework will result in changes in the rate of growth as is shown in Chapter 3. Romer (1990) uses a two sector set-up where one sector produces the intermediate goods which in turn are used as inputs in the production of the final good. Growth in this framework relies on two assumptions: the existence of an externality in production of the intermediate goods; and imperfect substitutability between intermediate inputs in production. The production function is given by

$$Y(H_Y, N, z) = H_Y{}^{\alpha} N^{\beta} \int_0^{\infty} z(j)^{1-\alpha-\beta} dj \qquad (2.9a)$$

where H_Y is human capital[7] devoted to final output, N is labour represented by number of workers, and z is a continuous variable representing the range of inputs (each indexed by j) used in the sector. Romer (1990) asserts that firms undertake research so as to discover new varieties of intermediate

[7] The notion of human capital used here, as in the rest of this thesis, is different from that used in labour market contexts that assume human capital to be individual specific. Consistent with the usage of human capital in growth models (see Romer 1990, Lucas 1988), we assume human capital that outlives any individual and accumulates over generations.

inputs. An unintended consequence of this research, according to Romer, is the addition to the existing stock of knowledge. This accumulation of publicly available knowledge is assumed to make future innovations easier - this externality results in perpetual growth in Romer's model. The evolution of the stock of publicly available knowledge ['number of designs for new goods' in Romer's terminology (page s79)], *D*, is given by

$$\dot{D} = \phi H_D D, \ \ \phi > 0 \qquad (2.10a)$$

where H_D is human capital engaged in research (creation of new designs), φ is a strictly positive constant, and *D* is the existing stock of designs. Note that the analytical form of equation (2.10a) is identical to that of (2.10). Intermediate inputs are imperfect substitutes in production as represented by (2.9a)[8], hence an increase in the number of intermediate inputs as a result of innovation through research by firms leads to a rise in production. Given the assumption that the cost of research declines over time, the number of intermediate inputs produced rises over time and so does the quantity of output. Grossman and Helpman (1991) have extended Romer's analytical framework to include improvements in quality of inputs to generate similar results.

Trade is also linked to growth via the advantages from economic integration of economies. Rivera-Batiz and Romer (1991) analyse the link between integration of two identical economies and their growth rates. They show that such integration, when innovation is the engine of growth, unambiguously enhances growth since the externality from the innovation now flows over a larger production base. ie. The gains from innovation,

[8] These model employ the production function from Dixit and Stiglitz (1977) as reinterpreted by Ethier (1982).

achieved at a fixed cost, flows on to a bigger market via economic integration. Romer (1990) shows that a larger market induces more research and therefore results in faster growth. Grossman and Helpman (1991) extend this analysis to dissimilar economies. Policies that impact on incentives for innovation and/or trade in these models directly impinge on long-run growth.

Note that in the above models long-run growth is determined by parameters including the savings rate, the productivity of resources in the research sector, the strength of externalities in production and research sectors, and the distribution of resources between sectors. A multitude of policies could in theory impact on these parameters and hence on growth, however we confine our attention here to the role of trade policy for the following reasons. First, it keeps the analysis tractable. Second, increasing importance has been placed on the role of trade in growth in an increasingly open world. Third, there is a widespread notion that the success of the NICs is at least partly attributable to their liberal trade policies[9]. Falvey (1994) notes that

> "Trade liberalization is likely to do more than simply shift an economy to a more appropriate position on its production possibility frontier." (page 54, emphasis is my own)

A liberal trade regime is often claimed to enhance growth, hence we now consider the role of trade liberalization on growth.

2.5 Trade Liberalization and Growth

It is now part of conventional wisdom that trade liberalization has beneficial resource allocation effects (Mussa 1993), but these benefits have in the past been assumed to be static (or perhaps transitory as the economy moves from

[9] Sachs and Warner (1995) generalise this result with evidence that open developing economies grow faster than closed ones.

one equilibrium to another) and estimates of these benefits are typically small (see Falvey 1994 & 1995 and Edwards 1993 for recent surveys on the subject of trade liberalization and growth). Sustained growth in models from endogenous growth theory is generated through reliance on externalities associated with capital formation, learning by doing, schooling and/or R&D. Externalities, by definition, are not captured within the competitive framework of the market, hence policy has a role in the efficient allocation of the total resources of the economy. The externalities are claimed to have dynamic effects that accumulate over time, hence static estimates of the gains from trade liberalization may be small[10] at any point in time, but their impact on growth implies that the impact of policy on welfare over time gets magnified. The conventional analysis with assumptions of constant returns to scale, perfect competition and absence of externalities implies free trade is optimal for a small country. The existence of externalities requires policy intervention for efficient resource allocation but note that this does not have to be in the form of trade intervention. For example, if the externalities are domestic in nature than domestic intervention only is required and any border intervention is obviously going to be a second best alternative.

The empirical evidence on association between trade orientation and growth

A number of empirical studies show a positive correlation between openness and long-run growth but these studies are far short of establishing any conclusive results. The empirics are short of establishing any causality since they often lack a well defined model (Edwards 1993). Measurement of trade restrictiveness has been another area of concern. Leamer (1988a) and Edwards (1993) observe that measures of protection and trade orientation are difficult to compute. Dean, Desai and Riedel (1994) show that the current measures of protection do not adequately reflect the extent of trade

[10] This is a level effect.

restrictiveness. The first is an empirical issue, the latter a theoretical one. A number of empirical studies use the sum of exports and imports as a proportion of GDP, the measure of openness in the Penn World Tables (PWT) (Summers and Heston 1991), as the measure of trade openness. The appeal of this measure is that data to construct the index is readily available, but Leamer (1988a) demonstrates that measures of trade intensity indicate the degree to which countries differ in their endowments. Hence, the openness index in PWT cannot be used as a measure of trade restrictiveness. In the absence of a satisfactory all-encompassing measure of trade restrictiveness, empirical studies will have to rely on proxies which by definition contain measurement errors. We take this issue up in more detail later and suggest an alternative measure of trade restrictiveness in Chapter 6.

Endogenous growth models such as Romer (1990 and 1986) rely on trade in differentiated inputs as a source of growth. Empirical tests of this proposition are tricky since measures of the extent of trade in intermediate inputs are not available. Empirical studies that attempt to test this association such as Backus, Kehoe and Kehoe (1992) use Grubel-Lloyd (1975) index as a measure of extent of trade in intermediate inputs. Again, the Grubel-Lloyd index is a measure of the extent of intra-industry trade, but whether this is the same as the extent of trade in <u>intermediate</u> inputs is arguable. These issues are taken up in further detail in the empirical part of the thesis.

Robustness of the observed partial correlations between a number of RHS variables and growth of GDP in the empirical studies has been another concern. Levine and Renelt (1992) observe that individual empirical studies show that, of a host of variables hypothesised to be linked to growth, only a subset is included in any one regression. The authors find that of all the variables hypothesised to be linked with growth, the average share of investment to GDP is the only one that is robust to slight alterations in the list of explanatory variables included in the regression equation.

A few studies at the firm level are now appearing that look at how the behaviour of economic agents is affected by changes in trade policy. Tybout, de Melo and Corbo (1991) study the effects on technical efficiency of manufacturing firms in Chile before and after the substantial trade liberalization in the 1970s. The authors report that industries that went through relatively large reductions in protection experienced large gains in efficiency levels. These studies have the attraction that they are done at the micro level and provide more convincing evidence on the possible links between trade policy and growth. But, these studies are difficult to replicate for other countries since obtaining data for such studies is extremely difficult. For example, our attempts to do a similar study for Australia was unsuccessful because release of firm level data by Australian Bureau of Statistics is prohibited by law.

We now consider some channels via which trade policy impacts on growth. Growth, both in the neoclassical and endogenous growth frameworks, arises from two sources; factor accumulation and increases in total factor productivity (TFP). Though the two are inter-twined, for tractability we consider each separately.

Factor Accumulation

Trade liberalization is often accompanied by a change in relative prices of factors of production. Assuming that the price of capital was depressed by policy prior to the liberalization, capital accumulation will follow the liberalization as the economy moves to a new steady state. The assumption of diminishing returns to capital (from equation (2.2b)) ensures that capital accumulation ceases on attainment of a steady state in the neoclassical setting but suspension of the assumption of diminishing returns, as in the AK model, implies growth is sustained indefinitely. A similar claim can be made about human capital accumulation but now given finite lives of people we also need the additional assumption that knowledge is readily passed on to the latter generations. Factor accumulation, therefore, results in positive growth in the transition phase only in the neoclassical model but this growth is sustained in the AK model.

TFP Growth

New growth theory stresses the role of TFP growth in maintaining a positive non-zero growth rate of output. A number of potential sources of steady state growth have been identified and include those attributable to externalities from accumulation of physical and human capital, and research & development. Furthermore, trade minimises the duplication of R&D effort between countries and also enhances diffusion of knowledge between countries. Knowledge creation is assumed to have significant scale economies, therefore trade should accrue significant gains to the process of knowledge creation. We consider the role of policy in capital accumulation and R&D in further detail in Chapters 5 and 6.

Capital Accumulation and Trade Policy

Physical capital accumulation can raise growth if it has an externality that offsets the diminishing returns associated with private capital accumulation. Barro (1990) and Findlay (1995) argue that public investments in infrastructure and other public intermediate inputs perform this role. Similarly, if border distortions raise the cost of investment and therefore discourage capital accumulation then their removal is going to be beneficial to growth.

The new growth theory has placed a lot more emphasis on the role of human capital as against physical capital in growth. Human capital, acquired either as an externality as learning-by-doing (LBD) or purposefully as schooling, is often the source of increasing returns to scale. In the latter case Romer (1993) points out that knowledge creation has the non-appropriability attribute of public goods. Stokey (1988) argues that private investment in schooling brings about an expansion of the social stock of knowledge which in turn raises the effectiveness of schooling of the later cohorts of scholars. This implies that the quality of education increases over time and is the source of growth. With trade, we allow each individual access to the pool of the 'global stock' of public knowledge which in turn should provide dynamic gains from economies of scale in the sector. The above implies that the competitive equilibrium will be inefficient and hence the scope for policies to "internalise" this externality. If the externality, as implied above, spills across national boundaries then perhaps border interventions may be appropriate. We consider a particular case to illustrate this.

Lucas (1988: section 5) has the world comprising a continuum of small open economies that trade in two goods, one of which experiences rapid LBD. If in autarky any one of these small open economies has a comparative advantage in the sector with higher LBD (the modern sector), then opening up to trade leads to instantaneous and complete specialisation in the good that the country initially had a comparative advantage in. All else equal, the rate of growth of this economy approaches the rate of LBD in the sector in which it specialises. If the small country had an initial comparative advantage in the low LBD sector, then its growth rate would approach the lower value of LBD. If policy could be employed to determine the initial pattern of trade then it would impact on the path of specialisation and long-run growth.

Lucas (1988) employs the small country assumption so as to abstract from policy-induced changes in world price. This could amount to an important omission. Relaxing the small country assumption will bring about two opposing effects: specialisation through active policy intervention by the large country in its high LBD sector will raise supply but this in turn will depress relative price of the product over time. The net effect on income growth of the economy specialising in either sector will depend on the relative magnitudes of the two opposing effects. Furthermore, by introducing diminishing returns to each factor of production within the Lucas (1988) framework we are able to generate incomplete specialisation in the short-run, though in the long-run trade 'locks' the small countries into a pattern of trade that ultimately leads to complete specialisation. We attend to this issue in further detail in the next chapter but for now note that interventionist trade policy could result in altering the path of specialisation and therefore has the potential to impact upon the rate of long-run growth.

A number of recent papers have built upon the notion of Schumpeter that innovation is the result of deliberate profit-maximising actions of economic agents. Romer (1990) and Grossman and Helpman (1991) model the process of technological innovation as the result of active R&D activity by firms who are motivated by the possibility of capturing monopoly rents from success at innovation. The process of innovation is assumed to be stochastic but given a large number of firms and sectors, the aggregate effect is a continual improvement in technology. TFP growth from technological improvements is now due to profit-seeking activity and is endogenous to the system. Sustained growth is possible in this framework from the assumption that innovation results in increment to the public stock of knowledge that then makes future innovations less expensive. Naturally, the innovators are unable to appropriate the full benefits of their addition to the knowledge stock. This framework incorporates both an externality[11] and imperfect markets, both of which add more explanatory power to the models but at a cost of increased complexity. Spill-overs in this framework occur across sectors, nations and generations. The competitive market is no longer efficient, hence a role for policy in TFP growth. Trade can now potentially take place at three levels - in patents, intermediate and final goods. Policy could be applied at any one or a combination of these stages so as to achieve the desired goals. Of particular interest is the impact of diffusion of knowledge across nations and its implication on individual country and global welfare. We expand on these issues in Chapter 4.

2.6 Conclusion

Endogenous growth theory admits a role for policy in long-run growth, a feature absent from neoclassical models of growth. Growth is sustained in models from new growth theory by suspension of one or more of the assumptions made in the neoclassical models. The fact that positive non-zero growth has been experienced by a number of countries over extended periods of time and the observation that policies in some of the rapidly growing economies have similarities have prompted economists to explain this growth. The neoclassical models of growth were of limited help and this has provided the impetus for work in endogenous growth theory. Work in this area still has a long way to go and this thesis is an attempt to comprehend some aspects of this much larger issue.

We note that any empirical work in economics is bound to face data problems. Part of the art of economics is to make the best use of all available information. Theoretical models provide a conceptual framework for

[11] Recall from the two-sector set up of section 2.4 that it is the externality that generates sustained growth in Romer (1990) and Grossman and Helpman (1991).

analysing the available information so as to reach meaningful conclusions. The thesis attempts to put this into practice, with the next two chapters exploring the role of trade in growth in a theoretical context and the following three chapters using the theory to analyse available data to reach some meaningful conclusions. Summary of the overall findings are reported in the final chapter.

Chapter 3

Trade and Endogenous Growth with Ricardo-Viner Production Technology.

Abstract

This chapter derives three main results. First, learning by doing is sufficient to generate endogenous growth under Ricardo-Viner production technology. One implication of this result is that policy has a role when agents do not internalise the dynamic gains from learning. Second, trade is advantageous for a small country and in the case of domestic goods having low elasticity of substitution in final consumption, high human capital content and/or a high learning rate. Third, border distortions in the form of import tariffs can affect pattern of specialisation and long run growth but only for large economies and under very special circumstances. Numerical simulations are used to illustrate the above results.

3.1 Introduction

The link between trade, trade policy and economic growth remains an open question. A number of empirical papers show a positive association between the extent of trade and economic growth in cross-country growth regressions, but critics such as Leamer (1992) point out that any such associations are not convincing given that the models used are improperly specified and often are completely ad-hoc. This chapter investigates the link between trade policy, the pattern of trade, the path of specialisation and economic growth. The role of trade policy in economic growth is considered an issue worthy of investigation given that trade policy is one of the most significant instruments used in the industrialisation of developing countries (Lee 1993).

Despite the overwhelming[1] empirical evidence showing strong positive links between "outward orientation" and economic growth (see for example World Bank 1988, Edwards 1992, and Dowrick 1994) both economists and policy makers are yet to be fully convinced that liberal trade policy is a means of promoting growth. Why? Leamer (1992) attributes this failure to inadequate theoretical analysis preceding empirical work. Traditionally, the theoretical foundations of long-run linkages between trade and growth have been fragile, hence most of the empirical work has not had the advantage of using rigorous theory to formulate hypotheses and test these using real data. Leamer's criticism stems from this weakness. In Leamer's terms, most of the studies exploring the link between openness and growth have proceeded too quickly to data analysis without the formulation of a conceptual framework to guide their work.

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[1] The one paper that we are aware of which casts doubts on the claimed positive association between trade policy and growth is Levine and Renelt (1992) who show an absence of any significant relationship between long-run growth rates and economic policy.

The study of the role of government policy on growth in general has also had its problems. In the standard neo-classical growth model government policy has no role in the determination of long-run economic growth. Trade economists, particularly those convinced that trade policy has a role to play in long-run economic growth, have alluded to economy-of-scale (EOS) arguments to establish a link between trade and growth. Feder (1982) is probably among the first to put such a case, appealing to a positive externality of exports on domestic production. Krugman (1987), Lucas (1988) and Young (1991) have used learning by doing (LBD from now on) as another form of positive (dynamic) externality that accrues gains over time and acts as a source of (dynamic) comparative advantage. In these models LBD acts as a determinant of the pattern of trade and path of specialisation. More recent work by Lucas (1993) amongst many others[2] seems to stress the role of human capital and its accumulation as a major determinant of comparative advantage, trade pattern, specialisation and economic growth. The East Asian "miracle" of high and sustained growth in Hong Kong, Korea, Singapore and Taiwan, according to Lucas (1993), is the result of rapid and sustained human capital accumulation via learning by doing[3].

All of the research quoted above stresses the role of dynamic economies of scale in linking trade with growth. However, there is another set of observations, termed the 'stylised facts' about international trade (Baxter 1992) that are at odds with the predictions of the factor proportions model of international trade. These are: an increasing degree of specialisation in production between countries; an increasing amount of intra-industry trade

[2] See the collection of papers in 1990 issue of JPE vol. 98 number 5 part 2 on human capital, and its role in growth.

[3] There is an alternate view, espoused by Rivera-Batiz *et al* (1991), that it is the dynamic economies of scale in R&D that impacts on growth. We abstract from this issue in this chapter but incorporate it in Chapter 5.

amongst similarly endowed countries; and an increasing volume of global trade. These observations are at odds with the predictions of the Heckscher-Ohlin-Samuelson (HOS) model, the work horse of trade theorists for a long time now. On the empirical front, Dollar (1993) attributes the high and increasing degree of specialisation in production and the "persistence" of comparative advantage amongst countries to technological factors. Porter (1990) observes that countries tend to specialise in specific industries (and industry segments) and again attributes this to the role of country-specific factors.

There has been a group of researchers (Dollar, Porter, etc.) who argue that such country-specific factors as technology are responsible for the increasing specialisation in global production. There is a second group (Krugman, Lucas, Young, etc.) who take the view that it is human capital and its accumulation that determines comparative advantage and drives specialisation. Linking this literature on human capital accumulation as the engine of growth with the claim that country-specific technology is the determinant of specialisation gives rise to the following testable hypothesis.

The Hypothesis: Sector-specific human capital and dynamic gains from its acquisition are the determinants of trade pattern, path of specialisation, and economic growth.

In the light of Leamer's (1992) criticism, we begin by first laying down the theoretical foundations for subsequent empirical work that is to follow in the latter half of the thesis.

Our analysis differs from previous work and particularly that cited above in that it extends the framework of Lucas (1988: Section 5) to address issues on the dynamics of specialisation and its impact on growth via trade. We differ from Lucas in that we permit use of constant returns to scale (CRS) whereas Lucas uses production technology that is strictly increasing-returns-to-scale (IRS)[4]. Furthermore, we trace the impact of productivity changes on changes in relative price in a two-good world both for the case of a small open economy as well as for large trading economies. The role of policy in influencing the trade pattern as in Baxter (1992) is studied but in a growth context. Young (1991) looks at the dynamic effects of learning by doing on international trade and growth much in the spirit of this chapter but his analysis differs from ours in many respects. Young (1991) has a continuum of goods indexed along a real number line by their degree of sophistication. Each good enters the preference function symmetrically, hence utility increases as the number of goods made available rises. Growth in Young's (1991) framework involves the production of a changing basket of goods in a two-country world where the number of goods produced (and consumed) increases over time. LBD is assumed to be bounded and sequentially exhausted over time in each good, hence growth is sustained by continual path-breaking innovation, the result of sustained efforts in the R&D sector. In contrast, our analysis has two final goods without any R&D. The analysis of Young (1991) and that of this chapter may be reconciled and considered as complementary in that the former considers goods at a highly dissaggregated level with the analysis having close parallels to the literature on product cycles while this chapter considers goods at a much more aggregated (industry) level. The advantage, we believe, is that our model is amenable to empirical testing given the availability of industry-level data.

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[4] Lucas (1988) uses production technology that is homogeneous of degree 2. This is made explicit in equation (2) and footnote 5 below. We show later that LBD is sufficient to generate endogenous growth without the use of IRS production technology as in Lucas' framework.

We assume that all human capital accumulation is via LBD. Why? Both learning or doing and learning by doing have strong economic implications. This thesis concentrates on the latter for the following reasons. First, abstracting from one form of learning keeps the analysis tractable. Second, learning by doing [as against learning or doing] has fewer appropriability problems when considered as a form of technology advantage (Baldwin and Krugman 1988) and hence is of greater relevance to the analysis of comparative advantage. ie. Process imitation is more difficult than product imitation since the former is firm-specific, hence 'hardwired' to the system, while the latter is available to any potential client. Arrow (1962) calls learning "the product of experience", a commodity far less transferable between industries than the final product. This property of non-transferability of knowledge acquired via LBD is the source of comparative advantage in the trade context.

The rest of the chapter is organised as follows. Section 2 presents the two-sector model of an economy operating under autarchy and looks at the determinants of relative price changes, the pattern of resource allocation and growth in this closed economy. Section 3 opens this economy to international trade and looks at the pattern of specialisation and growth both for the small and the large economy. The role of policy in influencing the trade pattern and growth is also analysed. Section 4 contains numerical simulations that demonstrate the short run implications of the analytical results of the two preceding sections. Section 5 concludes the chapter with a brief summary and suggestions for further research.

3.2 The Model

Following the tradition in this literature (Baxter 1992), we first study an economy operating in autarchy, then open the economy to trade. We first consider the effects for a small open economy then proceed to look at the implications of trade in a two-country world The model developed is a standard Ricardo-Viner 2 x 3 model comprising two final goods and three factors of production. One factor is specific to each of the sectors while the third is mobile between sectors. We call this sector-specific factor human capital. Sectoral human capital accumulates via a learning-by-doing technology as in Lucas (1988: section 5). Sector 1, named manufacturing for concreteness, is the high-tech sector in that it has a higher learning rate then the low-tech sector, agriculture.

Labour is mobile between sectors while human capital is not. We can rationalise the immobility of human capital between sectors despite labour mobility as due to the sector specificity of human capital. Should labour move between sectors, these movements do not change the existing stock of sectoral human capital. For simplicity we further assume that there is no cost of moving labour between the sectors. We assume trade in goods only.

Production Technology. - The two final goods are produced using a Ricardo-Viner technology that may exhibit constant returns to scale (CRS) in both factors and decreasing returns to each factor individually through the choice of appropriate parameters. The simulations of section 4 maintain this CRS assumption. The production of these two goods is assumed to be given by

$$y_i(t) = A_i(t) h_i(t)^{\beta} N_i(t)^{\gamma} \qquad (1)$$

where y_i is sectoral output, A_i is an index of sectoral total factor productivity, h_i is sector-specific human capital and N_i is labour employed in sector i. We further assume that total labour supply, N, is fixed, a fraction u_i ($\Sigma u_i = 1$) employed in sector i. Following Lucas (1988), we abstract from issues of population growth and Hicks-neutral technological progress, hence set both $A(t)$ and $N(t)$ equal to 1 for all t. The production technology in (1) can now be expressed as

$$y_i(t) = h_i(t)^{\beta} u_i(t)^{\gamma} \qquad (2).$$

where a constant returns to scale technology implies $\beta+\gamma = 1$[5] in (2) above.

Learning / Human Capital Accumulation. - We assume, following Krugman (1987) and Lucas (1988), that learning is entirely an industry phenomenon completely external to the firm/producer, so perfect competition continues to prevail. More specifically, the learning-by-doing is modelled as in Lucas (1988). This is represented by accumulation of sector-specific human capital in direct proportion to the quantity of resources, $u_i(t)$, devoted to the sector. Following the notation that a dot and circumflex over a variable represent the time and log-time derivative of the variable, respectively, we may now represent learning in sector i as

$$\dot{h}_i(t) = \delta_i u_i(t) h_i(t) \qquad (3)$$

where the rate of learning, δ_i, is constant for each i over the whole time horizon. Our assumption of good 1 being the high technology good implies $\delta_1 > \delta_2$. Setting $\beta+\gamma = 1$ in (2) above will give constant returns to scale at every point in time but the incorporation of (3) now implies dynamic

[5] Lucas (1988) has $\beta = \gamma = 1$ which is strictly IRS and is referred to as such throughout the paper.

increasing returns due exclusively to the learning effect. The assumption of many identical agents implies that the individual agent correctly ignores the effect of his decisions on future productivity via LBD. Hence, perfect competition is possible with each producer taking both prices and sectoral human capital as fixed at each t. A discrete analogue of equation (3) above, as used in the simulations of section 4 below, implies that learning affects production one period later. This could be rationalised by assuming that the dissemination of knowledge within the industry takes one time period.

Preferences. - The economy is populated by a single representative agent who is both a producer and consumer. The agent receives utility from consuming the two goods, manufactures and agriculture, with his/her preferences given by the CES instantaneous utility function

$$U(c_1, c_2) = [\alpha_1 c_1^{-\rho} + \alpha_2 c_2^{-\rho}]^{-1/\rho} \qquad (4)$$

where $\alpha_1 + \alpha_2 = 1$. Lucas (1988) uses the same formulation of preferences which excludes leisure. We may rationalise the exclusion of leisure as being the result of the agent deciding to devote a fixed fraction of his time to work. This is consistent with a two-tier nested utility function where the first aggregation between leisure and consumption is Cobb-Douglas while the second tier represents the aggregation of the two consumption goods given by equation (4) above. Since our model considers the two final consumption goods only, the analysis is simplified by considering (4) as the preference function. We further assume that the agent is myopic in that he/she does not incorporate the effect of learning in his/her maximisation problem. ie. The agent does not perceive (3) as entering his decision problem. This is justified by the fact that being one of the many similar agents in the economy, the learning-by-doing effect for this one individual is beyond the purview of his actions. Given many identical agents comprising this economy, all of the learning-by-doing constitutes a positive production externality which does not enter the optimisation problem of the individual agent.

Let q(t) denote the relative price of good 2 (Agriculture) in terms of good 1 (Manufactures). Consumer optimisation involves equating the marginal rate of substitution in consumption to the relative price, q. ie.

$$q = \frac{\partial U / \partial c_2}{\partial U / \partial c_1} \qquad (5).$$

Substituting (4) in (5) and rearranging terms gives relative demand as

$$\frac{c_2}{c_1} = \left(\frac{\alpha_2}{\alpha_1}\right)^{\sigma} q^{-\sigma} \qquad (6),$$

where σ [$=1/(1+\rho)$] is the elasticity of substitution in consumption between the two final goods. Producer optimisation involving profit maximisation gives the relative supply price as

$$q = \left(\frac{h_1}{h_2}\right)^{\beta} \left(\frac{u_1}{u_2}\right)^{\gamma-1} \qquad (7).$$

Equilibrium work force allocation can now be deduced from (2) and (7) as

$$\frac{y_2}{y_1} = \frac{1-u_1}{u_1} q^{-1} \qquad (8).$$

The autarchic equilibrium as characterised by Lucas can now be solved from (6) and (8). Resources are allocated to sector 1 such that

$$u_1 = [1 + (\frac{\alpha_2}{\alpha_1})^{\sigma} q^{1-\sigma}]^{-1} \qquad (9)$$

is satisfied at each time period t. ie. The allocation of resources to sector 1, the high tech sector, depends positively on the elasticity of substitution and negatively on the level of q. The first effect arises from the demand side while the level of q, which may be affected by policy, is the equilibrium price at time t.

The dynamics of the changes in relative price in this closed economy are introduced by differentiating (7) and substituting from (3) and (9). ie. In autarchy the dynamics of relative price are given by

$$\hat{q} = \frac{\beta}{\sigma - \gamma\sigma + \gamma}[(1 + (\frac{\alpha_2}{\alpha_1})^{\sigma} q^{1-\sigma})^{-1}(\delta_1 + \delta_2) - \delta_2] \qquad (10)$$

where $\hat{q}_{\beta} > 0$; $\hat{q}_{\gamma} < 0$; $\hat{q}_{\delta_1} > 0$; $\hat{q}_{\sigma} < 0$; for $\sigma > \frac{\gamma}{\gamma - 1}$ and $\gamma \neq 1$. Note that q evolves over time but we are as yet to find out if it converges to a steady state.

The assumption of competitive markets implies that the gain in production of manufactures due to the higher learning in the sector is completely offset by equi-proportionate changes in relative price of the good in this closed economy. ie. Competitive markets implies all productivity changes due to learning are dissipated by changes in relative price. These two opposing effects are of much greater significance in the trading equilibrium and will be looked at in more detail in Section 3 below.

The results of Lucas (1988: section 5) can be readily verified by setting $\beta = \gamma = 1$ in equation (10) above. For the present model, constant returns to scale technology simplifies (10) to

$$\hat{q} = \frac{\beta}{\beta(\sigma-1)+1}[(1+(\frac{\alpha_2}{\alpha_1})^{\sigma} q^{1-\sigma})^{-1}(\delta_1+\delta_2)-\delta_2] \qquad (10a)$$

where $\hat{q}_{\beta} > 0$; $\hat{q}_{\delta_1} > 0$ $\hat{q}_{\sigma} < 0$; for $\sigma > \frac{\beta-1}{\beta}$.

Equation (10) demonstrates that the relative price of the high tech good deteriorates faster, *ceteris paribus*, when it has a lower elasticity of substitution in final consumption, a higher rate of learning, and/or a higher human capital intensity.

The Steady State. - The steady state, defined as $\hat{q} = 0$, is characterised by

$$\bar{u}_1 = [1+(\frac{\alpha_2}{\alpha_1})^{\sigma} q^{1-\sigma}]^{-1} = \frac{\delta_2}{\delta_1+\delta_2} \qquad (11).$$

Rearrangement of (11) gives steady state relative price as

$$\bar{q} = (\frac{\alpha_1}{\alpha_2})^{\frac{\sigma}{1-\sigma}}(\frac{\delta_1}{\delta_2})^{\frac{1}{1-\sigma}} \qquad (11a).$$

Equation (11) shows that resource allocation in the steady state is fixed and a function of the learning parameters only. Equation (11a) shows that the steady-state price is a function of demand and supply parameters.

The fact that growth is sustained in the above framework with CRS production technology can easily be seen by substituting the steady state value of u_1 from (11) into (3) which gives human capital accumulation as

$$\hat{h}_i = \delta_i \bar{u}_i \qquad (12)$$

which is a constant given equation (11) above. The growth in output from (2) after substitution of (12) is given by

$$\hat{y}_i = \beta \hat{h}_i \qquad (13)$$

which is also constant from equation (12) above. Equation (13) shows that so long as we have strictly positive δ for each sector, we can indefinitely produce more of both goods with finite labour as a result of LBD. All we need for this perpetual rise in production is a linear (in logs) learning process as given in equation (3) above. If the two commodities are good substitutes then we can bias our growth towards the higher δ good by allocating our resources in favour of that good. Now we only need one of the goods, the high-tech good, to have significant LBD for growth. The perpetual rise in production of the high-tech good will lead to a perpetual increase in utility, hence the endogenous growth. For q to converge to a feasible steady state value we need strictly positive learning coefficients and demand share parameters for both the sectors as shown by equation (11a) above.

Perpetual growth in this model is due solely to the linear learning process though, as the simulations of section 4 show, in absolute terms the rate of growth in this model is much smaller than that in the IRS model of Lucas. This fact should be evident given a positive and less than unit value of β for the CRS model as against a unit value in the IRS model in equation (13) above.

This section echoes the Lucas result that learning by doing is sufficient to generate long-run growth. Change in relative price is a function of the elasticity of substitution, human capital intensity, demand share parameters and the rate of learning.

The Role of the Social Planner. -The competitive equilibrium reached in the above model is not efficient given that learning, a positive production externality, is not compensated for in the market. This implies that the mix of outputs produced in the competitive equilibrium is sub-optimal from an infinitely lived social planner's perspective. We can demonstrate this by solving the infinite horizon social planner's problem by maximising the current value Hamiltonian

$$H = U(\underline{c}) + \psi_1 \dot{h}_1 + \psi_2 \dot{h}_2 \qquad (14)$$

where ψ_i (positive) is the shadow price of human capital in sector i and U is the current value utility of the social planner.

The necessary condition on relative demand is still represented by equation (6). Resource allocation in the respective sectors now incorporates the effect of learning taking place in each sector so we now have an additional necessary condition,

$$\psi_1 h_1 \delta_1 = \psi_2 h_2 \delta_2 \qquad (15).$$

We also have an additional constraint in the form of the transversality condition,

$$\lim_{t \to \infty} e^{-rt} \psi_i(t) h_i(t) = 0 \qquad (16),$$

where r is the inter-temporal discount rate. Equation (15) states that at the socially efficient equilibrium the marginal social product, comprising the value of learning in each sector, is the same for the two sectors. The transversality condition states that the limiting present value of the economy's sectoral human capital stock is zero. For the competitive equilibrium to be a social optimum now requires simultaneous satisfaction of (6), (15) and (16). ie. The marginal rate of substitution in consumption between the two goods equals the marginal rate of transformation between the two goods in production when the value of learning is also included in the latter. The intuition for the role of policy in this framework is as follows. The laissez-faire equilibrium is sub-optimal since private agents do not incorporate the effect of learning in their production decisions. This implies that production in the high tech sector is lower than the social optimum which involves equating the value of learning in each sector as shown by equation (15) above. Dynamic efficiency also implies that the present value of stock of sectoral human capital, in the limit, be zero. The competitive equilibrium ensures that allocations are instantaneously efficient but this does not ensure dynamic efficiency due to the existence of the (dynamic) production externality. This latter observation identifies a market failure, hence the role of policy.

We next consider the effect of opening this economy to trade.

3.3 Trade

Introducing trade in the above framework requires the incorporation of the trade balance constraint. Abstracting from the international financial sector, we further assume that trade balances each period. ie.

$$y_1 + py_2 = c_1 + pc_2, \forall t \qquad (17)$$

where p is the world relative price of good 2. Equation (17) is also the budget constraint of the economy. World relative demand, given by identical homothetic preferences in equation (4), under undistorted trade is given by

$$\frac{c_2}{c_1} = (\frac{\alpha_2}{\alpha_1})^{\sigma} p^{-\sigma} \qquad (18).$$

Trade Policy. - The role of policy can be introduced in this framework via the ability of governments to change domestic prices. We only consider the case of border distortions in the form of import tariffs and export taxes. We assume that these distortions are *ad-valorem* in nature, consequently domestic prices are given by

$$q = (1+\tau)p \qquad (19)$$

where τ is the *ad-valorem* tariff on good 2[6]. We further assume that these tax revenues are distributed in a non-distortionary manner.

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[6] By Lerner's symmetry theorem τ can also be interpreted as an export tax on good 1.

Analogous to the autarchic case, producer optimisation now gives

$$q = (\frac{h_1}{h_2})^{\beta}(\frac{u_1}{u_2})^{\gamma-1} \qquad (20)$$

where resource allocation to sector 1 is now given by

$$u_1 = [1+(1+\tau)^{\frac{1}{1-\gamma}} p^{\frac{1}{1-\gamma}} (\frac{h_2}{h_1})^{\frac{\beta}{1-\gamma}}]^{-1} \qquad (21).$$

Relative supply from equation (2) on rearrangement and substitution of equation (21) gives

$$y_2 = (1+\tau)^{\frac{\gamma}{1-\gamma}} p^{\frac{\gamma}{1-\gamma}} (\frac{h_2}{h_1})^{\frac{\beta}{1-\gamma}} y_1 \qquad (22).$$

Substituting equation (22) into the trade balance constraint, equation (17), gives

$$y_1 + py_2 = y_1[1+(1+\tau)^{\frac{\gamma}{1-\gamma}} p^{\frac{1}{1-\gamma}} (\frac{h_2}{h_1})^{\frac{\beta}{1-\gamma}}] \qquad (23)$$

where from equations (2) and (21)

$$y_1 = h_1^{\beta}[1+(1+\tau)^{\frac{1}{1-\gamma}} p^{\frac{1}{1-\gamma}} (\frac{h_2}{h_1})^{\frac{\beta}{1-\gamma}}]^{-\gamma} \qquad (24).$$

From equation (18)

$$c_2 = (\frac{\alpha_2}{\alpha_1})^{\sigma}(1+\tau)^{-\sigma} p^{-\sigma} c_1 \qquad (25)$$

and now substituting equations (23), (24) and (25) into equation (17) gives

$$c_1 = \frac{1+(\frac{h_2}{h_1})^{\frac{\beta}{1-\gamma}}(1+\tau)^{\frac{\gamma}{1-\gamma}} p^{\frac{1}{1-\gamma}}}{1+(\frac{\alpha_2}{\alpha_1})^{-\sigma}(1+\tau)^{-\sigma} p^{1-\sigma}} y_1 \qquad (26).$$

Exports of good 1 as a fraction of total output of the good are

$$\frac{x_1}{y_1} = \frac{y_1 - c_1}{y_1} = \frac{(\frac{\alpha_2}{\alpha_1})^{\sigma}(1+\tau)^{-\sigma} p^{1-\sigma} - (1+\tau)^{\frac{\gamma}{1-\gamma}} p^{\frac{1}{1-\gamma}} (\frac{h_2}{h_1})^{\frac{\beta}{1-\gamma}}}{1+(\frac{\alpha_2}{\alpha_1})^{\sigma}(1+\tau)^{-\sigma} p^{1-\sigma}} \qquad (27)$$

where x_1 denotes exports of good 1. The two terms in the numerator of the RHS terms in (27) above show the respective contributions of demand and supply to exports. Equation (27) can be simplified by imposing the CRS assumption and carrying out the analysis at the international price, p, only. Note that p is the rate of exchange between agriculture and manufactures between the countries as well as the marginal rate of transformation and substitution locally when τ is zero. A non-zero τ changes the relevant domestic price according to equation (19) above.

Rearrangement of equation (27) shows that

$$x_1 > 0 \text{ if } \left(\frac{\alpha_2}{\alpha_1}\right)^{\sigma}\left(\frac{h_1}{h_2}\right)^{\frac{\beta}{1-\gamma}} > (1+\tau)^{\frac{\gamma+\sigma-\sigma\gamma}{1-\gamma}}\, p^{-\gamma\sigma} \qquad (28).$$

For a small open economy, p is exogenous, hence exports of manufactures are positive, *ceteris paribus*, for a low share of demand of the good (ie. low α_1), a low elasticity of substitution in consumption (ie. low σ) or a high endowment of the sector's human capital (ie. high h_1). Given that endowments change over time due to LBD, a tendency to specialise in exports of the high-tech good is enhanced over time. The small open economy can use policy to change domestic price from the international price and hence influence the pattern of trade. This in turn will affect LBD and hence growth given p is exogenous and assumed fixed for now. A policy designed to encourage production in the high-tech sector will push the economy's growth rate towards δ_1, and this policy intervention need only be imposed until endowments change so as to satisfy (28) above with τ equal to zero. This is the classic case of the infant industry argument for protection. The impact on welfare of this policy intervention depends on the trade-off between the present value of the social cost of such intervention and the gain in GNP over time from the higher LBD. If the initial endowments are such that an infinitesimal amount of h_1 is needed to satisfy (28) then a policy distortion favouring the high-tech sector is going to be welfare enhancing since the short-run costs would be low relative to the long-term gains.

How do the above findings differ from those of Lucas? The imposition of diminishing returns to each factor individually and constant returns in aggregate makes the transformation curve concave for the two goods in each country. In contrast to the model of Lucas (1988) we can now have interior solutions with no country completely specialising in the production of either good under a trading equilibrium. The diminishing returns assumption to each factor has made incomplete specialisation a much more likely outcome. Under free trade the dynamics are similar to those of Lucas in that countries get locked in place on an initial pattern of exports and continually move in the same direction of specialisation unless the terms of trade[7] deteriorate enough to outweigh the gains from learning-by-doing. For a small country and in the limit only (ie. as time approaches infinity) the Ricardian results prevail.

We next consider relaxing the small country assumption, hence allow p to evolve endogenously in response to changes in the stocks of sectoral human capital from LBD.

The Two Country Model

The simplest way of relaxing the small country assumption is to embed the model of the small country case in a two-country framework. Call these two countries North (N) and South (S). Trade is induced between the two countries by introducing some heterogeneity between them. The interesting case involves the South having a lower relative human capital stock than the North in sector 1, and also an intrinsic rate of learning in sector 1 which is no greater - generally less - than the rate in the North. Thus, letting an asterisk on a variable denote the North, in what follows, it shall be assumed that $\delta_1^* \geq \delta_1$ and $z > z^*$ where $z \equiv \dfrac{h_2}{h_1}$ is the relative stock of human capital in sector 2 in the South and z^* is the comparable variable for the North. We require an added condition that global markets for any one[8] good clear. Taking good 1 gives

[7] Terms of trade in this paper refers to the relative price, q.

[8] Walras law then ensures the same holds for the second good.

$$x_1^* + x_1 = 0 \qquad (29).$$

Substituting for x_1 from (27) into (29), setting $\alpha_1 = \alpha_2$ and τ = zero[9], and simplifying the resulting expression gives

$$\left(\frac{h_1}{h_1^*}\right)^\beta \frac{p^{-\sigma} - z^{\frac{\beta}{1-\gamma}} p^{\frac{\gamma}{1-\gamma}}}{p^{-\sigma} - z^{*\frac{\beta}{1-\gamma}} p^{\frac{\gamma}{1-\gamma}}} + \left[\frac{1 + p^{\frac{1}{1-\gamma}} z^{\frac{\beta}{1-\gamma}}}{1 + p^{\frac{1}{1-\gamma}} z^{*\frac{\beta}{1-\gamma}}}\right]^\gamma = 0 \qquad (30).$$

It has not been possible to explicitly solve for p but equation (30) shows that p is a function of the relative endowments of sectoral human capital. Including the demand share parameters and trade policy parameter in (30) adds in more parameters to the equation without providing any further insights. Endowments of sectoral human capital evolves over time through LBD and so does p. This adds a time dimension to the pattern of production and exchange as shown in equation (31) below. The international price p can be interpreted as the rate of exchange between the two goods between the two countries as well as the marginal rates of transformation in production and substitution in consumption domestically. Policy may be used to drive a wedge either at the rate of exchange between the countries or between the two goods in production or[10] consumption domestically.

The Dynamics of Trade and Specialisation.- Dynamics are introduced into the pattern of trade and specialisation by taking the time derivative of (27).

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[9] This is done to reduce clutter in the final expression.
[10] An equal *ad-valorem* consumption tax and production subsidy of the same amount will amount to the same border tariff.

$$\frac{d}{dt}\left(\frac{x_1}{y_1}\right)=\frac{\frac{\beta}{1-\gamma}(A+1)B(\delta_1-\delta_2)-(\sigma-1)A(B+1)\hat{p}-[(A+1)B\frac{\gamma}{1-\gamma}+\sigma A(B+1)]\hat{\tau}'}{(A+1)^2} \tag{31}$$

where

$$A=\left(\frac{\alpha_2}{\alpha_1}\right)^{\sigma}(1+\tau)p^{1-\sigma}\ ,\ B=(1+\tau)^{\frac{\gamma}{1-\gamma}}p^{\frac{1}{1-\gamma}}\left(\frac{h_2}{h_1}\right)^{1-\beta}\ \text{and}\ \ \tau'=(1+\tau).$$

It is clear that A and B are positive for all t. Equation (31) shows that the dynamics of specialisation is comprised of three effects. The first, represented by the first RHS term in (31), is the effect of the learning differential which is positive given our assumption that δ_1 and δ_2 are positive with $\delta_1 > \delta_2$. The second RHS term in (31) constitutes the contribution of changes in the relative price to specialisation.

For a small country this second term is absent altogether given that prices are exogenous and assumed constant for now[11], hence specialisation for the small country case proceeds as dictated by the first term. The third term is the effect of domestic trade policy on pattern of exports. It is only changes in τ that affect export pattern, hence a constant, but possibly non-zero, τ has no role in the dynamics of export specialisation. It is clear that a small country that has an initial static comparative advantage in the low tech sector will, under free trade, specialise in the sector with its long-run growth being equal to the rate of learning in this low tech good. In terms of rate of growth of output, free trade for this economy is worse than autarchy since in the absence of trade the economy would produce both the goods and enjoy a growth rate somewhere in-between δ_1 and δ_2. ie. Trade drives out the high

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[11] The model assumes perfect foresight hence any expected price changes will impinge on pattern of exports. To keep the analysis simple we abstract from the possibility of p changing exogenously.

tech sector from this economy. If policy can be used by this small country to alter its path of specialisation towards the high tech good then (distorted) trade results in a higher rate of growth of output to the country.

For a large country that can influence world market-clearing prices the conclusions are not so clear. The first two terms in equation (31) now work against each other in influencing the pattern of specialisation. It is now possible to completely reverse the pattern of specialisation via the imposition of a tariff when the negative effect of changes in relative price dominate the positive effect of learning. Policy now has both level and growth effects on the pattern of trade, specialisation and welfare. Furthermore, it is shown in the Appendix to this chapter that the two-country model does not have a balanced growth path, hence complete specialisation in at least one country is inevitable.[12] Because it is not possible to obtain general analytic solutions for this model, the above effects are illustrated in the following section via numerical simulations.

3.4 Simulations.

All simulations are carried out in discrete time and for a finite time horizon. These simulations should be considered as representing the short run since the choice of parameters imply the absence of a steady state for the free trade case. This is in contrast to the autarchy case discussed in section 2 above. The model simulated is not based on empirical data, thus this is only an illustrative 'dry' run based on fictitious parameters. For simplicity and concreteness we have called the high tech good (good 1) Manufactures and the low tech good (good 2) Agriculture. We further assume that learning

[12] This issue, which reflects the findings of Baxter (1992), is taken up in further detail in Chapter 4.

occurs only in Manufacturing with $\delta_1 = 0.3$[13] (and $\delta_2 = 0$). Note that setting δ_2 to zero implies that the steady state values of u_1 and q for the autarchy case are zero and infinity, respectively. This can be seen by substitution of the above values of the parameters into equations (11) and (11a) of section 2 above. The intuition for the absence of a steady state is clear. Given that only manufacturing enjoys productivity growth, output of manufacturing grows without bound. Since the output of agriculture is constrained by the resources devoted to the sector, competitive markets ensure that prices of manufactures as well as labour devoted to the sector is driven to zero for any finite σ.

We impose a constant returns to scale (CRS) production technology with β = 0.7. ie. Sector-specific (human) capital has a seventy percent share in production in each sector[14]. We hold the demand side neutral by making $\alpha_1 = \alpha_2 = 0.5$. This enables us to concentrate on the supply side effects of learning where comparative advantage is 'created' over time through the dynamics of learning alone. Lucas (1988:29-30) shows that on trade considerations, the interesting case is when the two goods are good substitutes in consumption (ie. $\sigma > 1$) so we set $\sigma = 1.5$. Sensitivity tests are carried out for σ being equal to 0.5 and 2 with the results reported in Table A1 in the Appendix. The models are simulated over fifteen time periods with the initial conditions chosen such that the initial price and utility are 1 and 0.5, respectively.

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[13] The maximum value of the learning coefficient in the high tech sector of Krugman (1987) of 30% translates approximately into this value for δ_1.

[14] The share of (human) capital in Agriculture of seventy percent may not sound reasonable but interpret this as the share of sector specific capital, land, which remains fixed over all t.

Three sets of simulations are carried out. The first compares the results of the IRS model of Lucas (1988) to the CRS model. The second looks at the effect of trade for a small open economy where terms of trade changes are absent. The last set of simulations is for a two country world where each country is of the same size and has equal influence on equilibrium prices.

IRS versus CRS model. - The IRS model of Lucas (1988: section 5) is simulated by setting the parameters β and γ equal to 1. The rest of the parameters are set identical to that given for the CRS model. The first set of results are for the autarchic case with Table 1 showing the average growth rate of variables of interest over the entire simulation period.

Table 1: Average Growth Rate of Variables in Autarchic Equilibrium

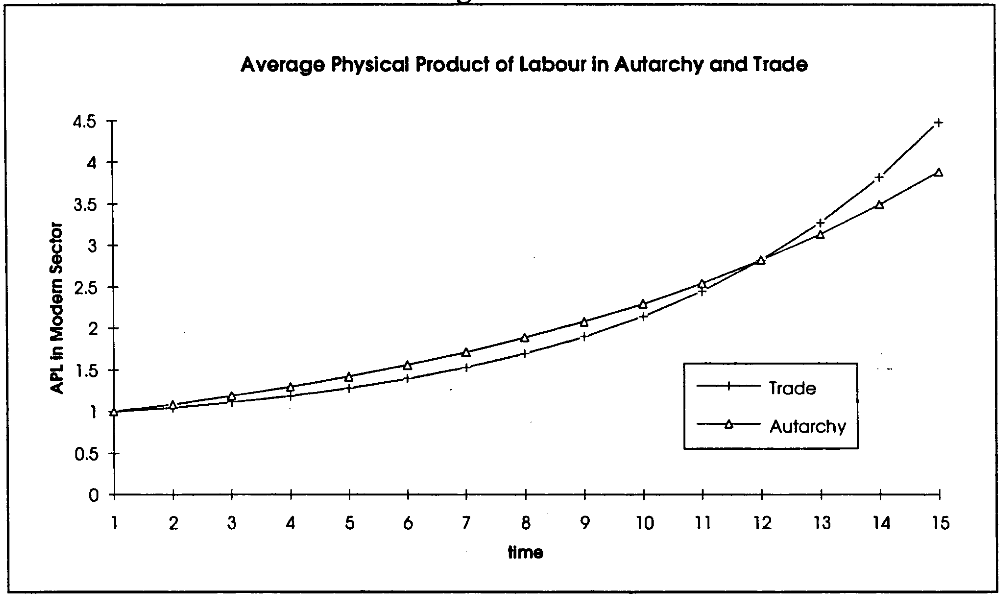
VARIABLE\MODEL	IRS	CRS
Output of Manufacturing (y_1)	0.17	0.10
Output of Agriculture (y_2)	-0.04	-0.01
Relative Price (q =P2/P1)	0.14	0.07
Utility	0.08	0.05

Given that our simulation model has only one primary factor, the average and total factor products are the same. The average product of labour in the high tech sector is higher in the IRS model than the CRS model since total output is higher in the IRS model. For the low-tech agriculture, the average product is constant for the IRS model while a positive trend over time is observed for the CRS model. The latter observation is due to the diminishing returns assumptions of the CRS model. The movement of labour to manufacturing due to learning in the sector raises productivity in low-tech agriculture as well. This rise in productivity in Agriculture predicted by the CRS model is more consistent with reality than the no-change prediction of the IRS model. ie. If we interpret agriculture and manufacturing in the literal sense then history shows rising productivity in both the sectors. The picture for the value of average product of labour is an inverse of that given for the average physical product since in autarchy all productivity changes are completely dissipated by offsetting changes in prices given the assumption of competitive markets. This latter effect is minimal in a trading equilibrium and particularly for a small country.

The Case of the Small Open Economy. - We will next consider the trading equilibrium. The results of trade are driven principally by the terms of trade equation. Imposing the small country assumption with $p = 1$ for all t turns off the terms of trade component of equation (31). This is the simplest scenario to simulate, the results of which should be interpreted as providing the upper bound on gains (or losses) from opening the economy to trade. We confine our attention to the CRS model for the remainder of the exercises.

The average growth rate of utility under free trade for the small country is 9 percent, approximately double that given in Table 1 for the autarchic case. Figure 3-1 shows the average physical product of labour for the high tech-manufacturing sector in the two equilibria.

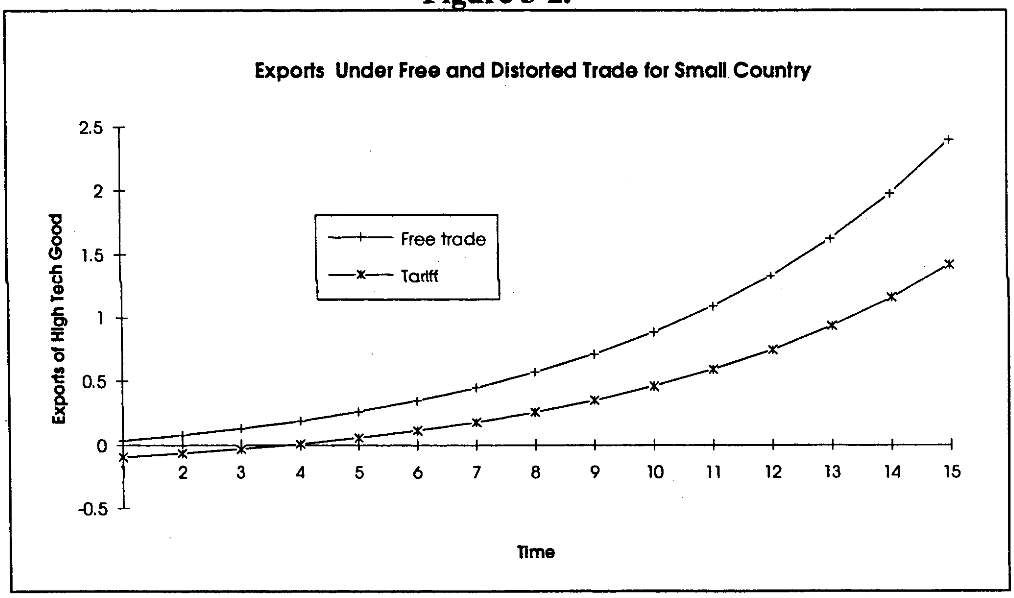
Figure 3-1



The average physical product of labour in the medium term for the high-tech sector is higher in autarchy then under free trade. The competitive equilibrium equates the value of the private marginal product of labour in the two sectors. Given the worsening of the relative price of good 1 in autarchy, this sector employs only 60 percent (as against 86 percent in free trade equilibrium) of the total labour force in the 10th time period. ie. Resource movements are more pronounced in the trading as against the autarchic equilibrium due to the difference in terms of trade effect under the two closures. This explains the lower average product under free trade relative to autarchy in the medium term. Over the longer run, trade allows more resources to shift to the high tech sector which in turn enhances the accumulation of sectoral human capital. Hence, with sufficient time, the average physical product of labour in the high tech sector under trade overtakes that under autarchy. In contrast, the <u>value</u> of the average product of labour is always higher under trade than autarchy given the absence of changes in relative prices in the former. These two effects together imply that the value of production is always higher under trade than in autarchy, hence consumption and utility are both higher under trade than in its absence.

Imposition of a tariff for this small economy has only a short term effect on the pattern of trade and specialisation. Over time the effect of the border distortion diminishes with the long run pattern of trade and specialisation determined completely by (Ricardian dynamic) comparative advantage. Figure 3-2 shows the pattern of imports under free trade and when an export subsidy of thirty percent is imposed on Agriculture.

Figure 3-2.



In the short term the export subsidy to low tech agriculture reverses the pattern of trade. The small country that exported high tech manufactures under free trade now exports low tech agriculture as a result of the imposition of an export subsidy (export tax) on agriculture (manufactures). But, this has only short-term effects. Over the longer run, the dynamics of learning push the small country back to exporting high-tech manufactures, the good in which it has true comparative advantage. Hence, errors in picking of "winners" do not have long term effects on pattern of specialisation.

The Two-Country Model. - We need heterogeneity between the two countries to induce trade. This is done by making the North have a slight learning advantage over the South but only for the high-tech sector. Specifically, we set the learning coefficient (δ_1) in the South 0.01 lower than the 0.3 of the North. The values of the rest of the parameters of the model are identical to those given above.

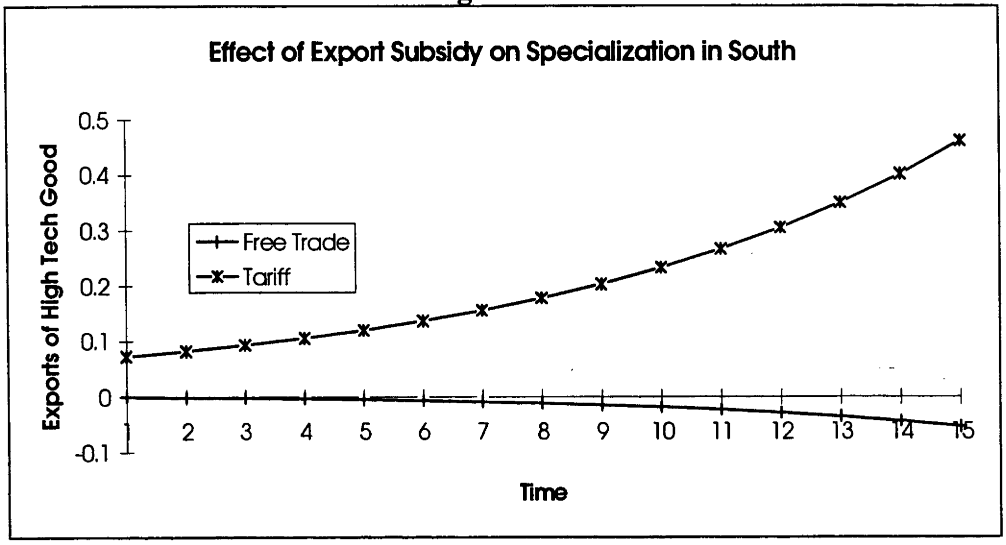
Let us first consider what the social planner would do in this world. The social planner's problem now is to allocate production between the two countries subject to the constraint that labour is immobile between the countries. The production decision would be the same as that reached under free trade but would also involve some transfer of resources from North to South given North gains in utility at the expense of South. ie. Free trade makes North specialise in manufactures but this leads to North getting a larger share of the gains from LBD than in the absence of trade. The social planner would need to transfer some of this gain to South so as to ensure gains from trade accrue to both the economies.

We explore these issues further through more simulations. At time t=0 the two countries have identical endowments implying there is no incentive to trade at this point in time. Note that we have set our initial conditions such that comparative advantage is 'created' over time via the difference in the rate of learning in the high-tech sector alone between the two countries. We now ask whether it is possible to use border distortions to completely alter the path of specialisation and trade in this set-up. We know from Section 3.3 above that the dynamics of comparative advantage in this two-country world depend on technological considerations (Ricardian dynamic comparative advantage) and pattern of distortionary taxation that affects equilibrium prices.

Under free trade, North specialises in the exports of the high tech manufactures while South specialises in the exports of low-tech agriculture. The relative price change in favour of the low tech agriculture and the dynamics of learning push each economy further into its own pattern of specialisation as determined by the difference in learning rates. North gains at the expense of South since it (North) gets a bigger share of the production externality under free trade then otherwise. We now let South subsidise its high-tech sector by providing a thirty percent export subsidy to the sector. Recall that a tariff, as modelled in this framework, becomes an export subsidy when an import switches to becoming an export. This results in a complete reversal of the pattern of trade and specialisation from that predicted by the Ricardian model under free trade. This is shown in Figure 3-3 below. We allow South to intervene in the trade of the high-tech good. In this experiment, the South imposes an export subsidy[15] of 30 percent on the output of the high-tech sector. North maintains a free-trade stance in all the experiments.

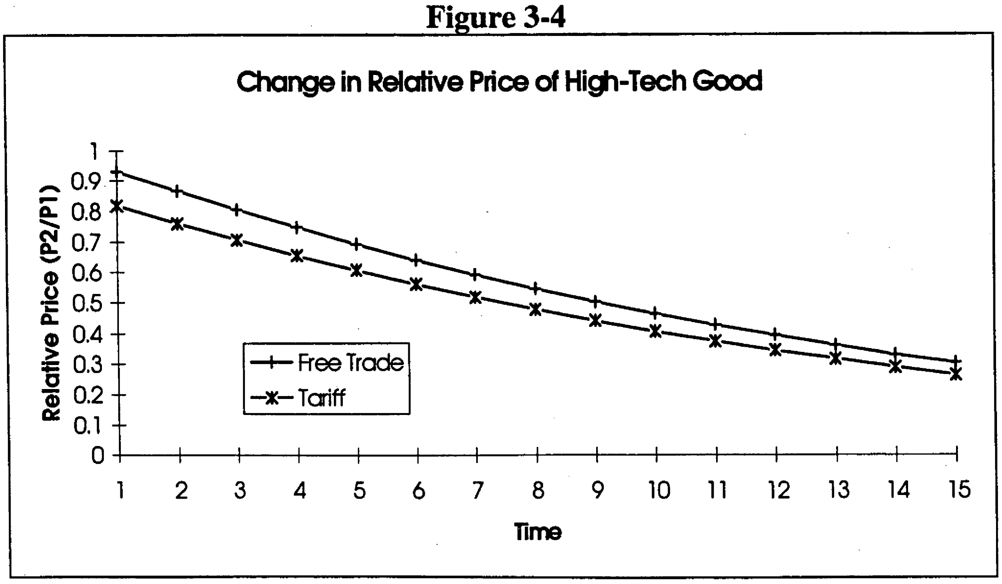
[15] Note that export subsidy is treated as an import tariff when the pattern of trade reverses.

Figure 3-3



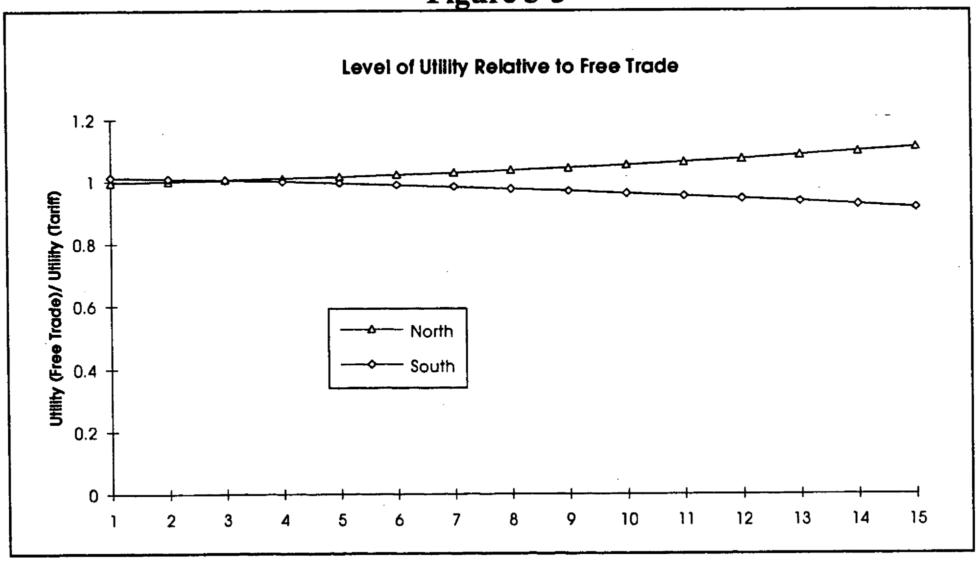
The reversal in the pattern of trade and specialisation is attributable to the terms-of-trade effect dominating the effects of learning. The zero-trade axis now acts as a razor's edge with tariffs being sufficient to push the economy to either side of this edge. Figure 3-4 shows the changes in relative price of good 1 under free and distorted trade.

Figure 3-4



The tariff has both reduced the level and rate of deterioration of the relative price of good 1. We next ask whether these distortions have any implications for the level and rate of growth of utility in the two economies. Figure 3-5 below shows the implications of the above distortion on utility in each country relative to free trade.

Figure 3-5



The border distortion introduced by the South brings about a short term gain in utility due to the adverse effects of its policy on the relative price of manufactures. The longer run is characterised by the North gaining at the expense of the South, hence the net gain to the South as a result of it's policy intervention depends on the discount rate employed to make the comparison.

The lessons from this experiment are the following: Free trade crowds out the high tech manufacturing sector in the South when endowments in the country are infinitesimally lower than that in North. In such a situation infant industry protection (Corden 1974: Chapter 4) in a permanent[16] form shifts gains from North to South, but this occurs only in the short term. The existence of dynamic economies of scale and the failure of the market to compensate for the immiserising effect of trade justify intervention for short term gains. If we

[16] This in contrast to Corden who shows that infant industry argument is valid for short term protection only.

allowed the learning rate in the high tech sector in South to catch-up[17], then protection would only be needed up to the stage when the South's endowments would have grown so as to give it a comparative advantage in the production of manufactures. This would have fresh implications for levels and rate of growth of welfare. We look at this possibility in the next Chapter.

3.5 Conclusion

Trade theory, as its fundamental problem, attempts to identify the determinants of specialisation and the pattern of trade. Of concern to international trade economists has been the question of role of policy in influencing trade patterns and growth. Conventional wisdom within the profession has been that free trade is efficient (Mussa 1993, Krugman 1993b) but reality has always been far from this ideal as pictured by the theorists. We have in this paper concentrated on how growth is affected by trade through its impact on the allocation of resources across sectors. Policy in this framework has a role since it can influence the allocation of resources between the sectors. But the stakes for policy blunders are much higher for large countries than for small countries. We have illustrated how in the case of the large country that the pattern of specialisation and long-run growth can be drastically affected by policy, a result in sharp contrast with the predictions of the traditional neo-classical models of growth.

Standard trade theory, with its extensive reliance on the factor proportions model, fails to give answers on the dynamic effects of international trade and policy on technological progress and growth in welfare. This chapter has extended the static Ricardo-Viner model to address these dynamic issues. Border distortions are shown to have only transitory effects on the pattern of specialisation and trade for a small open economy while potentially drastic

[17] This is probably realistic and is expanded upon in the next chapter.

and permanent effects are possible for a large economy. Simulations demonstrate that resource movements are more pronounced under trade than autarchy, consequently affecting average product, productivity and the level as well as the rate of growth of welfare.

One of the criticisms of our model and of endogenous growth models in general is their reliance on very special functional forms for the results. Our endogenous growth results rely exclusively on the human capital accumulation equation. The fact that our model is neo-classical except for the LBD equation, which *a-priori* has no reason to be otherwise, offers some hope for the usefulness of "old" tools of economics for analysing dynamic issues as growth and specialisation.

The model as yet is very crude and requires a number of modifications to enable it to capture the salient features of reality. Nevertheless, two qualifiers are in order: First, endogenous growth in the model is due solely to dynamic scale economies being wholly external to the producer; and second, all productivity changes and growth are the result of human capital accumulation as determined by the learning parameters. In reality economies initial conditions perhaps matter as much as anything else in determining trade pattern, specialisation and growth. Learning parameters, probably, change over time. But if we are to carry out controlled experiments then introducing the above simplifications are necessary. This raises a number of issues for future research, some of which are proposed below.

Proposed future research. The discussion above has assumed that the effects of learning do not spill across national boundaries. The assumption that in a two-country world one country permanently lags behind another is unrealistic and against the spirit of the literature on catch-up and convergence.

Allowance, therefore, has to be made for some form of diffusion of technology and catch-up in learning rates between the countries. The two country model can be used to study the pattern of relative wage growth in the context of North-South trade. This issue is taken up in the next Chapter.

The two-sector case has analytical tractability hence its extensive use. Any meaningful empirical work requires the incorporation of more than two sectors. This is an issue that is addressed in the empirical part of the thesis.

The infinite time horizon with a positive externality has been central to the endogenous growth results. Will these results hold in an overlapping generations framework when some of the EOS are internalised? Furthermore, individuals live for finite periods and probably maximise their lifetime utility while the social planner is infinitely lived and therefore has a different time horizon. Could there be a conflict between these two institutions? These issues are not addressed in the thesis but remain on the current research agenda.

APPENDIX

Proof that the Two-Country Model has No Balanced Growth Path Under Free Trade

Assume that a balanced growth path exists. From (2) and (7) incomplete specialisation implies

$$\frac{y_2}{y_1} = \left(\frac{h_2}{h_1}\right)^{\frac{\beta}{1-\gamma}} q^{\frac{\gamma}{1-\gamma}} \qquad \text{(A1).}$$

The existence of a balanced growth path implies that for each country

$$\hat{y}_2 - \hat{y}_1 = 0 \qquad \text{(A2)}$$

which on substitution from (A1) gives

$$\beta\hat{z} = -\gamma\hat{p} \qquad \text{(A3)}$$

where $z = \frac{h_2}{h_1}$. Using an analogous expression for North together with (A3) implies

$$\hat{z} = \hat{z}^* \qquad \text{(A4).}$$

Using (3) and noting that $u_2 = 1 - u_1$ gives

$$\delta_2 - (\delta_1 + \delta_2)u_1 = \delta_2^* - (\delta_1^* + \delta_2^*)u_1^* \qquad \text{(A5).}$$

Since we are assuming $\delta_1^* \geq \delta_1$ and $\delta_2^* = \delta_2$, rearrangement of (A5) gives

$$\frac{u_1}{u_1^*} = \frac{\delta_1^* + \delta_2}{\delta_1 + \delta_2} > (=) 1 \text{ for } \delta_1^* > (=) \delta_1 \qquad \text{(A6).}$$

Also, assuming that $z(0) > z^*(0)$ [ie. $h_1(0) < h_1{}^*(0)$; $h_2(0) \geq h_2{}^*(0)$], it is straightforward to show that

$$z(t) > z^*(t) \qquad \forall t.$$

To show this we note from (7), under incomplete specialisation,

$$p = \frac{1}{z^\beta}\left(\frac{u_2}{u_1}\right)^{1-\gamma} = \frac{1}{(z^*)^\beta}\left(\frac{u_2^*}{u_1^*}\right)^{1-\gamma} \qquad \text{(A7)}$$

Since $u_2 = 1 - u_1$, this can be written as:

$$\frac{1}{z^\beta}\left(\frac{1}{u_1} - 1\right)^{1-\gamma} = \frac{1}{(z^*)^\beta}\left(\frac{1}{u_1^*} - 1\right)^{1-\gamma} \qquad \text{(A8)}$$

$$\therefore \; z(0) > z^*(0) \Rightarrow \frac{1}{u_1(0)} > \frac{1}{u_1^*(0)} \Rightarrow u_1(0) < u_1^*(0).$$

This implies that

$$\hat{z}(0) - \hat{z}^*(0) = (\delta_1^* + \delta_2)u_1^*(0) - (\delta_1 + \delta_2)u_1(0) \geq (\delta_1 + \delta_2)(u_1^*(0) - u_1(0)) > 0.$$

Thus it follows that $z(t) > z^*(t) \quad \forall t \geq 0$. In other words, if the South starts behind (z > z*), it <u>cannot</u> reverse this through LBD if $\delta_1 < \delta_1^*$. This is because under incomplete specialisation, the South would put relatively less labour into the high-tech sector ($u_1 < u_1^*$). Hence, growth in h_1 ($=\delta_1 u_1$) in the South cannot be greater than that in the North.

Incomplete specialisation from (A7) with $z(t) > z^*(t)$ implies $u_1(t) < u_1^*(t)$ which contradicts (A6). Hence, there is no long-run balanced growth path for the case we are considering ($\delta_1^* \geq \delta_1$, $z > z^*$).

Table A1: Average Growth Rate of Variables for different values of σ in Autarchic Equilibrium

VARIABLE\MODEL	LINEAR		CRS	
	σ =0.5	σ =2.0	σ =0.5	σ =2.0
Output of Manufacturing (y1)	0.07	0.22	0.07	0.11
Output of Agriculture (y2)	0.02	-0.12	0.01	-0.01
Relative Price (q =P2/P1)	0.11	0.17	0.11	0.06
Utility	0.05	0.12	0.03	0.06

Chapter 4

North-South Trade, Technology Diffusion, Wages and Growth.

Abstract

This chapter presents a simple dynamic model that provides a theoretical basis for the observed diverse patterns of evolution of wages in the countries of the South relative to those in the North. Technology creation by learning-by-doing (LBD) in the North and the process of technology diffusion from technology-rich North to technology-scarce South are used as the principal explanators. In the long-run, wages in the South converge to those in the North when the two goods have elasticity of substitution that is less than unity. For the short-run, several results are deduced with the aid of numerical simulations. In particular free trade is *Pareto-superior* to distorted trade when diffusion takes place. The welfare cost of distorting trade is greater the higher the rate of technology accumulation in the North and the more rapid the diffusion process. Wages in the South rise in response to a rise in the level of diffusion and an increase in the protection accorded to agriculture in the North and/or manufacturing in the South, but with a detrimental impact on welfare of the countries individually as well as collectively.

4.1 Introduction

The fact that people with human capital migrate from places where it is scarce to places where it is abundant, as observed by Lucas (1988), is contrary to the predictions of neo-classical theory. At a superficial level, the migration of workers from the South to the North can be explained by observing wage differentials between the two regions. But the reasons for the observed disparity in wages between countries is as yet unexplained. This chapter uses recent advances in endogenous growth theory to explain one possible reason for wage divergence between the North and the South.

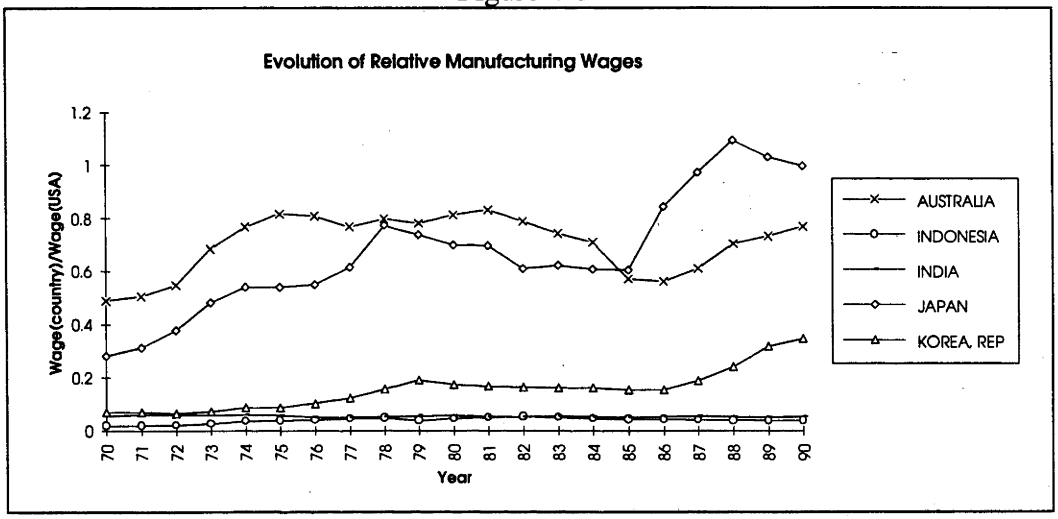
The chapter develops a simple two-country dynamic model which may be used to explain different patterns of evolution of wages in the South relative to those in the North. The stocks of human capital, interpreted synonymously with technology, its generation and diffusion from the technology-rich North to the technology-scarce South are the principal explanators. The implications of the evolution of the above variables with the role of policy on the evolutionary process and ultimately on welfare both at the country and global level are also analysed. But first, we consider the evidence on wage variability over time as well as across countries at any given point in time.

The variability in levels of relative wages across countries at any point in time as well as over time for any given country is surprisingly large[1]. For example, in 1989 an average Bangladeshi manufacturing employee earned one fiftieth the wage of his US counterpart. Even after correcting for PPP differences using Penn World Tables price level of consumption data (Summers and

[1] Data from the International Economic Data Bank (IEDB) at the Australian National University on total manufacturing wages and number of employees in the sector over the last two decades for a large sample of countries is used to calculate average wages in US dollars of employees in the sector. US wages are used as the numeraire for inter-country comparisons.

Heston 1991) this ratio drops by half but is still by no means trivial. The time path of evolution of relative wages between the countries is equally diverse. Figure 4-1 below shows the evolution of manufacturing wages relative to their level in the US for a sub-sample of countries from our data set.

Figure 4-1



Korean manufacturing wages were approximately seven percent of the US wages in 1970 but rose steadily over time to a figure of 35 percent in 1992. Japan started off in 1970 with its manufacturing wage at 28 percent of the US but this rose to approximately 8 percent <u>above</u> the US by 1991. India started off in 1970 with a figure of 6 percent but this dropped to 5 percent by 1990. That there should be such large differences in wages and in the pattern of evolution of wages between countries over time - even after correcting for PPP differences - is surprising. Measurement problems may explain some of this disparity but it is difficult to imagine that all variability in relative wages could be attributed to measurement error alone. In terms of hours worked, ILO data shows little variability between countries, and where-ever it does, the bias in terms of longer hours worked is towards the less developed countries (see ILO data for details on hours worked).

The issues investigated in this chapter are: why is labour so cheap in some countries in the South but not others and; more importantly, why is the pattern of evolution of wages so different amongst these same countries. This chapter attempts to shed some light on these two issues and explores their linkages with growth (in welfare). Before proceeding, it is worth noting the inadequacy of some existing explanations for the observed variations in wages between the North and the South. For example, the notion of disguised employment in the manufacturing sector is an unsatisfactory explanation given that agriculture is the "holding" sector for surplus labour (Bardhan 1993). Furthermore, manufacturing firms regardless of location are profit maximisers and therefore will not employ labour in excess of that required for profit maximisation. Additionally, these same firms are now considered to be mobile between countries so as to exploit profit making opportunities via choice of locational variables (Bhagwati and Dehejia 1994), hence their decisions to operate in the South is based on profit maximisation. The notion of <u>expensive</u> and scarce capital in the South, implying substitution of labour for capital, is also inadequate as an explanation of the wage divergence - as Bardhan (1993) has observed returns to (physical) capital differ little between countries. This chapter offers an alternative explanation based on the theory of human capital, its accumulation and the process of diffusion of technology from the technology-rich North to the technology-poor South.

The issue of evolution of wages is dynamic, therefore our analysis is carried out in a dynamic framework. Conventional trade theory, with its extensive reliance on the static factor proportions model, fails to give answers on the dynamic effects of technology diffusion on evolution of factor payments and growth in welfare. Despite the voluminous empirical research in support of the hypothesis that openness promotes growth (see for example World Bank

1988, Edwards 1992, etc.), this literature is still inconclusive in its findings due to the absence of rigorous theory to support such empirical work (Leamer 1992). This chapter attempts to narrow this gap between trade and growth theory and the empirical literature on the effect of openness on growth.

The Analytical Framework

Consider a world comprising two countries, the North and the South, each producing two final goods, manufactures and agriculture. A constant returns to scale (CRS) Ricardo-Viner production technology is assumed. This is consistent with Kohli (1993) who finds empirical support for technology represented by the specific-factors as against the mobile-factors Heckscher-Ohlin model. Dynamics are introduced into the analysis by incorporating the accumulation of sector-specific human capital via learning-by-doing (LBD from now on). The diffusion of technology in this context involves the movement of this sectoral (disembodied[2]) human capital from the technology-rich North to the technology-scarce South. This chapter, like the previous one, retains the assumption of perfectly competitive markets where LBD is a production externality.

The main findings are: In the long run, a positive technology gap exists between the North and the South for a constant rate of technology creation in the North and a positive level of diffusion of technology from the North to the South; and wages in the South converge to their level in the North when the two goods have elasticity of substitution that is less than unity. Short run numerical simulations suggest that free trade is preferred to distorted trade when diffusion is allowed. In terms of comparative statics, a rise in the level of diffusion brings about a decline in the wage gap between the two countries.

[2] Assumption of absence of labour mobility between countries is retained.

One disconcerting implication of the model is that diffusion substitutes for product trade, hence the volume of (inter-industry) trade in the presence of diffusion declines over time . This last observation may be in conflict with one of the 'stylised facts' of world trade (Baxter, 1992), but the observed rise in volume of world trade over time is due to increases in intra-industry as against inter-industry trade (Tharakan and Kol 1989), a phenomenon not captured by our model.

In the model, technology is represented by the stock of sectoral human capital. The production function entails use of physical units of labour and the stock of available human capital to produce sectoral output. We maintain the assumption of constant returns to scale in production, hence our production function is neo-classical. Human capital accumulates over time at a rate dependent on output. The average product of labour grows over time due to this accumulation of human capital. Since labour is the only primary factor of production, total factor productivity growth is represented by growth in the physical product of labour. Given competitive markets, wages are equal to the value of the physical marginal product of labour.

Technology diffuses from the technology-rich North to the technology-scarce South. This diffusion process is modelled following the two specifications of Nelson and Phelps (1966). In adapting the two models of technology diffusion of Nelson and Phelps we make three important changes to their models. First, we endogenise technology creation. Second, unlike Nelson and Phelps who assume that technology adoption is a function of educational attainment only, we assume that the rate of technology diffusion to the South is a function of a host of variables of which the level of education is but one. Lastly, the contexts of the analysis are different. Nelson and Phelps model the rate of adoption of technology that grows at an exogenous rate while we study the rate of diffusion of technology from North to South. Despite the above differences, our analysis of diffusion retains close parallels with the analysis of Nelson and Phelps.

Our analysis differs from the popular literature on intellectual property protection (IPP), as in Chin and Grossman (1990), Diwan and Rodrik (1991), and Helpman (1992), in a number of important respects. Most IPP models assume and often require the existence of imperfect competition. The analysis is often at the firm level. The incentive for the firms in the North to innovate is provided by their ability to reap monopoly rents up until the exhaustion of their lead in the product quality or superior production process. The existence of strict intellectual property rights in the South enhances this ability of the firms in the North to reap these short term monopoly rents, which often is argued as being the payment for R&D effort.

The analysis of the immiserising effect of North-South trade on wages of the unskilled in the North[3] as in Bhagwati (1994) and Lawrence and Slatter (1993) is beyond the scope of this chapter and is left as one of the issues for future research. The concern in this chapter is on the evolution of wages in the South relative to wages in the North, the contribution of policy and technology diffusion to this evolutionary process and the implications of the above for individual country and global welfare.

The rest of the chapter is organised as follows. The next section presents the basic model and incorporates the role of policy in the determination of wages and welfare. The third section incorporates technology creation and diffusion in the model, while the following section analyses relative wages. The fifth section shows via numerical simulations the dynamics of the evolution of

[3] This is often referred to as the Perot hypothesis (see *The Economist* of October 1st, 1994).

relative wages and welfare under different assumptions about diffusion of technology. Conclusions, caveats on the current analysis and suggestions for further work are offered in the final three sections.

4.2 The Model

Lucas (1988) examines the role of trade in growth using an increasing returns to scale (IRS) production technology. In contrast, the present analysis employs a CRS production technology in a two-good two-country world. We show elsewhere[4] that the IRS assumption is not necessary for perpetual growth in the Lucas model. LBD takes place in each sector and is the sole source of perpetual growth. The North differs from the South in that it initially has a higher stock of human capital in the high tech (manufacturing) sector.

Production technology

Each of the two goods, manufacturing (good 1) and agriculture (good 2), is produced using Ricardo-Viner CRS production technology by using sectoral human capital and labour. The CRS assumption implies diminishing returns to each factor individually and constant returns in aggregate, hence the production function is neo-classical. Furthermore, the CRS assumption makes the possibility of complete and instantaneous specialisation under trade less likely, in contrast to the IRS model of Lucas. The production function is given by

$$y_i(t) = A_i(t)h_i(t)^{\beta} N_i(t)^{\gamma} \qquad (1)$$

---

[4] See Chapter 3.

where y_i is sectoral output, h_i is the sectoral human capital, N_i ($\sum_i N_i = N$) the quantity of labour employed in sector i and A_i is the level of technology in sector i.

We abstract from the issues of Hicks-neutral technical progress and population growth and normalise both A and N to 1 for all t. Now (1) becomes

$$y_i(t) = h_i(t)^{\beta} u_i(t)^{\gamma} \quad , \beta + \gamma = 1 \qquad (2)$$

where u_i ($\Sigma u_i = 1$) is the fraction of a country's total labour employed in sector i.

The Initial Conditions

At some initial date t = 0 the North has its stock of sectoral human capital greater than the South by a factor ψ (≥ 1). ie.

$$h_i^N(0) = \psi_i h_i^S(0), \qquad \psi \geq 1 \qquad (3)$$

Let ψ be strictly greater than unity for manufacturing and equal to unity for agriculture. Thus, the two countries differ at some initial date, t = 0, only in their endowments of manufacturing sectoral human capital. Dynamics is introduced by incorporating sectoral human capital accumulation via learning-by-doing (LBD).

Learning/ Human Capital Accumulation

The North accumulates human capital in direct proportion to the fraction of resources it devotes to the sector and the magnitude of its (constant) learning parameter as in Lucas and elaborated upon in Chapter 3.

$$\dot{h}_i^N(t) = \delta_i^N u_i^N(t) h_i^N(t) \qquad (4)^5.$$

The learning parameter, δ, is assumed constant because it represents the rate of learning for the aggregate sector which may constitute the production of a changing mix of goods within the industry over time, as in Young (1991). The South accumulates its human capital via two means. First, it accumulates its own indigenous technology via a process analogous to equation (4) above. Second, human capital may diffuse from North to South. This diffusion of technology (human capital) from North to South does not deplete the stock of human capital in the North since technology is non-rival in, but excludable from, usage (Romer 1990). The poorer research infrastructure in the South may imply that the indigenous rate of LBD in the high-tech manufacturing sector in the South is lower than that in the North. ie. $\delta_1^S < \delta_1^N$. But this is not required for the results that follow. All of the learning is assumed to be an industry phenomenon beyond the purview of any individual producer. Hence, learning is simply a dynamic production externality.

We next consider the welfare implications of the technology creation both under autarchy and trade. This requires explicit consideration of preferences and representation of the consumer's budget constraint.

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5 A dot and circumflex over a variable represent the time and log time derivative, respectively, of the variable.

Preferences

Each of the two economies is populated by a single representative agent who is both a producer and consumer of the two final goods, agriculture (subscripted by 2) and manufactures (subscripted by 1), with preferences given by the CES instantaneous utility function

$$U(c_1,c_2)=[\alpha_1 c_1^{-\rho}+\alpha_2 c_2^{-\rho}]^{-1/\rho}, \quad \alpha_1+\alpha_2=1 \qquad (5).$$

We assume that the agent is myopic, implying inter-temporal separability of U. Note that leisure is absent from the utility function. The interpretation is that the agent decides to devote a fixed fraction of time to productive work, the income of which is then used to purchase the two consumption goods, c_1 and c_2.

Let q and p, respectively, be the domestic and world equilibrium price of agriculture (good 2) relative to the price of manufactures (good 1)[6]. Thus, q = q_2/q_1 and p = p_2/p_1. Consumer optimisation gives relative demand as

$$\frac{c_2}{c_1}=(\frac{\alpha_2}{\alpha_1})^{\sigma} q_d^{-\sigma} \qquad (6)$$

where $\sigma = 1/(1+\rho)$, is the elasticity of substitution in final consumption between manufactures and agriculture.

Analogously, producer optimisation gives relative supply as

[6] p may be interpreted as the (real) exchange rate between agriculture and manufactures.

$$\frac{y_2}{y_1} = q_x^{\frac{1}{1-\gamma}} (\frac{h_2}{h_1})^{\frac{\beta}{1-\gamma}} \qquad (7),$$

where q_d and q_x are the domestic prices faced by consumers and producers, respectively. Equation (6) shows demand as a function of the demand share parameters, price and the elasticity of substitution between the two goods. Equation (7) shows relative supply as a function of price, endowments of sectoral human capital and the production elasticities.

Autarchic Equilibrium

The steady state[7] autarchic equilibrium is characterised by each country producing both the goods with the rate of growth of technology, utility and output given by

$$\hat{h}_i^{A*} = \frac{\delta_1 \delta_2}{\delta_1 + \delta_2} \qquad (8),$$

and

$$\hat{U}^{A*} = \hat{y}_i^{A*} = \beta \frac{\delta_1 \delta_2}{\delta_1 + \delta_2} \qquad (9)$$

where superscript A^* denotes the autarchic steady state solutions and country superscripts have been omitted for notational clarity. Equation (9) shows that the rate of growth of utility (and output) is equal to the rate of growth of technology weighted by its share in production.

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[7] The steady state is defined as when relative prices are constant (ie. $\hat{q} = 0$). This is consistent with Lucas (1988).

Trade

Introducing trade in the above framework involves incorporating the trade balance constraint. Let trade balance each period so that

$$y_1 + py_2 = c_1 + pc_2, \quad \forall t \qquad (10)$$

for any one country[8]. Note that (10) is the budget constraint of the representative agent who maximises (5) by purchasing his basket of goods from the sale of labour all valued at the international price, p.

Let manufacturing be the high-tech sector in that $\delta_1 > \delta_2$ in both the countries. In the long-run (steady state) with free trade at least one country completely specialises in production.[9] The pattern of specialisation is easy to establish. On the commencement of trade, the difference in autarchy prices is

$$p^N - p^S = \left(\frac{\alpha_1}{\alpha_2}\right)^{\frac{\sigma(1-\gamma)}{\gamma+\sigma-\gamma\sigma}}\left[\frac{1}{z^N} - \frac{1}{z^S}\right] > 0 \qquad (11)$$

where $z = \frac{h_2}{h_1}$. Since $z^S > z^N$ by assumption, North specialises in the export of manufactures while the South in agriculture. The case where incentives exist for technology diffusion from North to South is where the North is completely specialised and the South produces both the goods. In such an equilibrium the price in the South will determine the world market clearing price (Baxter 1992). In contrast, the case where the two countries are completely specialised in production leaves no incentives for diffusion. In such an equilibrium the growth in world output is given by

[8] Walras law then ensures that the constraint holds for the second country.
[9] This result echoes similar results arrived at in Baxter (1992). Proof is given in Appendix to Chapter 3.

$$\hat{y}_1^{T*} = \beta\delta_1^{N} \qquad \text{and} \qquad \hat{y}_2^{T*} = \beta\delta_2^{S} \qquad (12)$$

while growth in global utility is given by

$$\hat{U}^{T*} = \beta[\alpha_1 c_1^{-\rho} + \alpha_2 c_2^{-\rho}]^{-1}[\alpha_1 c_1^{-\rho}\delta_1^{N} + \alpha_2 c_2^{-\rho}\delta_2^{S}] \qquad (13).$$

The world price in this equilibrium is determined solely by demand (see Baxter 1992). With complete specialisation by both the countries, trade is beneficial to global growth in welfare if the RHS of (13) is greater than the RHS of (9) averaged over the two countries. This will be true as long as relative endowments of sectoral human capital, z, are sufficiently different between the two countries. The intuition is analogous to the arguments for trade in a Ricardian static world.

We now consider the role of diffusion in this model. The only interesting case to consider is where, in the long-run, the North is completely specialised in production of manufactures while South produces both the goods. The appropriation of the gains to the two countries from technology accumulation is now done by the price mechanism where the market clearing price is the price in the South.

4.3 Technology Creation and Diffusion

Technology is interpreted as the stock of sectoral human capital. This stock grows in the North by LBD and then may diffuse to the South. The stock of technology in the North at any instant T is given by solving the differential equation (4) which gives

$$h^N(T) = h_0^N e^{\delta^N \int_0^T u(t)dt} \qquad (14)$$

where sectoral subscripts have been dropped for notational simplicity. Equation (14) states that the stock of human capital at some instant T is equal to the initial stock that has grown by the rate of learning adjusted for by LBD as represented by the total amount of resources devoted to the sector up until T. Equation (14) shows that both the initial condition and history matter in the determination of sectoral human capital stocks.

The North, by assumption, has higher manufacturing human capital and hence a comparative advantage in the production of manufactures. Complete specialisation in the long-run implies that u(t) equals unity for all t in (14) above. Thus (14) simplifies to

$$h^N(T) = h_0^N e^{\delta^N T} \qquad (15).$$

Technology Diffusion

To keep the analysis simple we assume no LBD in the South.[10] ie. The South acquires all its manufacturing human capital via diffusion only. To keep things simple and focus on the role of diffusion, assume that technology grows only in Northern manufacturing, hence set δ_1^S, δ_2^S and δ_2^N to zero while δ_1^N is strictly positive[11]. Apart from the assumption that $\delta_2 = 0$, this is consistent with Bliss (1989) who argues that most of the technological progress in the developing countries involves moving local practice closer to the best practice in the advanced countries. We follow Nelson and Phelps and adapt their two specifications of technology diffusion.

[10] Relaxing this assumption gives the possibility of leapfrogging between the two countries. See Section 4.7.

[11] Simulations of Section 5 relax these assumptions of zero values on the learning parameters.

First Model of Diffusion: We postulate that there is a lag ω before the South adopts the technology of the North. The length of this lag is a function of an amalgam of variables constituting the level of education[12] in the South, the degree of trade, the level of communications between the two countries, etc. We call this amalgam of variables G and interpret it as being a vector comprising all the variables referred to above. Technology adoption has a positive opportunity cost which reflects the fact that the South has to invest in order to acquire foreign technology. We choose units of each variable in G such that an increase in any components of G reduce the length of the lag. Specifically,

$$h^S(T) = h_0{}^N e^{\delta^N(T-\omega(G))}, \qquad \omega'(G) < 0 \qquad (16).$$

The marginal productivity of G with respect to the stock of technology in the South is an increasing function of the learning coefficient, δ^N, as shown by equation (17) below.

$$\frac{\partial h^S}{\partial G} = -\delta^N \omega'(G) h_0{}^N e^{\delta^N(T-\omega(G))} = -\delta^N \omega'(G) h^S > 0 \qquad (17).$$

We now deduce our first result. Equation (17) shows that the more technologically progressive the North the greater the gain in terms of technology stocks to the South from increasing G.

The first model employs the lag as the distinguishing feature between technology in the North as against that in the South. Though this formulation

[12] A number of studies including Barro (1991) and Ogawa *et al* (1993) attribute the rapid growth of Japan and the Asian NICs to their ability to adopt and adapt advanced Western technology, made possible by the rich human resource base of these countries.

is simple, hence its attractiveness, it is unsatisfactory in that the diffusion process is considered independent of the opportunities for making profit from such adoptions. Nelson and Phelps propose an alternate model that rectifies this shortfall. We adapt this second model in the analysis that follows.

Second Model of Diffusion: This model postulates that the rate at which the South adopts Northern technology depends upon G, as defined above, and also on the technology gap between the two countries.[13] Specifically,

$$\dot{h}^S(t) = \phi(G)[h^N(t) - h^S(t)], \qquad \phi(0) = 0 \text{ and } \phi'(\mathrm{G}) > 0 \qquad (18).$$

The two conditions on the RHS of (18) postulate that technology does not diffuse below a certain threshold[14] value of G, normalised to zero, and an increase in G, *ceteris paribus*, increases diffusion. Solving the differential equation (18) after substituting in equation (15) gives

$$h^S(t) = [h_0{}^S - \frac{\phi}{\phi + \delta^N} h_0{}^N]e^{-\phi t} + \frac{\phi}{\phi + \delta^N} h^N(t) \qquad (19).$$

The first RHS term in equation (19) shows the role of initial conditions - the effect of these on technology stocks in the South diminishes over time. The second term prevails in the long run, hence the long-run equilibrium path of technology in the South is characterised by

$$h^{S^*}(t) = \frac{\phi}{\phi + \delta} h^N(t) \qquad (20)$$

[13] This formulation encompasses the notion from the physical sciences that the degree of pressure for diffusion is directly proportional to the extent of difference between the two states.

[14] The intuition for the existence of this threshold is similar to that given in Azariadis *et al* (1990).

and the equilibrium technology gap is given by

$$\frac{h^N(t)-h^{S^*}(t)}{h^{S^*}(t)}=\frac{\delta^N}{\phi(G)} \qquad (21)$$

Equation (21) gives us our second set of results. In a technologically stagnant sector ($\delta^N = 0$), the gap approaches zero for any positive G while in a technologically progressive sector ($\delta^N > 0$) the gap is positive for every G and δ^N. Furthermore, the equilibrium gap is increasing in δ and decreasing in G.

The elasticity of the long-run equilibrium level of technology in the South with respect to a change in the level of (each component of) G is positive as shown below.

$$\frac{\partial h^{s^*}}{\partial G}\frac{G}{h^{s^*}}=G\frac{\phi'(G)}{\phi(G)}\frac{\delta}{\phi(G)+\delta}>0 \qquad (22).$$

Given that G is a vector comprising a number of variables, the results in (22) hold only when each of these variables is at least at its threshold level. This condition has already been stated in equation (18) above. The intuition for the result in (22) is as follows. An increase in any component of G will increase diffusion so long as the rest of the variables are at least at their threshold levels. As an example, trade liberalization by the South is going to be advantageous in terms of acquiring more human capital via diffusion only if the country has the requisite amount of human capital to begin with. A further implication of (22) is that a simultaneous increase in more than one variable in G will result in an increase in h^S by approximately the sum of the individual impacts of the variables not withstanding the threshold requirement given above. Since no assumptions have been made about the curvature of ϕ, the exact magnitude of the joint effect of the variables can not be deduced from the above.

We next consider the role of policy.

Policy

As in chapter 3, each country has a government with the ability to distort domestic prices either by imposing production and/or consumption taxes/subsidies or through imposition of border tariffs. All distortions are ad-valorem in nature. A distortion of magnitude τ implies

$$q^j = (1+\tau^j)p, \quad \text{for j = N, S} \qquad (23)$$[15]

where p, the world equilibrium price, is determined through clearing of global markets. Note that a border distortion has a symmetrical impact on domestic consumer and producer prices while a domestic consumption/production tax affects the targeted price only. All tariff revenue is redistributed in a non-distortionary manner. Given that each country is large and of equal size in terms of demand, all distortions impact on p. For any given set of parameters and initial conditions, all endogenous variables are solved separately for each t, hence their values evolve over time.

[15] This is equation (19) in Chapter 3.

4.4 Relative Wages, both in the Absence and Presence of Diffusion

Relative Wages in the Absence of Diffusion

First we consider the level and evolution of relative wages when diffusion does not occur. Labour is perfectly mobile between sectors but completely immobile between countries.[16] Competitive markets with an absence of complete specialisation imply that wages equal the value of the marginal product of labour.[17]

$$w = \gamma \frac{qy_2}{u_2} = \gamma \frac{y_1}{u_1} \qquad (24)$$

where country superscripts have been suppressed for notational simplicity. The dynamics of factor rewards are introduced by taking log time derivative of (24).

In the case where each country is completely specialised in the production of a single good, the growth in relative wages is given by

$$\hat{w}^S - \hat{w}^N = \beta(\hat{h}_2{}^S - \hat{h}_1{}^N) + \hat{p} = \beta(\delta_2^S - \delta_1^N) + \hat{p} \qquad (25).$$

Equation (25) shows that relative wages converge iff

$$\hat{p} > \beta(\delta_1{}^N - \delta_2{}^S) \qquad (26).$$

ie. Relative wages converge only if the terms of trade adjustment in favour of the low-tech good more than offsets the difference in rates of LBD between

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16 We conjecture that the incorporation of physical capital under the assumption of perfect capital mobility between the countries will not change the results since output now will be labours' share of value added.

17 The numeraire in these valuations is the domestic price of good 1.

the sectors weighted by the elasticity of output with respect to sectoral human capital. It is shown in the Appendix to this chapter that the inequality in (26) is satisfied only when $\sigma < 1$. In other words, when the two goods are poor substitutes then the terms of trade gain in favour of the low-tech good more than offsets the LBD differential between the two goods. Equations (25) and (26) also show that tariffs impinge only on the level and not the rate of growth of wages. This is because constant tariffs act merely as scalers on the relative price and as such do not have any dynamic effects.

Long-Run Relative Wages in the Presence of Diffusion

Assuming that in the long-run the North is specialised in the production of manufactures, both specifications of diffusion given in (16) and (20) give

$$\hat{h}_1^S = \hat{h}_1^N = \delta_1^N \qquad (27).$$

Growth in relative wages from (24) is given by

$$\hat{w}^S - \hat{w}^N = \beta(\hat{h}_1^S - \hat{h}_1^N) - (1-\gamma)\hat{u}_1^S \qquad (28).$$

In the presence of diffusion, the terms in the first RHS parenthesis in (28) equal zero from (27). For any given relative world price, p, the fraction of labour allocated to manufacturing from producer optimisation is given by

$$u_1 = [1 + p^{\frac{1}{1-\gamma}} z^{\frac{\beta}{1-\gamma}}]^{-1} \qquad (29),$$

the pattern of trade remains unchanged relative to that under no diffusion since $z^S > z^N$ for all t. Thus, as in the case with no diffusion, wage convergence requires that $\sigma < 1$.[18] The main difference between the two cases is in the transitional dynamics where the pace of progress towards specialisation in production is now slower because of the leakage of human capital from North to South.

We trace the evolution of w in a non-specialised equilibrium via numerical simulations. Note that goods prices equalise via trade. Factor prices need not equalise given our Ricardo-Viner production structure. The short run is characterised by the two countries producing both the goods. The non-specialised equilibrium permits the changes in relative prices of the goods to impinge upon factor prices. In the absence of diffusion, the non-specialised equilibrium is not a steady state as shown in the Appendix to Chapter 3. Hence these simulations may be viewed as those for the short-run only.

4.5 Dynamics via Numerical Simulations

These are for the short run and in discrete time. Specifically, all simulations cover a time period commencing at $t = 1$ and finishing at $t = 20$. These simulations are based on notional parameters and should therefore be seen as illustrations of the implications of the model given above.

Recall that a border distortion, as shown by (23) above, affects the demand and supply prices identically while an agent-specific tax has asymmetric effects. eg. We can use a production subsidy on agriculture to increase q_x above p by a factor $(1 + \tau)$ but leave q_d at the international price, p. This is permissible in the above framework.

Model Parameterisation - North and South differ in their endowments of human capital in the manufacturing sector. Specifically, we assume that the

[18] Proof given in Appendix to this chapter.

North, at some arbitrary date $t = 0$, has four times the human capital of the South in the high-tech manufacturing sector . Manufacturing is the high-tech sector in that the rate of learning in the sector is higher than in agriculture. We set the learning parameters in the two countries, N and S, as: $\delta_1^N = 0.1$; $\delta_1^S = 0.05$[19]; and $\delta_2 = 0.01$ in both the countries. Technology diffusion is captured by (16) with $\omega = 2$. Human capital in the absence of diffusion accumulates in each country (and sector) by equation (4) above.

The remaining parameters are set identical in each country. The demand share, α, is set to 0.5 so as to keep the effect of the share of demand neutral between the two goods. The elasticity of substitution in final consumption between the two goods is 1.5, making the two goods good substitutes and hence the 'interesting case' of Lucas. The production parameters, β and γ are set at 0.7 and 0.3, respectively.

Two experiments are carried out. The first compares free trade with autarchy both in the presence and absence of technology diffusion between the North and the South. The second considers the effect of policy on welfare in the presence and then absence of diffusion, respectively.

Experiment 1: Figure 4-2 below shows the gains in instantaneous welfare from trade as against autarchy in the absence of technology diffusion.

An absence of diffusion results in a greater proportion of the gains from higher LBD now accruing to the workers in the North. Wages in the North rise relative to those in the South permitting the Northern worker to purchase a greater fraction of total output than when diffusion is permitted. Figure 4-3

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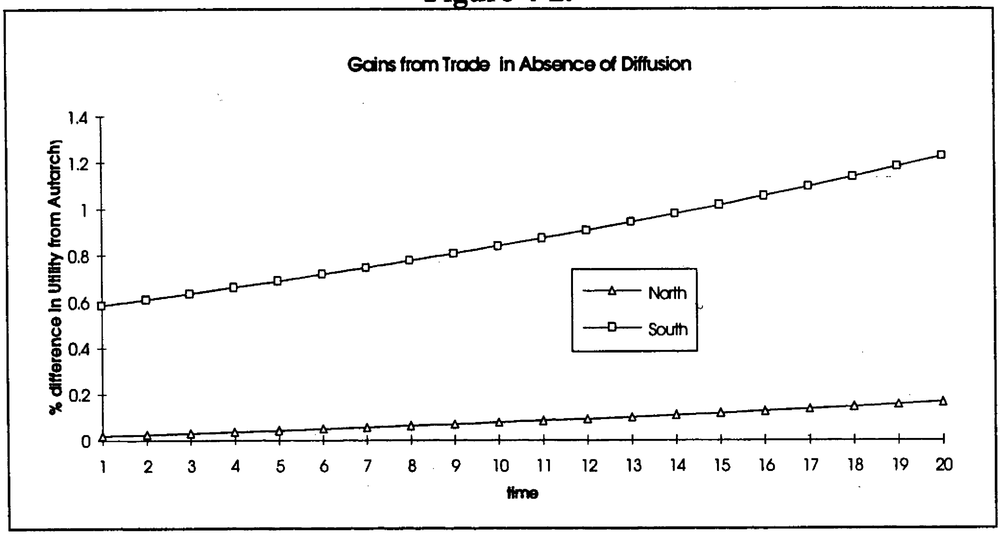
[19] δ_1^S is set lower than δ_1^N to reflect the poorer research infrastructure in South. The results are not affected qualitatively when the learning rates are set as being equal.

below shows the evolution of relative wages in the presence and absence of diffusion, respectively.

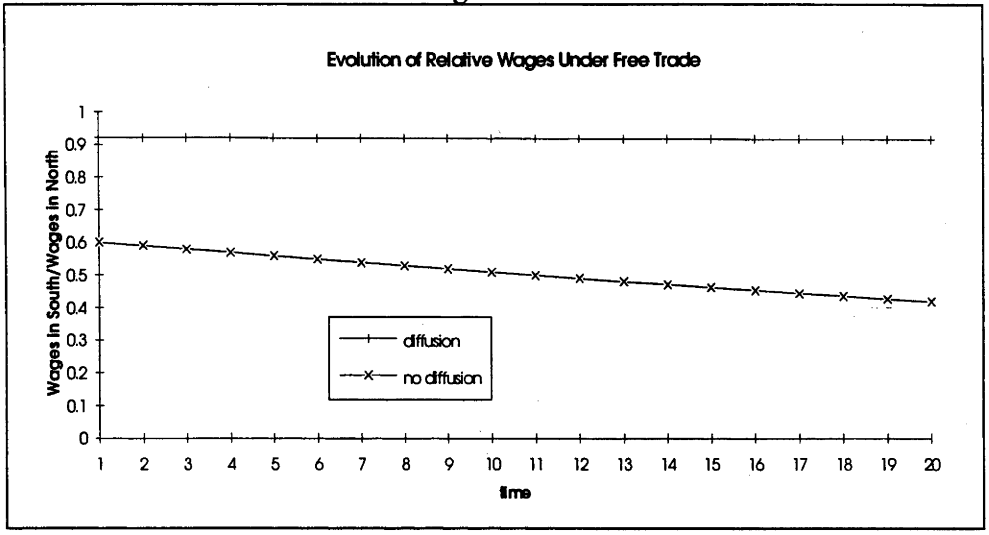
Figure 4-2.



The vertical axis shows the percentage deviation of utility under free trade from that of autarchy. <u>Both</u> countries gain from trade, the South gains more in percentage terms due to its lower level of utility. Total output under trade is greater than in autarchy, a fact attributable to gains from specialisation and increased LBD in the North. The output is distributed between the two countries by the price mechanism which ensures that some of the gains from LBD in the North are also transferred to the South. Allowing for diffusion of technology increases the gains to the South at the expense of some of the gains to the North but trade, on welfare grounds, is still preferred to autarchy by both the countries.

Period 1 wages in the South are approximately 90 percent of those in the North in the presence of diffusion while the corresponding ratio under an absence of diffusion is only 60 percent. Relative wages diverge in both the scenarios, though the rate of divergence is lower in the presence of diffusion.

Figure 4-3.



Some Comparative Statics: An increase in σ, the elasticity of substitution between manufactures and agriculture, increases the gain to both the countries when diffusion is allowed. The intuition for this result is as follows. A higher substitutability between manufactures and agriculture reduces the terms of trade deterioration against the North and hence enables the North to devote a greater fraction of its labour to the high tech manufacturing sector. This results in an increase in LBD and consequently a rise in the stock of manufacturing human capital and manufacturing output in the North. Some of the gains in technology then diffuse over to the South. Total output increases and so does utility in both the countries.

An increase in the level of diffusion increases the level of utility and relative wages in the South. Free trade ensures that the pattern of trade is governed by comparative advantage, hence North exports manufactures and imports agriculture. The larger the value of δ^N, the greater the gain to South from an increase in G. ie. The South gains more from diffusion the more progressive the Northern technology.

The result that trade is preferred to autarchy is robust to choice of alternative parameters and initial conditions only when diffusion is allowed. Trade is harmful to the South in the absence of diffusion when learning rates and initial endowments in the South are infinitesimally lower than that in the North. This is because trade crowds out the high tech sector in the South and has detrimental effects on welfare in South, a fact demonstrated in Chapter 3.

Experiment 2: Let North protect its agricultural production by imposition of a 10 percent tariff. South retains free trade and diffusion takes place. Utility is lower than under free trade and by the twentieth period the difference is 1.5 percent of the level under free trade for both the countries. Wages in the South rise by six percentage points to a level of ninety-five percent of that of the North. The policy distortion of the North has raised wages in the South, lowered total output and utility but the pattern of trade has remained unchanged from that under free trade.

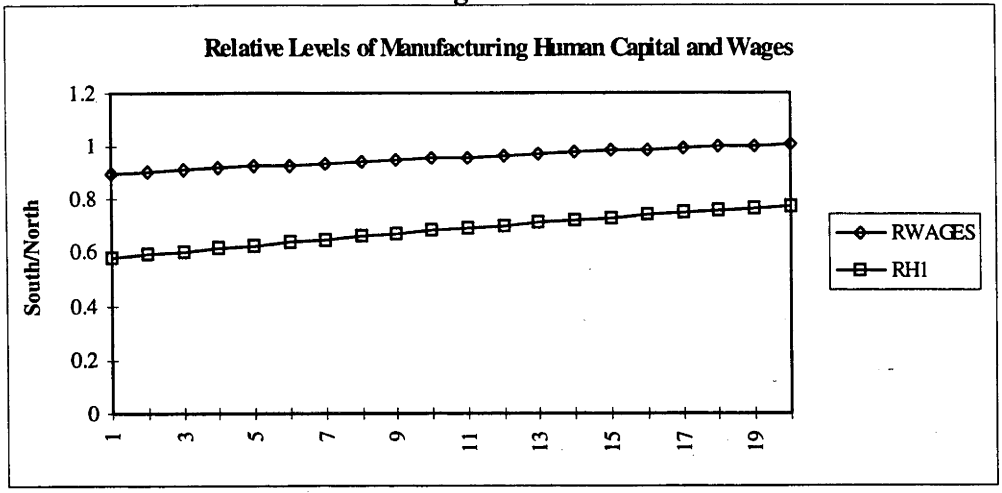
If we now let the South subsidise its manufacturing production by imposition of a 10 percent export subsidy[20] on manufactures[21], the trade pattern reverses with the South now exporting manufactures. Wages in the South surpass that in the North by one percentage points, aggregate output and welfare decline by one percentage points in the final period in each country.

Figure 4-4 shows that the trade distortion has pushed wages in the South above that in the North in the final period despite the level of human capital in the South being lower than that in the North.

[20] By Lerner's symmetry theorem this is equivalent to an import tariff of 10 percent on agriculture.

[21] North still has a 10 percent import tariff (export subsidy) on agriculture.

Figure 4-4.



In the absence of diffusion a tariff of five times the magnitude is required to reverse the pattern of trade from that under free trade.

The lessons from this experiment are that a policy distortion in the presence technology diffusion is welfare reducing, and a reversal of trade pattern is more likely for a given policy distortion in the presence of diffusion then in its absence.

4.6 Conclusion

The findings of this chapter can be divided into two sections. The first concentrates on the long-run while the second studies the short-run dynamics via numerical simulations. In the long run, a positive technology gap exists between the North and the South for a constant rate of technology creation in the North and a positive level of diffusion of technology from the North to the South. Furthermore, this equilibrium technology gap increases with a rise in the rate of LBD and declines as the level of diffusion rises. Wages in the South converge to that in the North when the two goods have an elasticity of substitution that is less than unity. The short-run simulations suggest that the welfare cost of moving away from free trade is greater the higher the rate of learning in the North and the more rapid the rate of technology diffusion from North to South. These simulations also suggest that free trade, in the presence of diffusion, is preferred to distorted trade. This result is robust to changes in the parameter values of the model. The price mechanism is adequately able to handle the production externality in the form of LBD under free trade. Policy is far more damaging to global and individual country welfare in the presence then in the absence of diffusion.

Wages in the countries are affected by policy in either country. We note that protection of agriculture by the North and/or subsidy to manufacturing in the South raises relative wages in the South. If our concern is with welfare, then the movements in relative wages are of secondary concern given utility decline in each country as a consequence of the policy distortion(s). The policy lesson is to allow for free trade and for the South to increase the level of diffusion so as to catch up with the North. The first-best policy for the North is to subsidise its manufacturing production and make the South pay for access to its technology. This involves picking winners and containment of outflow of information but with goods trade, a difficult task for any policy maker. The pragmatic alternative is to allow free trade in the North as well.

The experiments are supposed to reflect some elements of reality. The world is characterised by increasing communications, principally due to improvements in transportation and telecommunications technology. Policy distortions in such a context are far more damaging to welfare than when there is minimal contact and hence lower levels of diffusion. This result implies that the stakes for freer trade are higher now than in the past. The North has been protecting its agriculture while some of the countries in the South have been protecting their manufacturing sector. Our simulations suggest that these policy distortions have increased relative wages in these

Southern countries and decreased welfare overall as well as for each country. For countries in the South who do not experience (encourage) diffusion, the relative wages diverge, the welfare cost of the absence of this diffusion is large given the high technological progressivity of the North.

4.7 Areas for further research.

There is evidence that much of the success of the NICs can be attributed to their successful adoption then adaptation of foreign technology to their own circumstances (Evenson and Westphal 1994 and Pack 1993). The role of indigenous effort on the part of the LDCs in the successful adaptation of foreign technology has as yet to be incorporated in the theoretical model. We conjecture that doing so with the possibility of diffusion from the technology-rich to technology-scarce country will bring about leapfrogging between the two countries. This is left as part of future work.

APPENDIX

4.1 Proof that inequality in (26) is satisfied only when $\sigma < 1$.

Assumptions:

A1) North specialises in Good 1;

A2) South specialises in Good 2; and

A3) For simplicity, let $\tau = 0$.

$$c_2 = (\frac{\alpha_2}{\alpha_1})^{\sigma} p^{-\sigma} c_1 \quad \text{from (6) in Chapter 3} \qquad \text{(A1.1).}$$

The budget constraint for South is given by

$$c_1 + pc_2 = c_1[1 + (\frac{\alpha_2}{\alpha_1})^{\sigma} p^{-\sigma}] = ph_2^{\beta} \qquad \text{(A1.2),}$$

which gives consumption of good 1 by South as

$$c_1 = \frac{ph_2^{\beta}}{[1 + (\frac{\alpha_2}{\alpha_1})^{\sigma} p^{1-\sigma}]} \qquad \text{(A1.3).}$$

This consumption of good 1 is satisfied through imports from North, given as

$$y_1^N - c_1^N = x_1^N = \frac{(\frac{\alpha_2}{\alpha_1})^{\sigma} p^{1-\sigma} (h_1^N)^{\beta}}{[1 + (\frac{\alpha_2}{\alpha_1})^{\sigma} p^{1-\sigma}]} \qquad \text{(A1.4).}$$

Equating (A1.3) and (A1.4) and solving for the market clearing price gives

$$p = \frac{\alpha_2}{\alpha_1}\left(\frac{h_1^N}{h_2^S}\right)^{\frac{\beta}{\sigma}} \qquad \text{(A1.5).}$$

Differentiating (A1.5) and substituting in (4) gives

$$\hat{p} = \frac{\beta}{\sigma}(\delta_1^N - \delta_2^S) \qquad \text{(A1.6).}$$

Substituting for $\hat{p}$ in (26) and solving for σ gives the reported result.

A4.2 Proof that $\sigma < 1$ is necessary for wage convergence in the presence of diffusion.

From (28)

$$\hat{w}^S - \hat{w}^N > 0 \text{ iff } \hat{u}_1^S < 0 \qquad \text{(A2.1).}$$

From equation (21) in Chapter 3

$$\hat{u}_1^S = -\frac{1}{1-\gamma} u_2^S (\hat{p} + \beta \hat{z}^S) \qquad \text{(A2.2).}$$

But in the presence of diffusion,

$$\hat{z}^S = (\hat{h}_1^S - \hat{h}_2^S) = (\delta_1^N - \delta_2^S u_2^S) \qquad \text{(A2.3)}$$

Hence, the inequality in (A2.1) is satisfied iff

$$\hat{p} > \beta(\delta_1^N - \delta_2^S u_2) > \beta(\delta_1^N - \delta_2^S) \qquad \text{(A2.3)}$$

since $u_2 < 1$. From (A1.6), a necessary (but not sufficient) condition for wage convergence is $\sigma < 1$. The important assumption to note here is that the South is non-specialised in production while the North is completely specialised in the production of manufactures.

Chapter 5

Sources of TFP Growth: Evidence from OECD Manufacturing

Abstract

This chapter looks for empirical support for four hypothesised sources of growth: learning by doing (LBD); investment in human capital; increases in use of intermediate inputs; and gains from specialisation in production and/or exports. The findings, using data over the last two decades for OECD manufacturing, shows qualified support for the first two only. The panel data analysis shows that a higher capital intensity and greater R&D employment are associated with increases in sectoral TFP. In contrast, growth in intra-industry trade and in specialisation are insignificant in explaining TFP growth. The above findings give empirical support to the current trend in the theoretical literature that places increasing emphasis on the role of human capital in economic growth.

5.1 Introduction

The previous two chapters have developed theoretical models in support of the role of learning by doing (LBD) and diffusion of technology via trade in growth. This chapter considers empirical evidence in support of four hypothesised sources of growth in total factor productivity (TFP): learning by doing; investment in human capital; increases in use of differentiated inputs in production; and increases in specialisation in production and/or exports. The role of trade in growth is highlighted by the empirical development economics literature which shows a positive association between extent of exports and economic growth. This evidence is then used to support the claim that 'outward orientation' is necessary for growth (see World Bank 1988). Work within endogenous growth theory, particularly that over the last ten years, has attempted to formalise this link (Ruffin 1994). However, to date, these models have been subjected to relatively few empirical tests.

We consider each of four hypotheses, that could either be competing or complementary, on sources of endogenous growth. The first is based on the spill-over model, captured in our analysis as LBD, where growth results from the presence of some positive externality. Proponents of this hypothesis include Arrow (1962), Lucas (1988), Stokey (1988) and Young (1991). The second hypothesised source of growth is via investment in human capital via research and development (R&D) activity. In this framework only a fraction of the returns from such investments are internalised, the remainder spills over as a source of gain to future R&D activity giving the final goods sector significant dynamic economies of scale (EOS). This in turn brings about perpetual growth. Romer (1989, 93a &b, and 94) has been the most vigorous and recent proponent of this hypothesis but others such as Uzawa (1965), Lucas (1988), and Stokey (1988) have also expressed support for the same hypothesis. Ethier (1982) using the 'love of variety' formulation of Dixit and Stiglitz (1977) has shown that an increase in the number of varieties of intermediate goods used in production of the final good leads to an increase in output. Romer (1987) and Grossman and Helpman (1991) have used this notion of increases in the number of specialised inputs for production over time as a (third) source of sustained growth. Feder (1982) and Dollar (1992) have put a slightly different perspective on gains from specialisation in exports and hence trade. They have argued that exports have a positive externality on production in the rest of the economy, hence the link between export specialisation and growth. This positive association between the extent of exports and growth in aggregate output is often used in support of the claim that outward orientation enhances economic growth. The last hypothesis gives trade, and the extent of exports in particular, a direct role in growth. A number of empirical studies including Edwards (1992) and World Bank (1988) have lent support to the last hypothesis.

The aim of this chapter is to carry out a test of support for endogenous growth theory. The task set is to quantify and separate out the contribution of each of the hypothesised sources of growth. Pack (1994) observes a lack of direct support for endogenous growth theory and notes that the

> "challenge for empirical work is to test the implications of the new theory more directly" (page 70),

a challenge taken up in this chapter. The analysis is similar to that of Backus, Kehoe and Kehoe (1992) [BKK from now on], however unlike BKK who assume particular forms of spill-overs and then deduce their estimable equations from these assumptions[1] we deduce all our estimable equations directly from the production and human capital accumulation equations. Furthermore, where BKK search for scale effects in growth, we attempt to identify the sources of these scale effects. Additionally and in contrast to BKK, we employ sectoral total factor productivity (TFP)[2] data for our analysis which we consider to be a contribution given that the link between trade and growth "is still scanty and mixed" (Bardhan 1993: 13). Finally, our analysis uses panel data (with many of its advantages as is made clear later) and is carried out with a different data set to that of BKK.

The theory in this chapter focuses exclusively on the production technology. This is to avoid complications that arise in a fully specified general equilibrium model as demonstrated in Chapter 3. The aim of this chapter to test for support for each of the four hypothesised sources of TFP growth. The theoretical link between trade and growth is assumed to be from the supply side.[3].

This chapter augments the Solow growth accounting identity so as to test for sources of scale effects in the growth of manufacturing output within twelve OECD economies. The analysis reveals support for human capital explanations, specifically R&D effort and LBD. The rest of the chapter is organised as follows. Section two considers each of the four hypothesised sources of endogenous growth and translates each of them into a form

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[1] BKK estimate the equation $(\frac{\hat{Y}}{N}) = a_0 + a_1 Scale + a_2 Intensity$ where Y is output, N is labour employed, scale variables include logs of per-capita GDP and manufacturing output, and intensity variables include measures of intra-industry trade, imports, etc.

[2] BKK mention productivity growth in their Table IV (page 399) but the variable used is growth in average product of labour.

[3] Feder (1982) and the references contained therein point out that use of supply-side analysis in study of sources of growth is a common practice in this literature.

suitable for empirical testing. Section three discusses the data, their sources and the econometric techniques employed. Section four contains the results. Conclusions and suggestions for further work follow.

5.2 Four Hypothesised Sources of Perpetual Growth

5.2.1 Learning by doing as a source of growth

The production function of Lucas (1988) and Chapter 3 is augmented to include physical capital as well. Sectoral output can now be represented as

$$Y_i = AK_i^{\alpha}(N_i h_i^{\gamma})^{\beta} \qquad 0 < \alpha, \beta, \gamma < 1 \qquad (1)^4$$

where K_i, N_i, and h_i are physical capital, labour (number of workers) and per-worker[5] human capital, respectively, employed in sector i and Y_i is output of the sector. Hicks-neutral technological progress is captured by *A* which is dependent on time only. The terms in parenthesis on the RHS of (1) denote effective workers employed in the sector. As in Lucas (1988), learning by doing is a function of the amount of resources, physical capital intensity in the above framework, devoted to the sector. Additionally, we also assume that the potential for learning declines as per-capita output, y, increases. Hence, learning is characterised by

$$\dot{h} = f(h_i)g(k,y) \quad f' > 0;\ g_k > 0,\ g_{kk} < 0 \text{ while } g_y < 0, \text{and } g_{yy} > 0 \qquad (2)$$

where subscripts on *g* represent the partial derivative of *g* with respect to the variable. This specification assumes that the rate of human capital accumulation is a positive but declining function of capital intensity and that

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[4] A constant returns to scale technology in K and L will imply $\alpha + \beta = 1$, a proposition we test in Section 4. Hicks neutral technological progress is captured by the constant term in the regression equation.

[5] Small letters are used to denote quantities in per-worker terms.

the rate of learning declines, but at a diminishing rate, with rises in the level of per-capita output. The reason for concavity in the first variable may be obvious, but the convexity in the second needs elaboration. Per-capita output proxies for the level of TFP, or the (inverse of the) distance from the production frontier. Our specification above assumes that the potential for learning diminishes as one approaches the frontier, hence the convexity of g in y.[6] As for function f, we assume

$$f(h) = h^{\xi}, \qquad \xi > 0 \qquad (3).$$

Note that in the formulation of Lucas (1988) $\xi = 1$, an assumption we retain for tractability. A value of $\xi > 1$ gives rise to the possibility of multiple equilibria while $\xi < 1$ snuffs-out perpetual growth from the model altogether (see Srinivasan 1992 for further discussion on this issue). The rate of growth[7] of sectoral output can now be obtained by taking log time derivative of (1) which on substitution of (2) and (3) gives

$$\hat{Y}_i = \hat{A} + \alpha\hat{K}_i + \beta\hat{N} + \beta\gamma h_i^{\xi-1} g(k, y) \qquad (4).$$

Equation (4) can be rearranged so that the growth in the Solow residual ($T\hat{F}P$) can be expressed as

$$T\hat{F}P_i = \hat{A} + \beta\gamma h_i^{\xi-1} g(k, y) \qquad (5)$$

---

6 This is catch-up, but in the rate of learning only. This is elaborated in further detail in the next Chapter.

7 The rate of growth of a variable is represented by a caret over the variable. In the empirical section this growth is given by the log first difference of the variable. eg. $\hat{Y}_t = \ln Y_t - \ln Y_{t-1}$.

where $T\hat{F}P = \hat{Y}_i - \alpha\hat{K}_i - \beta\hat{N}$. Equation (5) states that the growth in TFP is dependent on the scale of output as represented by the level of capital intensity and per-worker output in the sector. Setting ξ to one makes equation (5) linear in its variables which then makes empirical implementation easy. To permit empirical implementation of (5), we assume separability between k and y and let g be the natural log function.

$$g(k,y) = \gamma_0 \ln k - \gamma_1 \ln y \qquad (5a)^{8}$$

5.2.2 Investment in human capital and R&D as a source of growth

The human capital accumulation hypothesis is distinguished from the LBD hypothesis in that in the former at least some of the gains from investment in human capital are internalised while none are internalised in the latter. Hence there is some incentive for the agent to invest in human capital accumulation in the former in contrast to there being none in the latter. Romer (1989, 1993 and 1994) argues very strongly in favour of this latter hypothesis on the role of R&D in growth.

The sectoral production function in (1) is retained, but human capital accumulation is now the result of dedication of labour to sectoral R&D activity. This is represented by

$$\dot{h}_i = h_i m(R_i) \;\; , \; m' > 0, \;\; m'' < 0 \qquad (6)^{9}.$$

where R_i is the number of people engaged in R&D in sector i. We have postulated in equation (6) that the rate of human capital accumulation in the

[8] We could allow cross-terms but this will be at a cost of loss in degrees of freedom at the estimation stage.

[9] We could also incorporate per-capita output here as in (2), with analogous justification, but this will not affect the reduced form of the equation to be estimated in section 4.

sector depends on the amount of labour devoted to sectoral R&D activity. We have assumed diminishing returns to R and instantaneous diffusion of knowledge gained from sectoral R&D to the whole work force[10]. The latter assumption is relaxed at the empirical implementation stage of the model. The implied stock of human capital from equation (6) at instant T is given by

$$h(T) = h(0)e^{\int_0^T m(R(t))dt} .$$

We again let m be the log function. Taking log time derivative of (1) then substituting in (6) and expressing the result in terms of the growth in the Solow residual gives

$$T\hat{F}P_i = \gamma_{h_i} \ln R_i \qquad (7).$$

The RHS term in (7) shows the scale effect from employment in sectoral R&D activity.

5.2.3 Rise in availability of specialised inputs as a source of growth

The production function that captures the positive contribution on growth of increases in availability of specialised inputs over time (following Ethier 1982, Grossman and Helpman 1991 and BKK) can be expressed as

$$Y_{it} = [\sum_{j=0}^{\infty} z_t(j)^{\rho}]^{\frac{\alpha}{\rho}} N_{it}^{\beta} , \qquad \alpha + \beta = 1 \qquad (8)^{11}$$

where z(j) is the jth intermediate input and time has been made explicit by subscript t. Note that a positive ρ implies that output is positive even in the

10 This is consistent with Romer (1990) where R&D involves making of blue prints.

11 This restricts the technology to be CRS.

absence of some inputs. At any time t the resource constraint on the number of intermediate goods produced is given by the fixed amount of physical capital available to the sector. ie.

$$\sum_{0}^{\infty} z_t(j) = K_t \qquad (9).$$

Assuming positive but declining[12] fixed cost of production of each variety and imposing symmetrical production technologies across the intermediate input varieties implies that a finite number, Z, of the inputs are produced at any t. Furthermore, the technology in (8) implies that for each of the inputs produced, the quantity produced is identical between the inputs. Hence[13]

$$z_t(j) = \bar{z}_t \text{ for } j \leq Z \text{ and } z_t(j) = 0 \text{ otherwise} \qquad (10).$$

Carrying out operations analogous to those used above to get (7) we now get

$$T\hat{F}P = \frac{\alpha(1-\rho)}{\rho}\hat{Z} \qquad (11)$$

where Z is the number of intermediate inputs available at time t. Growth in this framework results from the rise in the number of available intermediate inputs, either due to increased trade or via increases in capital stock. Trade impacts on growth in this framework by allowing a country access to specialised inputs from abroad. This is in contrast to the view that trade allows for greater specialisation in production, an issue taken up in detail in

[12] The fixed cost declines due to some externality as current R&D lowering cost of future innovation.

[13] The proofs of these propositions are contained in Grossman and Helpman (1991: Chapters 3 and 4).

section 5.2.4 below. Data on extent of trade in intermediate inputs is not available, hence we consider the use of a proxy.[14].

Intra-industry Trade Index

The growth literature has traditionally used the Grubel-Lloyd index of intra-industry trade (Grubel and Lloyd 1975). We follow this lead, and that of BKK in particular, to test the contribution of growth in trade in intermediate inputs on TFP growth. If countries are less than perfectly open to trade in intermediates then an increase in intra-industry trade will give the importing country access to an increased variety of inputs which in turn brings about an increase in the growth rate of aggregate output from the production function in (8) above. Trade now has a central role in inducing growth, the extent of intra-industry trade is given by the

$$\text{Grubel-Lloyd Index} = \frac{\sum_{i=1}^{I}(X_i + M_i - |X_i - M_i|)}{\sum_{i=1}^{I} X_i + \sum_{i=1}^{I} M_i} \qquad (12),$$

where X and M are exports and imports, respectively. Note that this index is zero when either imports or exports within all of the dissaggregated industries is zero and one when imports and exports are equal in the dissaggregated industries. The growth in this index is used as a proxy for $\hat{Z}$

[14] The use of a proxy raises econometric issues pertaining to latent variables. We discuss this issue further later.

5.2.4 Increased Specialisation in Production and Exports as a Source of Growth

Trade also affects growth through enabling countries to specialise in production and exports. Increases in specialisation raise growth via two channels; the first is from specialisation *per se*[15] while the second is from shifting resources out of non-export sectors to exports. The mechanics of the latter association between the extent of exports and TFP growth are provided by Feder (1982) and Dollar (1992). The first study uses a cross-country empirical analysis to show that the social marginal product of factors of production in export sectors is higher than that in the non-export sectors. This evidence is then used to suggest that a shift of resources out of the non-export sectors to the export sectors will lead to a rise in aggregate output. Dollar (1992), again using another cross-country empirical analysis, shows a statistically significant relationship between growth of GDP and measures of outward orientation. The mechanics of this association are argued to be different; Dollar points out that outward orientation accelerates technology transfer which in turn raises growth. The above two arguments imply that having a larger export base will raise efficiency in the economy both through its direct effect from aggregation as well indirectly via the positive externality the export sectors are purported to have on the non-export sectors.

Furthermore, a number of empirical studies of developing countries, including Edwards (1992 and 1993) and World Bank (1988), have lent support to the view that outward orientation and growth are positively associated. The theory under-pinning this link has relied on the existence of some positive externality from trade as in Feder (1982). This hypothesis can be tested by constructing an export specialisation index. The production structure implied by this externality assumption is similar to that given in equation (1). An

[15] This is Adam Smith's argument of the pin factory.

index of specialisation, in production and/or exports, can now be used to test the specialisation hypothesis by including it as a RHS variable in equation (5) above. It is to be noted that the extent of specialisation is a function of the degree of trade and also the resource endowments of the country. We therefore need a measure of specialisation that is free of scale, otherwise differences in country size and diversity of resource endowments would have to be controlled for in the regression estimates. We measure the degree of output and export specialisation by the specialisation indices of BKK.

$$YSPI_t = \sum_{i=1}^{I} \left(\frac{Y_{it}}{Y_t}\right)^2 \qquad (13a).$$

and

$$XSPI_t = \sum_{i=1}^{I} \left(\frac{X_{it}}{Y_t}\right)^2 \qquad (13b).$$

where X_{it} is exports of sector i at time t, Y_{it} is output of sector i at t, Y is the total output of the industry aggregated one echelon up. YSPI and XSPI denote the output and export specialisation indices as given by BKK[16]. BKK show that their index is scale free and therefore differences in country endowments do not have to be controlled for explicitly in our regression equations.[17].

[16] BKK use export specialisation index of the form given in (13b) but with the denominator being total exports instead of total output, their reason for the change being absence of sectoral production data. BKK assume that their export specialisation index is a good proxy for output specialisation. Our data for OECD manufacturing show a correlation between BKK's measure of export specialisation and output specialisation dissaggregated at 3-digit ISIC of 3 percent.

[17] It is to be noted that export specialisation is not the only means by which outward orientation is linked to growth. Stiglitz (1994) argues economic organisation, efficient use of capital and technology transfer, all assisted by openness, have lead to the success of the NICs.

We draw on equations (5), (7), (11) and (13a&b) to construct the set of RHS variables that determine the rate of growth of TFP.

$$T\hat{F}P_i = a_0 + a_1 \ln k_i + a_2 \ln y + a_3 \ln R_i + a_4 \hat{Z}_i + a_5 XSPI_i + a_6 YSPI_i \qquad (14),$$

where k_i is the level of per-worker sectoral physical capital, R_i is the number of people engaged in R&D in the sector, $\hat{Z}$ measures the growth in the number of intermediate inputs in the sector, XSPI is the export specialisation index, and YSPI the output specialisation index. Note that the theory above has the <u>levels</u> of specialisation instead of their growth rates affecting TFP growth. The intuition is that the level of specialisation has an externality on efficiency of production at the aggregate level within the manufacturing sector (Feder 1982).

The theory posits the following signs of the coefficients. A positive a_1 will be interpreted as support for LBD as a source of growth, while positive a_3 would indicate support for growth caused by human capital accumulation via R&D. a_2 is expected to be negative from the restrictions on g in equation (2), while support for the hypothesis that trade in intermediate inputs enhances growth would require a_4 to be positive. Positive a_5 and a_6 would be interpreted as support for the specialisation hypotheses.

Note that our specification in equation (9) states that the number of intermediate inputs is constrained by the total stock of physical capital. Hence Z_i and K_i are collinear, but this collinearity would be less significant between $\hat{Z}$ and K_i. Furthermore, levels of output, physical capital, sectoral employment and R&D employment are also expected to be correlated. The presence of this multicollinearity amongst the independent variables is investigated at the empirical stage.

5.3 Data

Data on output, capital stocks and employment are obtained from the International Sectoral Data Bank (ISDB) (see Meyer-Zu-Slochtern 1988 for documentation). Additional data had to be compiled specifically for this paper. These include data on the number of people engaged in R&D, the specialisation indices and Grubel-Lloyd intra-industry trade index. The number of people engaged in R&D is from UNESCO (Various Issues). The specialisation indices and the Grubel-Lloyd intra-industry trade index are computed using the formulas given above and data from STARS[18]. A complete description of variables used, sources of primary data and countries covered in the study is given in the Appendix. All variables are in real terms.

The study is restricted to the aggregate manufacturing sector within the OECD for four reasons: i) data on manufactures, and particularly for the OECD, are most readily available; ii) the OECD can be considered as a relatively homogeneous group of countries; iii) BKK show that their scale hypothesis is weakly supported for the case of manufacturing with no such support at the level of aggregate GDP; and iv) valuation problems for manufactures across countries are minimal given the tradeable nature of the goods. Furthermore, Ark and Pilat (1993) point out that the bulk of the world output of manufactures is still produced by the industrial countries and the sector still generates the most technological innovations with important spill-overs to the rest of the economy in these countries. Hence the presence

[18] STARS (for Statistical Analysis and Retrieval Service) is provided by the International Economic Data Bank (IEDB) at the Australian National University. The data used in this paper are sourced from UNIDO and made available by IEDB via STARS.

of scale effects is likely to be most pervasive within the manufacturing sector of the OECD countries.

5.4 The Empirics

A data panel for the twelve[19] countries each with time series from 1970 to 1990 is used for estimation. The main reason for using a panel as against either a single time series or cross-section is the benefit of tapping into a larger number of data points. The trade-off is that if the parameters of (14) are homogeneous across countries then pooling should increase the efficiency of the estimates, but should the parameters be different between countries then pooling will give inconsistent parameter estimates.[20]

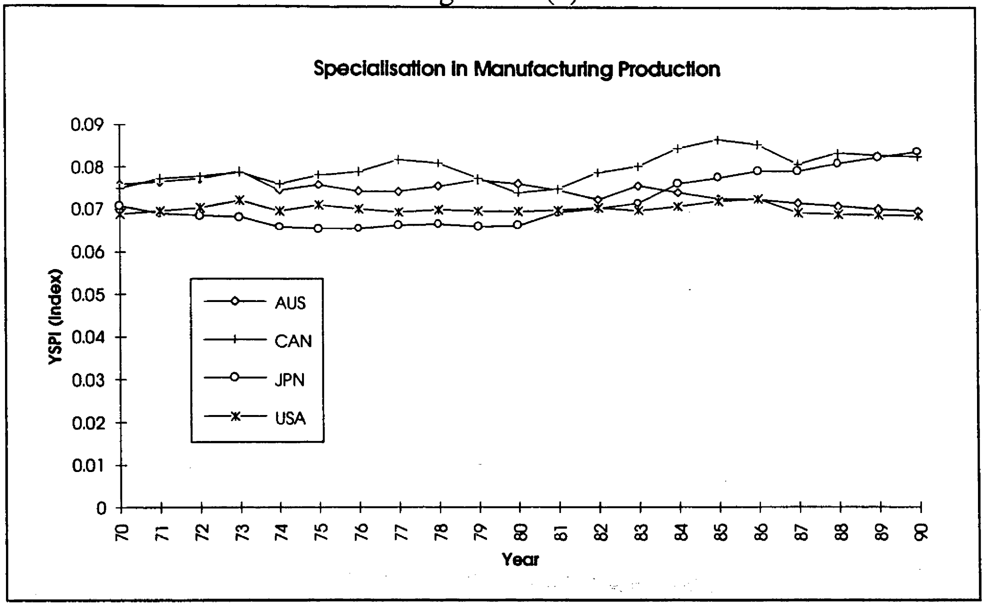
Some Preliminary Data Exploratory Exercises

Prior to estimating (14) we look for some regularities within the data. Table A1 in Appendix shows the simple correlation between the RHS variables in (14). Note the high (> 0.9) simple correlation between levels of output, employment, capital stocks and R&D employment.

The distribution of the measures of specialisation shows that the OECD countries have much greater uniformity in production than exports (ie. the coefficient of variation on YSPI is 17% while that on XSPI is 107%). Figures 5-1(a) and (b) below show the magnitude and time trend in the two specialisation indices for the four Pacific basin countries.

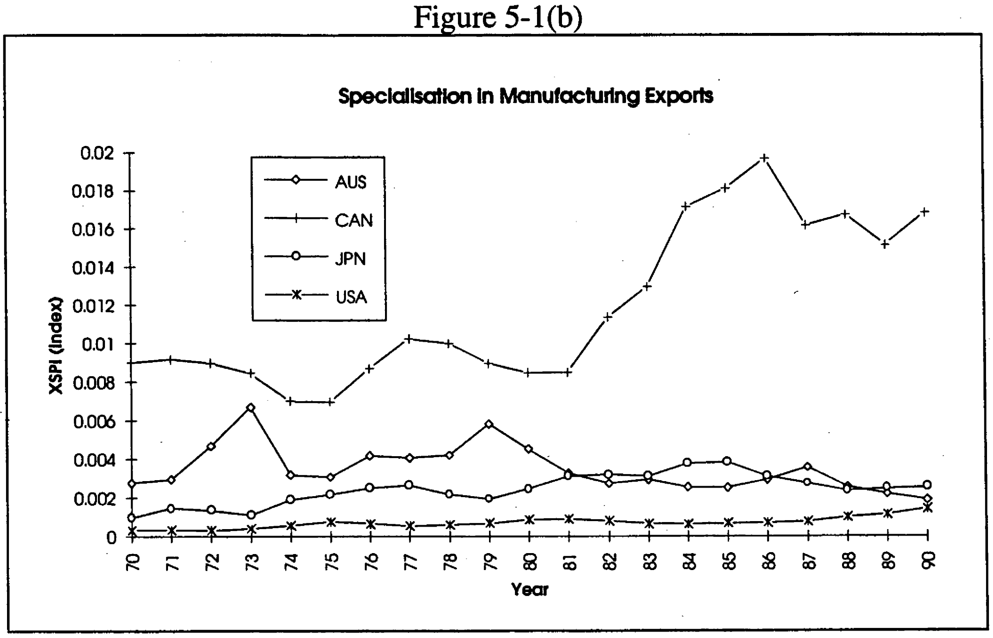
[19] ISDB provides data on Y, K and N on fourteen OECD countries but trade data for Denmark and R&D employment data for Belgium are not available.
[20] Unfortunately, the available degrees of freedom do not permit a test of this homogeneity restriction.

Figure 5-1(a)



Note the similarity of YSPI between the countries and the relative constancy of the index over time and contrast this with XSPI shown in Figure 1(b) below.

Figure 5-1(b)

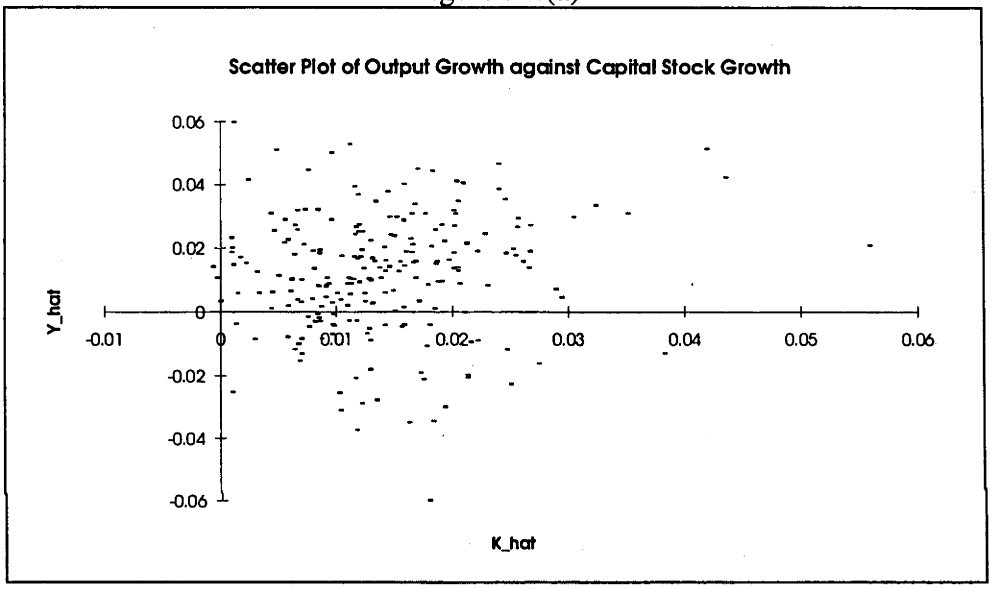


Canada not only has higher export specialisation but the index also has a strong positive time trend. The steep climb of the index for Canada from

1981 to 1986 is most noticeable, however the reason for this climb is not known and it is not considered important for this paper.

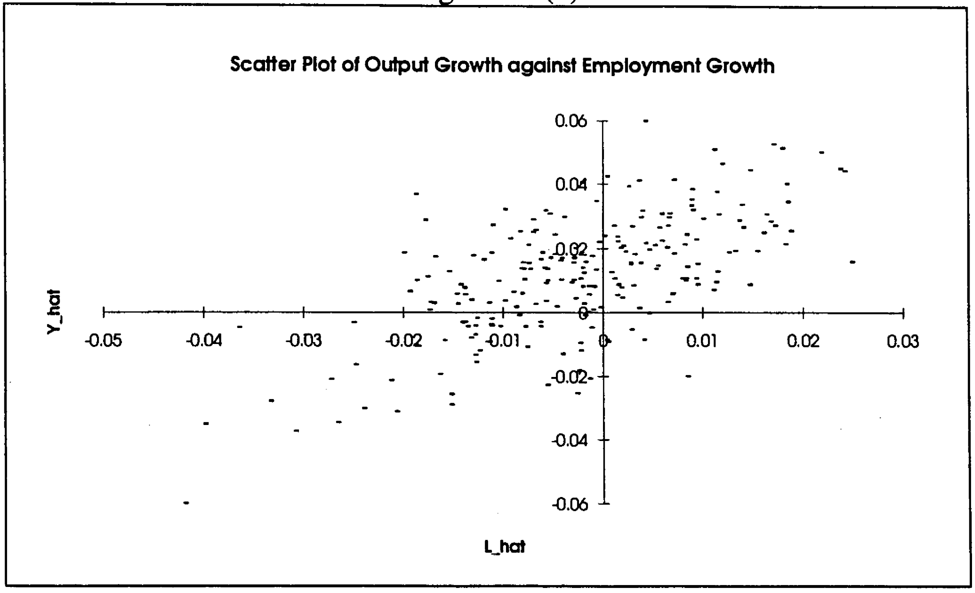
We next consider the pattern of output growth *vis-a-vis* growth in inputs of capital and labour. Figures 5-2(a) and (b) give a scatter plot of output growth as against growth in inputs of the two primary factors of production.

Figure 5-2(a)



The scatter plots in Figures 5-2a and 5-2b suggest that employment adjusts more readily to changes in output on an <u>annual</u> basis. This is consistent with expectation given greater sectoral specificity of capital relative to labour. The annual variability could be due to the effects of business cycles, hence we use levels of variables averaged over five-year non-overlapping periods. The choice of five-year averages is considered sufficient to iron-out short term disturbances in the data so as to allow identification of the underlying growth process (Islam 1995). Data ranging from 1970 to 1989 are divided into three five-year non-overlapping periods which then is used for more detailed econometric analysis.

Figure 5-2(b)



Estimation Results

We do not have data on growth of TFP. An estimate of growth in TFP requires knowledge of the elasticities of substitution in production of labour and capital. Given the absence of data on TFP growth and elasticities of substitution of capital and labour in production, we extract these parameters from the primary data. This is done by regressing the growth rate of output on growth rate of labour and capital and the RHS variables in (14). The model estimated is of the form

$$\hat{Y}_i = b_0 + b_1\hat{K} + b_2\hat{N} + b_3 \ln y_{t-1} + b_4 \ln k_{t-1} + b_5 \ln R_{t-1} + b_6 G\hat{L}I + b_7 XSPI_{t-1} + b_8 YSPI_{t-1} \tag{15}$$

Note that (15) in comparison to (14) has incorporated first lags for each of the level variables. Lags are introduced to account for the dynamics in the system.[21] First lags only are considered for two reasons: first, there are insufficient data to pick up any longer-run dynamics; and second, we expect

[21] R&D and the externalities from LBD and level of exports take time to impact on growth of output.

the first order effects to be most pervasive and as such be picked up adequately by the model. We first estimate equation (15) with data pooled across all countries and over the whole time horizon using ordinary least squares (OLS). Our model may be expressed as

$$\hat{Y}_{jt} = \theta_j + \phi_j{}' \mathbf{z}_{jt} + u_{jt} \qquad \text{for j = 1 ... J and t = 1 ... T} \qquad (16)$$

where Y is the dependent variable, **z** a vector of explanatory variables, subscript j denotes countries (cross-sectional units) and t time. The disturbance term, u_{jt}, is assumed to be independently and identically distributed (iid) random variable. Our first estimate is based on data pooled over all the countries and time periods. This (pooling) imposes the restriction that $\theta_j = \theta$ and $\phi_j = \phi$ for all j.

The homogeneity assumption, using annual data and an F test, is rejected with p-value being less than one percent (see Table A2 in Appendix for estimation results). Introducing fixed effects country dummies by employing the least squares dummy variable (LSDV) procedure does not alter this finding. The data rejects the assumption that the RHS variables have equal impact on rate of growth of output across the countries. This rejection of homogeneity of slope coefficients may indicate one of the following: an absence of synchronisation in short-term disturbances between the countries; or, that the data are not poolable. In the case of the former, averaging should rectify the problem, while the latter raises serious doubts on the validity of cross-country growth regressions such as those in Barro (1991), Dollar (1992), Dowrick (1994), etc. The implausible magnitude of elasticity of output with respect to capital, as given by the estimate of b_1, is some evidence in favour of the first explanation. Hence, we proceed with the estimation using averaged data.

Table 1 below gives the estimation results when averaged data are used. Model A is an estimate of the Solow growth accounting equation using OLS. The estimates in this model provide a benchmark for comparisons with other model estimates. Model B is an estimate of equation (15) employing OLS while C is obtained from the least squares dummy variable (LSDV) procedure.

A comparison of parameter estimates of Models A and B shows that the implied production function is constant-returns-to-scale (CRS) in K and N. The constant term which is statistically significant in Model A is insignificant in B, suggesting that the additional variables contained in Model B relative to those in Model A are now able to account for exogenous technological progress. The adjusted coefficient of variation suggests that Model B is able to account for 20 percentage points more of the variation in the data relative to Model A. All of the coefficient estimates in Model B, except that on output specialisation, have signs consistent with the respective hypotheses, but the assumption of a common intercept is rejected. A comparison of parameter estimates in Models B with C leaves most of the above findings - in qualitative terms - unchanged. The exceptions in the case of Model C are that the coefficients on lagged per-worker output and R&D employment are now statistically insignificant, but this probably suggests that country dummies now subsume the contribution of these two variables on TFP growth.

Table 1: Estimates of equation (15). Dependent variable: Growth of manufacturing output ($\hat{Y}$). t-ratios given in parentheses.

Variable	Model A (OLS Estimate)	Model B (OLS Estimate)	Model C (LSDV Estimate)
$\hat{K}$	0.49**	0.75**	1.24**
	(3.07)	(3.99)	(4.27)
$\hat{N}$	0.60**	0.42*	0.76**
	(2.41)	(1.81)	(2.55)
$\ln y_{t-1}$		-0.061*	-0.13
		(-1.67)	(-1.62)
$\ln k_{t-1}$		0.087**	0.12**
		(3.09)	(2.08)
$\ln R_{t-1}$		0.014**	0.067
		(2.10)	(1.14)
$G\hat{L}I$		0.050	0.017
		(0.30)	(0.085)
$XSPI_{t-1}$		0.49	1.12
		(0.34)	(0.52)
$YSPI_{t-1}$		-0.68	-4.31
		(0.34)	(-1.50)
Constant	0.025**	-0.43	—
	(2.01)	(1.30)	
# of obs.	36	35	35
Adj. R-SQ	0.32	0.53	0.52
SER	0.0374	0.0317	0.0234
F statistic	1.9675	2.9435	
(p-value)	(0.0851)	(0.0273)	

The F statistic is test for common intercept between the countries. Data on Y, K, N, XSPI, YSI, R and GLI are averaged over five-year non-overlapping periods. Growth rates are then computed as log first differences of the levels. Data on R&D employment for Great Britain was not available for the last time period, hence the sample size is reduced by one for estimates of Models B and C. Variable definitions, data sources, and list of countries covered is given in Appendix. A * and ** indicate that the coefficient is statistically significant at the ten and five percent significance levels, respectively.

The quantitative findings can be summarised as follows. The estimate of the elasticity of output with respect to capital (labour) is high (low) relative to the value of 0.3 (0.7) generally used in calibration exercises. Endogenous growth models such as that in Chapter 3 and in Rebelo (1991) suggest a capital output elasticity of one, but this parameter is not of primary interest to this chapter. We, therefore, do not elaborate on this issue any further. The statistically significant parameter estimates on capital intensity and R&D employment provide empirical support for hypotheses that rely on human capital accumulation as sources of TFP growth. The results lend no support to the hypothesis that increased trade in intermediate inputs is a source of TFP growth, but this cannot be taken as being conclusive since GLI is a proxy - perhaps a poor one - for the extent of trade in <u>intermediate</u> inputs. The evidence against the specialisation hypothesis seems to be stronger. This final finding is not inconsistent with Feder's (1982) results which were based on developing countries since ours are based on the industrial countries.

The specification in equation (15) is an all-encompassing one in terms of possible sources of growth. Should these sources of growth be <u>complementary</u>, the regression estimate would be prone to the presence of multicollinearity[22]. We examine this possibility by looking at the magnitude of the adjusted coefficient of variation from regressing <u>each</u> of the RHS variables on the remainder. Table A1a in Appendix reports the correlation coefficient between the levels of the variables when annual data is used while Table 1b reports values of adjusted R^2 when averaged data is used in the regressions. The only variable that satisfies the orthogonality condition is $G\hat{L}I$, the specialisation indices are highly collinear with the partial correlation $\frac{\partial XSPI}{\partial YSPI} = 0.52$, this estimate being statistically significant at the five per cent

[22] The limited degrees of freedom disallow use of interactive terms in the model.

level. Omitting any one of the specialisation indices from the estimate of equation (15) does not alter the above qualitative findings on sources of growth.

We examine the robustness of the above findings. This is done by re-estimating equation (15) with restrictions imposed on the parameters. In our first estimate, we restrict the production function to be CRS. In the second, we impose a capital elasticity of 0.3 and that for labour of 0.7, values used in calibration exercises as in Mankiw, Romer and Weil (1992). The results are reported in Appendix Table A3. We note that the above findings on sources of TFP growth within OECD manufacturing are robust to the above restrictions.

5.5 Conclusion

One of the contributions of this chapter is to demonstrate that cross-country growth regressions may suffer from the failure of the assumption that the RHS variables have equal impact across countries on growth of output. Cross country growth regressions such as those of Barro (1991), Levine and Renelt (1992), Benhabib and Spiegel (1994) always assume homogeneity of the effect of the RHS variables on the dependent variable, an assumption that may not hold as suggested by the empirics in this chapter. This may be one reason why empirical support for endogenous growth theory is far from being conclusive. Not withstanding this criticism, the positive findings of this paper can be summarised as follows.

This chapter has extended the existing theoretical models on sources of growth into estimable equations. Annual data on the manufacturing sector for twelve OECD countries from 1970 to 1990 have been used to test for support on four hypothesised sources of growth: increases in use of specialised inputs; human capital accumulation through an externality as LBD; investment in R&D and gains from specialisation in production and/or exports. The empirical analysis shows qualified[23] support for all except the very last. These findings seem to justify the current move in the literature emphasising the importance of human capital (Romer 1989, 1993a&b, 1994; Baumol et al 1994; etc) in growth. The role of trade in intermediate inputs in TFP growth is debatable and can only be sorted out through use of a better measure of the variable.

There are two issues that deserve further investigation. First, we would like to discern the role of trade policy in TFP growth for the sample of countries studied in this chapter. Absence of data on trade restrictiveness have not made this investigation possible yet[24], but we are able to extend the analytical framework developed in this chapter so as to test the role of trade policy in TFP growth within Australian manufacturing industries. This is the subject of the next chapter. Second, whether these findings extend to developing countries, on which most of the empirical support for outward orientation is based, is another issue for investigation. Chapter 7 throws some light on this issue.

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[23] The qualification is that homogeneity assumption with respect to slope coefficients hold. As yet we do not have sufficient degrees of freedom to test this assumption.

[24] Compilation of data on extent of trade restrictiveness within the manufacturing sector of the OECD economies is a priority area for future research.

APPENDIX

AI. Variable definitions and Data Sources

GLI - Grubel-Lloyd intra-industry index computed using data from STARS.

K - Capital stock in 1985 US billions of dollars. Source: ISDB, OECD (1993)

N - Employment in manufacturing. Source: ISDB, OECD (1993)

R - Number, in thousands, of scientists and engineers engaged in R&D. Source: UNESCO (various issues).

XSPI - Export specialisation index (decimal scalar) computed using data from STARS.

Y - Output of manufactures in 1985 US billions of dollars. Source: ISDB, OECD (1993)

AII. Countries covered in the study.

Australia

Canada

Finland

France

Germany, F R

Great Britain

Italy

Japan

Netherlands

Norway

Sweden

United States of America

AIII Time period covered: 1970 to 1990. Absence of data on some variables meant that the number of observations got reduced as more variables were included in the regressions.

Table A1a: Simple correlation using annual data

NUMBER OF OBSERVATIONS: 222

CORRELATION BETWEEN VARIABLES

	Y	K	L	Y/L	R&D	XSPI	YSPI	XSPIA
Y	1							
K	0.97898	1						
L	0.94486	0.91844	1					
Y/L	0.60018	0.59938	0.41276	1				
R&D	0.95418	0.92558	0.92138	0.51657	1			
XSPI	-0.50746	-0.50378	-0.57253	-0.1053	-0.47075	1		
YSPI	-0.43877	-0.48105	-0.53451	-0.18325	-0.33285	0.77266	1	
XSPIA	-0.01759	-0.07508	-0.03873	0.006442	0.093094	-0.23788	-0.01122	1

Note, $XSPIA_t = \sum_{i=1}^{I}(\frac{x_{it}}{x_t})^2$, is export specialisation index used by BKK (see footnote 15).

Table A1b: Extent of multicollinearity in (15)

Dependent Variable	Adjusted R^2
$\hat{K}$	0.38
$\hat{L}$	0.08
$\ln y_{t-1}$	0.47
$\ln k_{t-1}$	0.57
$\ln R_{t-1}$	0.59
$G\hat{L}I$	-0.11
$XSPI_{t-1}$	0.74
$YSPI_{t-1}$	0.75

Note: Averaged data used for above estimates.

Table A2: OLS estimates based on pooled data. Dependent variable: Annual growth of manufacturing output ($\hat{Y}$). t-ratios given in parenthesis.

Variable	**Model 1**	**Model 2**	**Model 3**
$\hat{K}$	-0.095	-0.16	-0.40**
	(-0.84)	(-1.08)	(-2.48)
$\hat{L}$	0.95**	1.00**	1.04**
	(12.99)	(12.20)	(12.8)
$\ln y_{t-1}$		-0.025**	-0.026**
		(-3.49)	(-4.23)
$\ln k_{t-1}$		0.007	0.0071
		(1.63)	(1.63)
$\ln R_{t-1}$		0.0033**	0.0050**
		(3.42)	(4.49)
$G\hat{L}I$		0.13**	0.11**
		(2.88)	(2.48)
$XSPI_{t-1}$		omitted	-0.28
			(-1.42)
$YSPI_{t-1}$		omitted	0.42**
			(3.01)
Constant	0.015*	0.11**	0.12**
	(8.43)	(2.89)	(2.33)
# of obs.	272	222	222
SER	0.0141	0.0137	0.0135
Adj. R-SQ	0.39	0.46	0.48
F-statistic	2.15	4.73	4.22
(p-value)	(0.0003)	(0.0000)	(0.0000)

K is capital stock in billions of 1985 US dollars. N is number of employees in millions. R is total number (in thousands) of scientists and engineers engaged in R&D in the economy. GLI, XSPI and YSPI are Grubel-Lloyd, export and output specialisation indices computed using (12) and (13), respectively, and data from STARS. F-statistic is test for homogeneity of all the parameters. A carat over a variable denotes its annual growth rate (see footnote 2). ** denotes the coefficient is statistically significant at 5 percent significance level. Model 1 is an estimate of the Solow growth accounting equation. Model 2 is an estimate of (15) but without the specialisation indices, while 3 is a complete estimate of equation (15).

Table A3: Estimates of equation (15) with parameter restrictions. Dependent variable: Growth of manufacturing output ($\hat{Y}$). t-ratios given in parentheses.

Variable	**Model D (OLS Estimate)**	**Model E (OLS Estimate)**
$\hat{K}$	0.69	0.3
	(imposed)	(imposed)
$\hat{N}$	0.31*	0.7
	(1.88)	(imposed)
$\ln y_{t-1}$	-0.065*	0.072**
	(-1.83)	(2.88)
$\ln k_{t-1}$	0.087**	0.015**
	(3.16)	(2.33)
$\ln R_{t-1}$	0.015**	0.015**
	(3.16)	(2.33)
$G\hat{L}I$	0.066	0.080
	(0.40)	(0.51)
$XSPI_{t-1}$	0.29	0.39
	(0.21)	(0.28)
$YSPI_{t-1}$	-0.53	-0.49
	(-0.59)	(-0.57)
Constant	-0.42	-0.27
	(-1.27)	(-0.93)
# of obs.	35	35
Adj. R-SQ	0.46	0.22
SER	0.0313	0.0314
F statistic	2.0133	2.3718
(p-value)	(0.0987)	(0.0533)

Model D has CRS with respect to K and N, while E has the first two parameters imposed. For further notes see Table 2 in the text.

Chapter 6

Trade Liberalization and Australian Manufacturing Growth: A 3-Digit Econometric Study.

Abstract

This chapter employs panel data from Australian manufacturing industry at three-digit level of disaggregation to explain sources of growth over the 1970 - 1991 period. An augmented Solow growth accounting equation is used to test hypotheses from endogenous growth literature, in particular the hypothesis that trade liberalization promotes growth. The empirical analysis reveals support for the latter hypothesis, showing that there is a significant negative association between sectoral protection, measured as deviation of domestic from foreign prices, and sectoral output growth. The analysis shows that production in the sector is constant-returns-to-scale with respect to labour and physical capital but increasing-returns-to-scale when human capital is included as an additional factor of production. The paper also shows that capital intensity has been a significant factor in explaining output growth in the sector. This may be interpreted as support for human capital explanations of sustained/endogenous growth.

6.1 Introduction

The role of trade liberalization in growth is an interesting issue, and particularly so in the context of Australian manufacturing given the strong view held by the policy makers that reductions in protection to the sector are the principal means by which government can induce productivity growth (see Charles, 1986). Surprisingly, empirical support for this stance has generally been lacking.

Evidence in support of the hypothesis that trade liberalization enhances growth has generally been collated via two methods: the first relies on cross-country growth regressions showing a positive (partial) correlation between growth in GDP and some measure of trade orientation (see for example Dollar 1992, Dowrick 1994, and Edwards 1992); the second, and far less popular method, is evidence at the micro level showing improvement in firm-level technical efficiency following major episodes of trade liberalization (see Tybout, Corbo and de-Melo 1991). The problem with the first method is that the regression equations estimated are not deduced from a rigorous theoretical structure, hence the observed positive (partial) correlation between some measure of trade orientation and GDP growth cannot be interpreted as implying any causality; the second method has very severe data demands in that episodes of major trade policy changes are rare[1] and in the few instances when they do occur collection and release of the requisite data is prone to further problems. For example, Industries Commission (1995) reports that Australia went through two phases of major trade liberalization, one in the early 70s and the other commencing July, 1988. The Australian Bureau of Statistics collects firm level data but release of such data is prohibited by law.

[1] Normally, trade is liberalised over extended periods of time.

The traditional neoclassical Solow-Swan model of growth does not admit a role for policy in growth and therefore does not provide a theoretical framework for empirical analysis of the association between trade policy and growth. The recent developments in endogenous growth theory have, according to Romer (1989a), delivered some of the tools necessary to analyse the role of policy in growth. A number of researchers in this area including Backus, Kehoe and Kehoe (1992) and Falvey (1995) suggest that empirical studies of sources of growth are likely to be more informative if carried out at the sectoral level. This paper is an attempt to use these developments in order to analyse the role of trade liberalization in growth of manufacturing output in Australia.

The standard Solow growth accounting equation is augmented to allow a role for human capital accumulation and trade liberalization in growth of output and total factor productivity (TFP). This augmentation is done such that the resulting equation is amenable to empirical implementation with readily available industry level data. Australian manufacturing data is then used to show that the data accepts the model.

Trade liberalization and output/TFP growth.

From a policy maker's perspective, current research in endogenous growth theory raises interesting possibilities for policy to have a non-trivial role in growth[2]. We incorporate the role of policy in the augmented growth accounting relationship so as to allow an examination of the hypothesis that protection adversely affects productivity growth. Limitations[3] on availability of data on a number of the relevant variables constrain us to limit our empirical analysis to Australian manufacturing dissaggregated at 2 digit ASIC

[2] See Falvey (1995) for a recent survey on role of trade policy in growth.

[3] These limitations are time series in nature in that data for the requisite variables are available but their time series is either tattered or not long enough.

and 3 digit ISIC. The objective is to separate out the contribution of human capital accumulation to output growth from the contribution of changes in trade protection.

The main findings of this Chapter include: the Solow growth accounting equation can be augmented to account for endogenous growth; human capital accumulation has been significant in explaining output growth of the manufacturing sector in Australia over the last two decades; and reductions in protection in Australia have been significant in impacting on TFP and output growth in the sector over the same period.

The rest of the Chapter is organised as follows. Section 2 develops the analytical framework and then presents the core equation to be estimated. Section 3 reviews the current literature on the association between trade policy and growth, then extends the analytical framework developed previously so as to allow a test of the hypothesis that trade protection affects TFP and output growth. Section 4 further augments the model by introducing other possible sources of growth. Section 5 presents the data and 6 the empirics. Conclusion follows.

6.2 The analytical framework

The aggregate production function used is neoclassical and is represented by

$$Y = F(K, L(N,h), t), \quad L_N > 0 \quad L_h > 0 \text{ and } L(0,h) = 0 \qquad (1)$$

where Y is aggregate output, K is physical capital stock, L is labour input which in turn is a function of the number (N) of workers and average endowment of human capital (h) per worker[4], and t (for time) captures

[4] We use the notation that small letters represent per-worker (capita) level of the variable.

Solow's exogenous technological progress. The first pair of restrictions on L simply state that an increase in either N or h increases labour input. The last restriction together with the Inada conditions implies that K and N are essential for production. F, being neoclassical, satisfies the usual regularity conditions. Taking the derivative of (1), with some rearrangement, gives the growth accounting identity.

$$\frac{dY}{Y} = K\frac{F_K}{F}\frac{dK}{K} + L\frac{F_L}{F}\frac{dL}{L} + \frac{F_t}{F}dt \qquad (2)$$

The number of workers and average human capital per worker combine via a Cobb-Douglas technology to produce labour input. ie

$$L = N^{\alpha}h^{\beta};\ \ 0 < \alpha, 0 \leq \beta,\ \text{and}\ \alpha + \beta \geq 1 \qquad (3).$$

The restrictions allow two possibilities: that human capital does not augment labour ($\alpha = 1, \beta = 0$); and the technology is increasing returns to scale ($\alpha + \beta > 1$). Substitution of (3) into (2), with the assumption of competitive factor markets, gives

$$\hat{Y} = A(t) + \sigma_K\hat{K} + \alpha\sigma_L\hat{N} + \beta\sigma_L\hat{h} \qquad (4)^5$$

where $A(t)$ captures exogenous technological progress and σ_v represents the share of factor v (=L, K) in production. Note that (4) is the familiar growth accounting equation but now augmented with human capital. If we assume that the production function is constant returns to scale (CRS) in K and N and that all human capital accumulates via an externality as learning-by-doing (LBD) (Lucas 1988) then

5 A carat over a variable represents its proportional/growth rate.

$$\sigma_K + \alpha\sigma_L = 1 \qquad (4a).$$

which by construction gives increasing returns to scale (IRS) in the three factors as implied by new growth theory. ie.

$$\sigma_K + (\alpha + \beta)\sigma_L > 1 \qquad (4b)$$

for a strictly positive β and σ_L. The absence of data on h necessitates the specification of the process of human capital accumulation. The human capital accumulation technology of Lucas (1988) is augmented by incorporating the claims that: learning is bounded and subject to diminishing returns (Young 1991); and that the process of learning is sector-specific with the possibility of leap-frogging between sectors (Brezis, Krugman, and Tsiddon 1993). Human capital accumulation technology takes the form

$$\hat{h} = g(k, y, T), \;\; g_k > 0 \;\;\; g_{kk} < 0 \;\;\; g_y < 0 \;\;\; g_{yy} > 0 \quad (5),$$

where k and y denote per-worker levels of physical capital and output, respectively and T is a shift parameter that captures the impact of technological break-throughs. The first two restrictions on g imply that the rate of human capital accumulation is increasing in k but at a diminishing rate. This captures the fact that a worker endowed with more physical capital accumulates human capital at a faster rate, but this process is subject to diminishing returns[6]. The last two restrictions on g show that for given human capital accumulation technology, a higher level of per-capita output implies a lower rate of learning, but this process is convex in y. Hence, the

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[6] Findlay (1995) assumes that the rate of learning-by-doing (LBD) across sectors in the standard two factor n good trade model is positively related to their capital intensities

second pair of restrictions on g capture convergence in the rate of human capital accumulation for given level of capital intensity. Young (1991) claims considerable empirical support for his claim that learning is bounded in each good (sector) and that growth is sustained by 'path-breaking' innovations that are financed by R&D expenditure. The curvature assumptions imposed on the learning technology capture the former, while the shift parameter enables the incorporation of the latter effect. Specifically, we assume *g(k,y, T)* takes the form

$$g(k,y,T) = \ln T + \gamma \ln k - \delta \ln y \quad 0 < \gamma, \delta; \; \frac{\gamma}{\delta}\frac{y}{k} > f'(k) \text{ and}$$

$$\left(\frac{f'(k)}{f(k)}\right)^2 - \frac{f''(k)}{f(k)} < \frac{\gamma}{\delta}k^2 \qquad (6)$$

where $f = \dfrac{F}{L}$ and the last pair of restrictions follow from the curvature assumptions made in (5) above. Now, substituting (6) into (4) gives an estimable equation of the form

$$\hat{Y} = A(t) + \sigma_K \hat{K} + \alpha\sigma_L \hat{N} + \beta\sigma_L(\gamma \ln k - \delta \ln y) \qquad (7).$$

The empirical implementation of (7) has the following strengths: the data on K and N are readily available; we have some feel for the magnitudes of σ_K and σ_L; and, (7) is an extension of the growth accounting equation with which we are familiar. Furthermore, equation (7) has been deduced from a general neoclassical production function where part of the TFP growth in the model is due to human capital accumulation. Note that for a given technology shock, the above model has steady state characteristics identical to that of the neoclassical growth model. The model admits long-run growth via shifts in the learning schedule, perhaps the result of path-breaking innovations as in Young (1991). Growth in the short to intermediate term, when the learning schedule is assumed to be static, is permissible as the economy moves down its learning curve. Shifts in the learning curve can be interpreted as exogenous technological progress and therefore captured by the constant term in equation (7) above.

As yet, and contrary to the common wisdom within endogenous growth theory (Rebelo 1991), policy has no role in impacting on growth. We attempt to rectify this by further augmentation of the model. We consider the role of trade policy, protection in particular, on output growth.

6.3 The association between trade policy and growth

There is limited theoretical work on the relationship between trade policy, protection in particular, and TFP growth but model-based empirical work in the area is even more rare. The theorised linkages between trade policy and protection include Verdoon's law which claims a positive association between output growth and productivity growth, the link between the two variables being most apparent for manufactures and hypothesised as being due to the presence of some form of economies of scale (EOS) in the sector. Hence a bilateral opening of trade, resulting in the widening of markets, is perceived as being a means of taking greater advantages of EOS in the sector which then shows up as TFP growth. Other associations between trade and growth include those arising from knowledge diffusion and incentives for innovation (Grossman and Helpman 1991) and trade in differentiated inputs (Romer 1986).

A second mechanism via which trade policy and TFP are linked emerges from the X-inefficiency literature. This literature claims that protection given to domestic firms shelters them from foreign competition and in the process confers some monopoly power to the firms, hence allowing them to enjoy some excess profits in the sector. This excess profit may then induce slack amongst employees and managers which shows up as lower TFP levels for the protected sector (see Vousden 1993; Vousden and Campbell 1994; Campbell and Vousden 1995; and Horn, Lang and Lundgren 1991).

Horstmann and Markusen (1986) show that when an industry is characterised by Chamberlinean competition, protection attracts inefficient entry of small producers which in turn raises average cost of production. This shows up as a lowering of TFP when protection is raised for the sector. In general, any intervention that induces deadweight losses or leakages of rents from the national economy will manifest as a decline in TFP when national data are used in the computations.

Despite the many theoretical models that predict an association between protection and TFP, albeit at times with conflicting signs on the directions of such hypothesised association, there is still a dearth of empirical support for any of these conjectures. Two of the more notable empirical studies are Nishimizu and Page (1991) and Tybout, Melo and Corbo (1991). The latter, whose study is in the same spirit as in this paper, use Chilean firm level data to give weak support to the hypothesis that the level of protection is negatively associated with plant level technical efficiency. Pack (1994) notes that

> ' to date there is no clear confirmation of the hypothesis that countries with an external orientation benefit from greater growth in technical efficiency in component sectors of manufacturing'

while Bhagwati (1988) concludes that

> ' although the arguments for the success of the export promotion strategy based on economies of scale and X-efficiency are plausible, empirical support for them is not available'.

The analytical framework developed in the last section is extended so as to enable a test of the association between changes in protection and TFP growth. The analysis employing changes in as against levels of variables of primary interest is important given that factors inherent in particular industries are not going to contaminate the findings when use is made of the former rather than the latter. For example, the role of non-traded goods is not considered in our model. This would not contaminate the findings if the role of non-traded goods does not change over time.

Further augmentation of the estimable equation

The framework developed in the last section is augmented to allow for a role for trade policy in TFP growth. Of the two factors of production, *K* and *L*, the X-inefficiency literature suggests that protection affects the latter. Vousden and Campbell (1994) model this to demonstrate how protection may induce a fall in cost-reducing activity within the firm. We follow this lead and state labour input into production as

$$L = L(N, h, R), \quad L_R < 0 \qquad (8)$$

where R is the level of protection. Alternatively, labour input in (8) can be interpreted as incorporating effort, E, such that

$$L = (EN)^{\alpha} h^{\beta} \qquad (8a)$$

where $E_R < 0$ in the presence of a "cold shower" effect of trade liberalization. The restriction on (8) shows that an increase in protection reduces the amount of effective labour input (L), a restriction that is imposed in addition to those given in (1) above. Differentiating (8) gives

$$\hat{L}(N,h;R) = \hat{L}(N,h) - \tau\hat{R} \qquad (9)$$

where a zero value of τ would imply an absence of any "cold shower" effect. The actual magnitude of τ is an empirical issue and attended to in section 6 below. Substituting (3) into (9), the resulting expression into (7) gives

$$\hat{Y} = A(t) + \sigma_K\hat{K} + \sigma_L[\alpha\hat{N} + \beta(\gamma \ln k - \delta \ln y) - \tau\hat{R}] \quad (10).$$

Equation (10) shows that the growth in output is the sum of growth in exogenous technological progress and growth in factor inputs weighted by their shares in production. The growth in labour, in turn, is the sum of growth of its components weighted by their respective elasticities.

6.4 Other possible sources of growth

We know that (10) is not completely specified given that human capital accumulation is not the only source of output growth. Other possible sources of growth[7] include those arising from trade in differentiated inputs (Grossman and Helpman 1991, Romer 1989, etc), from increases in specialisation in production (Backus, Kehoe and Kehoe 1992), and from outward orientation (Dollar 1992, Feder 1982, and World Bank 1988). We incorporate these additional potential sources of growth in our augmented model for two reasons: first, to minimise the possibility of omitting relevant variables from

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[7] We attended to these additional sources of growth in detail in the last chapter, hence keep this section brief.

the model; and second, to allow a test of the robustness of the variables in (10) to inclusion of additional explanatory variables. We employ the measures developed in Backus *et al* (1992) to quantify the extent of specialisation in exports and production.

$$XSPI_t = \sum_{i=1}^{I} (\frac{X_{it}}{Y_t})^2 \text{ and } YSPI_t = \sum_{i=1}^{I} (\frac{Y_{it}}{Y_t})^2$$

where X_{it} is exports of sector i at time t, Y_{it} is output of sector i at t, and Y is the total output of the industry aggregated one echelon up. The extent of intra-industry trade is proxied by the Grubel-Lloyd index.

$$\text{Grubel-Lloyd Index} = \frac{\sum_{i=1}^{I} (X_i + M_i - |X_i - M_i|)}{\sum_{i=1}^{I} X_i + \sum_{i=1}^{I} M_i}$$

In augmenting (10) with additional variables representing other possible sources of growth we run the risk of including irrelevant variables which will be at a cost of loss of efficiency at the estimation stage. On the other hand, should the above variables be relevant for the true model, then their omission will constitute a specification error resulting in parameter estimates being both biased and inconsistent. We attend to these issues after having examined the data.

6.5 Data

Data on manufacturing output, labour, and capital stocks at three digit ISIC are obtained from our Departmental database[8]. Data on the effective rates of protection (ERP) are obtained from the Industries Commission (1995).

[8] See Chand, Forsyth, Oh and Vousden (1995) for more detail on the database.

These data are available at the two and three digit ASIC levels of disaggregation. The number of people engaged in R&D is available at the two digit ASIC for most of the industries but only for a limited number of years. These data are obtained from ABS (various issues: catalogue number 8104.0). The limitation on the level of disaggregation of data available for R&D confines our study to two digit ASIC sectors when this variable is included in the model. Specialisation and intra-industry trade indices are computed using data from UNIDO via STARS[9]. Given that STARS provides data up to a maximum three digit ISIC level of industry disaggregation, the specialisation indices could be computed only up to two digit ASIC. Where appropriate, the 3-digit data has been aggregated up to two digit level. A listing of the sectors used is given in the Appendix.

The Departmental database contains annual data from 1970 to 1987 only. The reason for lack of post-1987 data is that the Australian Bureau of Statistics (ABS) stopped collecting investment data by sector from 1986. Capital stocks[10], which are constructed using a perpetual inventory method on investment data, could not therefore be compiled for the period after 1987. The omission of the post-1987 period from the study is considered to be serious in this context given that Australian manufacturing has undergone rapid changes in this period. For example, the Industries Commission (1995) reports that the local manufacturing sector went through two phases of deregulation, the first in the early 70s and the second commencing July, 1988. The database, therefore, has been extended to 1991, the latest for which output and employment data is available from UNIDO. As for capital stock series, we have used figures on annual new capital expenditure from ABS

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[9] STARS, for Statistical Analysis and Retrieval Service, is provided by the International Economic Data Bank (IEDB) at the Australian National University.

[10] Capital stocks are not adjusted for capacity utilisation since doing so will the necessitate a similar adjustment to effective labour.

(catalogue number 5626.0), available at approximately two digit ASIC, as opposed to the use of UNIDO data at three digit ISIC for the pre-1987 period, to extend the investment series to 1990. We have assumed uniform investment growth in the three-digit components of the two-digit category. eg. ABS (cat. No. 5626.0) contains a category called 'other manufacturing' which includes wood, wood products and furniture, glass, clay or other non-metallic mineral products, leather, rubber and plastic products. In constructing investment series post-1986, we have assumed that the proportional changes over time in annual investment in each of the component sectors has been the same. This is a simplification introduced to generate the required data which will introduce measurement error in capital stocks generated from the data. We therefore present two sets of estimation results, one using the data that extends up to 1987 only and another that extends up to 1991. Capital stock estimates are also contaminated to the extent of lease financing in the sector. Our inquiry with ABS reveals that data on lease financing will be collected from the September quarter of 1995, hence we are unable to assess the effect of lease-financed capital at this stage. The problem is considered to be serious in the latter half of the 1980s (see Walters and Dippelsman 1985), hence our estimates based on the full sample may also be adversely affected.

Australian data is used due to its availability. The manufacturing sector is used for the following two reasons: Backus *et al* (1992) show evidence in support of presence of scale in manufacturing only; and Roeger (1995) and references contained therein show that measurement error is at a minimum in the sector. Furthermore, the role of trade liberalization as a source of productivity growth has been an important consideration amongst Australian policy makers. Charles[11] (1986:4) contends that the 'strongest case for active government intervention' in order to facilitate productivity growth within the manufacturing sector is by gradual reduction in industry assistance to the most highly protected segments. The author also makes a case for increases in exports of manufactures so as to raise productivity in the sector.

An alternate measure of protection

Measurement of the extent of trade protection is a contentious issue and of considerable current research interest. Dean, Desai and Riedal (1994) point out that the minimum set of requirements for any index that measures trade restrictiveness include the following: the index must be objectively deduced; it should be comprehensive; it should have a wide breadth in terms coverage of distortions; and it should be sensitive to policy changes. The authors show that none of the existing measures satisfy all of the above requirements. In the case of Australia, the Industries Commission (1995) provides data on effective rates of protection (ERP) but this measure does not capture the effect of efficiency changes in support services and exchange rate movements, the latter of great significance in the context of Australia over the last two decades. Furthermore, the ERP figures show very little variation over the period of study, a characteristic of significant disadvantage in regression analysis. The sectoral real exchange rate is therefore used as an alternate measure of trade restrictiveness.

The Departmental database provides us with data on sectoral prices at three digit ISIC in US dollars after adjustment has been made for purchasing power parity between the OECD countries. This enables us to compute a time series

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[11] David Charles in 1986 was the secretary of the Department of Industry, Technology and Commerce.

of the extent of protection as represented by the price difference between Australia and the US[12] ie.

$$R_{it} = \frac{p_{it}^{AUS}}{p_{it}^{USA} e_t} \qquad (11)$$

where p_{it} is the domestic currency price of value added in sector i at time t and e is the Australian dollar price of a US dollar. Note that R_{it}-1 gives a measure analogous[13] to the effective rate of protection. Given the data constraints, R can be computed for sectors disaggregated at three digit ISIC only. Note that R is sensitive to the composition of the sector, a change of which over time would be reflected in changes in the index. Furthermore, R would be influenced by policy as well as any changes in efficiency of production in either of the two economies. It is clear that this measure is objectively deduced and is able to capture the effects of policy changes in the two countries. The one drawback of the measure is that it is unable to account for differences in prices of non-traded goods between the two countries, but this would not be of serious concern if changes as against levels of the variable are used and relative prices of individual traded goods to non-traded goods remain constant over time.

Figure 6-1 below gives a time plot of R for the four sectors: ISIC311 (food manufacturing); ISIC322 (manufacture of wearing apparel); ISIC371 (iron and steel industries); and ISIC384 (transport equipment).

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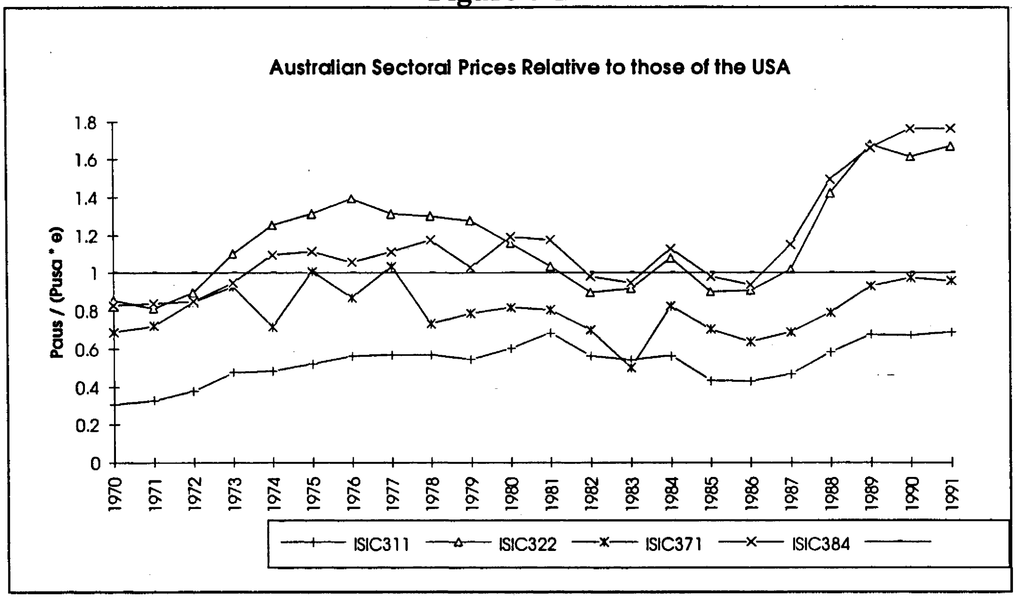
[12] The choice of US sectoral prices as numeraire is on pragmatic considerations only. Ideally, one would want the world free trade price but constructing such a price series is extremely difficult.

[13] R is the sectoral real exchange rate. A value of R less than one would imply that Australia has a price advantage in export of the good.

Figure 6-1



Points below the dotted line show sectors that have prices lower than in the United States. Exportables should have, on average, a value of *R* less than one while the opposite should hold for importables. The reason for such an association is readily found in standard comparative advantage theory. This seems to be confirmed by the picture above. Australia seems to have a comparative advantage in natural resource based industries such as food and steel & iron relative to secondary industries such as manufacture of transport equipment. But this explanation does not hold for <u>changes</u> in R, the RHS variable used in (10) above.

Note the sharp rise in R from 1987 for ISIC322 and ISIC384. Some, but not all, of this rise can be attributed to appreciation of the Australian dollar since the extent of this rise varies considerably between the sectors. This observation is in contrast to the published figures for ERP (Industries Commission, 1995) for the two sectors which shows a continual decline over the same period. R also has far more variability than ERP, a feature of great value in regression analysis. The value of R in 1970 is below one for the four industries, this possibly due to the method employed to construct the index. We note that the level of R obtained from (11) is sensitive to the particular ICP (UN, 1987) figures used, but this problem is not considered serious since it is the changes rather than the level of the variable that is used in the regression analysis.

6.6 The Empirics

The risk of omitting relevant variables is resolved by estimating two models, one as given by (10) and the other where (10) is augmented with all 'other' possible sources of growth. Including the additional hypothesised sources of growth and incorporating dynamics in the structure gives an estimable equation of the form

$$\hat{Y} = a_0 + a_1\hat{K} + a_2\hat{N} + a_3 \ln k_{t-1} - a_4 \ln y_{t-1} - a_5\hat{R} + a_6 XSPI_{t-1} + a_7 YSPI_{t-1} + a_8 G\hat{L}I \tag{12}$$

where *XSPI*, *YSPI* and *GLI* are export, output and Grubel-Lloyd indices, respectively. Lags are included to capture the dynamics of the system. The model has been restricted to first lags only for two reasons: first, there is insufficient data to model any long-run dynamics; and second, first order effects are perceived to be most pervasive and hence likely to be picked up adequately by the model.

For estimation purposes equation (12) can be viewed as a simple dynamic model incorporating first lags. The theory in Section 2 employed continuous time, but data is available in discrete time hence growth rates are taken as first differences in the variable divided by their lagged level. eg

$$\hat{Y} = \frac{Y_t - Y_{t-1}}{Y_{t-1}} \cong \ln Y_t - \ln Y_{t-1} \qquad (13)$$

Considering the variables in equation (10), and taking proportional changes in variables as being equal to their first log differences as given in equation (13) gives a reduced form of equation (12) of the form

$$\ln Y_t = b_0 + b_1 \ln K_t + b_2 \ln N_t + b_3 \ln Y_{t-1} + b_4 \ln K_{t-1} + b_5 \ln N_{t-1} + b_6 \hat{R} \qquad (14)$$

where equation (12) implies that $b_5 = (1+ b_2 + b_4 - b_1 - b_3)$. The original parameters can be recovered since $a_0 = b_0$, $a_1 = b_1$, $a_2 = b_2$, $a_3 = b_4 - b_1$, $a_4 = 1 - b_3$, and $a_5 = -b_6$. We can test if these restrictions are accepted by the data by employing the standard F-test. Furthermore, a value of b_3 of one in equation (14) will imply that estimation of (12) involves a regression of first differences on a set of RHS variables that includes both first differences and levels necessitating that these RHS variables be cointegrated for the estimation to be valid. This potential for failure of cointegration is examined by testing for presence of serial correlation. The impact of business cycles on the parameter estimates is another concern. The robustness of the results to business cycles is examined by re-estimating equation (12) using data averaged over five-year non-overlapping periods.

Results

Table 1 below gives estimation results when data from 1970 to 1987 disaggregated at the three digit ISIC is used. The same estimates when data up to 1991 are used are given in Appendix Table A1. Model A is an estimate of the Solow growth accounting relationship. Model B is an estimate of (10) when OLS is employed on pooled data while C is that obtained from LSDV[14] procedure. The F-statistic is a test for homogeneity of all coefficients in the OLS estimates while that in the LSDV estimates is a test for homogeneity of slope coefficients only. The computed values of F and the p-value for each computed F-statistic is reported in the Table as well. Equation (14) is estimated to test the restrictions on parameters imposed by theory in equation (12). The p-value on the F-statistic is 0.14793 suggesting that the data accepts the parameter restrictions contained in equation (12) at the five per cent significance level.

The assumption of overall homogeneity of coefficients is accepted at the 5 per cent significance level in model A and that for slope homogeneity is accepted in model C[15]. Production is constant returns to scale in *K* and *N* given the restriction in equation (4a) of section 2 is satisfied. The restriction given in (4b) is also satisfied suggesting IRS and support for human capital explanations for endogenous growth. The coefficient on level of sectoral physical capital per worker is positive and significant, giving support to the human capital accumulation hypothesis via increases in capital intensity. The sum of elasticities for each factor of production is not significantly different from one at the five per cent significance level[16], hence support for IRS (and endogenous growth via human capital accumulation) is weak.

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[14] This is the least squares dummy variable procedure. This is the same as the within estimator in Hsiao (1986).

[15] The magnitude of p-values on the F-statistic is sensitive to inclusion of food (ISIC 311), textile manufacturing (ISIC 321), and other non-metallic mineral products (ISIC 369). The exclusion of these sectors increases the p-value on the F-statistic significantly, but the qualitative findings, including their statistical significance, remains unaffected.

[16] The test, as implied by (10), is if $\sigma_K + \alpha\sigma_L + \beta\gamma\sigma_L > 1$.

Table 1: Result of estimation of equation (10) with a constant. Dependent variable: Annual growth of manufacturing output ($\hat{Y}$). Variables defined at <u>three</u> digit ISIC. t-ratios given in parenthesis.

Variable	**Model A (OLS Estimate)**	**Model B (OLS Estimate)**	**Model C (LSDV estimate)**
$\hat{K}$	0.23*	0.27*	0.30*
	(2.11)	(3.15)	(2.82)
$\hat{N}$	0.53*	0.66*	0.69*
	(6.27)	(9.69)	(10.08)
$\ln y_{t-1}$		-0.04*	-0.058*
		(-5.51)	(-6.12)
$\ln k_{t-1}$		0.017*	0.038*
		(5.00)	(2.22)
$\hat{R}$		-0.34*	-0.34*
		(-9.92)	(-9.83)
Constant	0.011*	0.37*	—
	(3.91)	(5.59)	
# of obs.	204	204	204
SER	0.0345	0.0272	0.0266
Adj. R-SQ	0.17	0.48	0.48
F-statistic	1.0988	1.4408	1.3491
(p-value)	(0.3398)	(0.0390)	(0.0851)

Notes: K is capital stock in billions of 1985 dollars; N is number of employees in millions; R is protection as defined in (11) above; A caret over a variable denotes its annual growth rate; * denotes the coefficient is statistically significant at 5 percent significance level; F-statistic in model B is test for overall homogeneity while that in C is test for slope homogeneity only.

The coefficients on $\hat{K}$ and $\hat{N}$ are surprisingly similar to the shares these two variables have in total output. This is very strong support for the view that factor markets are competitive and production in the sector is well represented by a Cobb-Douglas technology. The coefficient on lagged output is significant and negative in all the estimates. This is consistent with the theory of section 2 and the empirics of Barro and Lee (1994). The coefficient on $\hat{R}$ is negative and statistically significant giving support to the hypothesis that protection growth is negatively associated with output growth in the sector. The magnitude of this coefficient suggests that a one per cent increase in R leads to 0.3 per cent decline in TFP growth. The augmentation of the Solow growth accounting equation with variables from "new" growth theory has enabled another thirty per cent of the variation in the data to be explained by the model.

The LSDV model allows for differences between sectors, but these differences are assumed to be constant over time. The model diagnostics reported in Table 1 show that the assumption of homogeneity of all coefficients is rejected but that for slope homogeneity is accepted at the five per cent significance level. The parameter estimates in model C are not significantly different from those of model B. The absolute magnitude of the coefficient on lagged output is greater in the LSDV than the OLS estimates. This suggests that convergence over time is faster across industries when industry differences are accounted for by a time invariant industry dummy, an observation consistent with similar findings for the United States (Costello 1993 and Kollmann 1995). Results of estimation of models B and C with an updated data set that extends from 1970 to 1991 is reported in Appendix Table A1. The coefficient estimates obtained are similar to those reported above but the assumption of homogeneous coefficients is now rejected. We would like to believe that this is due to measurement error in estimates of capital stocks for the period following 1987 for reasons explained in section 5 above. Furthermore, restricting elasticities of production to be identical across the 3-digit ISIC sectors may be an unrealistic imposition on the model. The qualitative findings remain unchanged when the same model is estimated using data averaged over five year non-overlapping periods so as to control for effects of business cycles. This result is reported in Appendix Table A2. Test for serial correlation in all of the above models does not suggest failure of cointegration in any of the estimates.

The measure of protection as given by (11) includes the three components, the levels of domestic price, the US price and the exchange rate. We can therefore decompose the changes in protection as

$$\hat{R} = \hat{p}^{AUS} - \hat{p}^{US} - \hat{e} \qquad (15).$$

Substituting the RHS of (15) in place of $\hat{R}$ in (10) and re-estimating the model allows us to discern the sources of protection. The estimation results are given in Appendix Table A3. The coefficients on the individual components of $\hat{R}$ have the correct signs but that on $\hat{e}$ is statistically not different from zero. The magnitudes of the coefficients suggest that changes in domestic prices have the largest contribution to $\hat{R}$, followed by changes in US prices, while movements in the exchange rate have no significant impact. This result is qualified by the fact that the assumption of slope homogeneity is now rejected, but only marginally.

Inclusion of 'other' possible sources of growth

Data on the extent of intra-industry trade and level of specialisation are unavailable at the three digit ISIC level of disaggregation. We therefore estimate (12) with two digit ASIC data and figures for ERP as reported in

Industries Commission(1995). The results are reported in Appendix Tables A4 and A5. The coefficients on output specialisation, export specialisation, growth in intra-industry trade, and changes in levels of protection are not statistically different from zero. The positive, but statistically insignificant coefficient on the change-in-protection variable is opposite to that obtained from estimation of equation (10) as reported in Table 1 above. These results remain the same when R&D employment is added as an additional variable, but due to the small number of observations on sectoral R&D employment the LSDV procedure could not be employed in the estimation.

The estimates obtained when two digit ASIC data as against three digit ISIC data is used are very similar except for the coefficient on the measure of protection. When protection is measured as the difference in sectoral prices between Australia and the United States, changes in this variable have a negative and significant impact on output growth. This finding is robust to both the OLS and LSDV formulations. Replacing R by ERP as supplied by the Industries Commission (1995) in models B and C results in a negative but statistically insignificant coefficient on the variable. The assumptions of homogeneity of coefficients is also rejected at the five percent significance level in both the estimates.

The robustness of the finding that increases in protection are negatively associated with TFP growth is tested by using alternative measures of protection. First, we use 1985 purchasing power parity (PPP) price of consumption[17] to deflate current prices. The objective is to use a numeraire that is independent of exchange rate movements. Specifically, we let $P_{it} = \frac{p_{it}}{p_{Ct}}$,

[17] This data is extracted from the Penn World Tables and is net of exchange rate.

where p_i is price of good i, and p_C is price of consumption. We can now express our modified R as

$$R' = \frac{P_{it}^{AUS}}{P_{it}^{USA}} = \frac{p_{it}^{AUS} / p_{Ct}^{AUS}}{p_{it}^{USA} / p_{Ct}^{USA}} \qquad (11')$$

such that

$$\hat{R}' = (\frac{\hat{P}^{AUS}}{P^{USA}}) = (\hat{p}^{AUS} - \hat{p}^{USA}) - (\hat{p}_C^{AUS} - \hat{p}_C^{USA}) \qquad (15').$$

The last RHS pair of terms in (15') now replaces the exchange rate movements as captured in (15) above. Replacing $\hat{R}$ by $\hat{R}'$ as defined in (15') above leaves the qualitative findings unchanged (see Appendix Table A6 for results). We next measure the exposure of an industry to foreign competition by it's import penetration ratio (*IMP*), defined as $IMP = \frac{M}{Y + M - X}$. Replacing $\hat{R}$ by growth in sectoral import penetration ratio reveals that increases in imports lead to increases in sectoral TFP (see Appendix Table A7). Though we have some reservations on use of imports as a measure of openness (See Leamer, 1988 for a critique[18]), the empirics lend support to the view that greater exposure to imports leads to increased productivity.

6.7 Conclusion

This paper has augmented the Solow growth accounting equation so as to enable it to test for support for endogenous growth theory. Data from Australian manufacturing sectors at two and three digit levels of disaggregation and panel data econometrics is then used to test for empirical support for the (crude) model. The data accepts the model, the production

[18] Leamer (1988) contends that extent of imports is determined by endowments of a country in addition to the extent of trade restrictiveness. We agree with this view but, growth in imports would track changes in trade openness if endowments are constant over time and income effects on demand for imports are negligible.

technology is shown to be constant returns to scale (CRS) in physical capital and labour, measured as number of workers, but weakly increasing returns to scale when human capital is included as an additional factor of production.

The model is used to test the hypotheses that trade deregulation, increases in intra-industry trade and in specialisation in production and exports, raises TFP growth. The empirics lends support to the first hypothesis but only when protection is measured as the difference in sectoral prices between Australia and the United States. To date, this is the only evidence for the Australian manufacturing sector showing a negative association between changes in levels of protection and output growth in the sector. This finding is robust to use of two alternate measures of protection, the import penetration ratio and sectoral prices expressed in terms of price of consumption.

The empirics offer support for the role of human capital accumulation, as depicted by (5), in growth of output of manufactures in Australia. This supports endogenous growth theories based on human capital accumulation. Our theoretical structure suggests that growth takes place in spurts after each shift in the human capital accumulation schedule. This implies convergence, but only for those which are on the same learning schedule. TFP growth in this framework is driven by the process of human capital accumulation and could be perpetual, the latter a requirement for endogenous growth.

APPENDIX

AI. This paper uses the following industries

Industry Description	ISIC
Food manufacturing	311
Manufacture of textiles	321
Manufacture of wearing apparel excluding footwear	322
Manufacture of leather products excluding footwear	323
Manufacture of footwear excluding rubber	324
Manufacture of Wood and Cork products	331
Manufacture of furniture	332
Manufacture of paper products	341
Manufacture of industrial chemicals	351
Other non-metallic mineral products	369
Iron and steel basic industries	371
Transport equipment	384

ASIC Two Digit Sectors	ASIC
Food, Beverages and Tobacco	21
Clothing and Footwear	24
Wood, Wood Products and Furniture	25
Paper, Paper Products, Printing	26
Chemicals, Petroleum and Coal Products	27
Non-Metallic Mineral products	28
Basic Metal Products	29
Transport Equipment	32

Table A1: Result of estimation of equation (10). Data from 1970 to 1991 employed. Dependent variable: Annual growth of manufacturing output ($\hat{Y}$). Variables defined at <u>three</u> digit ISIC. t-ratios given in parenthesis.

Variable	**Model B' (OLS Estimate)**	**Model C' (LSDV estimate)**
$\hat{K}$	0.19*	0.15
	(2.44)	(1.76)
$\hat{L}$	0.74*	0.75*
	(10.92)	(10.97)
$\ln y_{t-1}$	-0.036*	-0.051*
	(-4.76)	(-5.50)
$\ln k_{t-1}$	0.017*	0.013
	(4.95)	(0.87)
$\hat{R}$	-0.36*	-0.36
	(-10.84)	(-10.87)
Constant	0.33*	
	(4.79)	
# of obs.	240	240
SER	0.0290	0.0287
Adj. R-SQ	0.48	0.47
F-statistic	1.7486	1.7418
(p-value)	(0.0022)	(0.0038)

Table A2: Result of estimation of equation (10). Data averaged over four five-year non-overlapping periods from 1970 to 1989. Dependent variable: Annual growth of manufacturing output ($\hat{Y}$). Variables defined at three digit ISIC. t-ratios given in parenthesis.

Variable	**(LSDV estimate)**
$\hat{K}$	-0.0012
	(-0.0093)
$\hat{L}$	0.82*
	(4.41)
$\ln y_{-1}$	-0.0053
	(-0.81)
$\ln k_{t-1}$	0.0069*
	(2.35)
$\hat{R}$	-0.61*
	(-5.24)
Constant	0.048
	(0.79)
# of obs.	39
SER	0.011
Adj. R-SQ	0.46

NOTE: The lagged values are averages for the previous five-year period. Tests for homogeneity of parameters could not be carried out due to lack of sufficient degrees of freedom.

Table A3: Result of estimation of equation (10) augmented with components of $\hat{R}$. Data from 1970 to 1987 employed. Dependent variable: Annual growth of manufacturing output ($\hat{Y}$). Variables defined at <u>three</u> digit ISIC. t-ratios given in parenthesis.

Variable	**(LSDV estimate)**
$\hat{K}$	0.19*
	(2.19)
$\hat{L}$	0.65*
	(11.83)
$\ln y_{t-1}$	-0.038*
	(-4.64)
$\ln k_{t-1}$	0.042*
	(3.01)
$\hat{p}^{US}$	0.14*
	(2.55)
$\hat{e}$	0.044
	(0.96)
$\hat{p}^{AUS}$	-0.62*
	(-15.66)
Constant	
# of obs.	204
SER	0.0215
Adj. R-SQ	0.66
F-statistic	1.4609
(p-value)	(0.0346

Table A4: Results of pooled estimation using OLS. Data at two digit ASIC from 1970 to 1987 used. Dependent variable: Annual growth of manufacturing output ($\hat{Y}$). t-ratios given in parenthesis.

Variable	**Model A**	**Model B**	**Model C**
$\hat{K}$	0.23*	0.21*	0.22
	(4.69)	(4.52)	(4.47)
$\hat{L}$	0.75*	0.78*	0.78*
	(7.53)	(8.17)	(8.08)
$\ln y_{t-1}$		-0.034*	-0.033*
		(-4.23)	(-3.85)
$\ln k_{t-1}$		0.016*	0.014*
		(4.00)	(2.44)
$XSPI_{t-1}$			-0.022
			(-1.11)
$YSPI_{t-1}$			0.0024
			(0.16)
$G\hat{L}I$			0.016
			(0.54)
$E\hat{R}P$			0.020
			(0.60)
Constant	0.013*	0.31*	0.32*
	(5.40)	(4.17)	(4.17)
# of obs.	153	120	120
SER	0.0271	0.0229	0.0231
Adj. R-SQ	0.56	0.69	0.68
F-statistic	1.3178	1.3614	1.2979
(p-value)	(0.1658)	(0.1352)	(0.1669)

Table A5: Results from LSDV procedure. Data at two digit ASIC from 1970 to 1987 used. Dependent variable: Annual growth of manufacturing output ($\hat{Y}$). (t-ratios given in parenthesis.)

Variable	Model A	Model B	Model C
$\hat{K}$	0.24*	0.18*	0.19*
	(4.83)	(2.82)	(2.71)
$\hat{L}$	0.75*	0.81*	0.83*
	(7.62)	(8.48)	(8.38)
$\ln y_{t-1}$		-0.042*	-0.043*
		(-3.92)	(-3.91)
$\ln k_{t-1}$		0.010	0.020
		(0.45)	(0.79)
$XSPI_{t-1}$			-0.014
			(-0.32)
$YSPI_{t-1}$			0.19
			(0.86)
$G\hat{L}I$			0.018
			(0.49)
$E\hat{R}P$			0.016
			(0.59)
# of obs.	153	120	120
SER	0.0265	0.0226	0.0229
Adj. R-SQ	0.55	0.69	0.68
F-statistic	1.0036	1.4382	1.2691
(p-value)	(0.4574)	(0.1975)	(0.1945)

Table A6: Result of estimation of equation (10) but with $\hat{R}$ replaced by growth in $\hat{R}'$ as defined in (15'). Data from 1970 to 1987 at three digit ISIC used. Dependent variable: Annual growth of output ($\hat{Y}$). t-ratios given in parenthesis.

Variable	**Model C"** (LSDV Estimate)
$\hat{K}$	0.29*
	(2.70)
$\hat{L}$	0.67*
	(9.65)
$\ln y_{t-1}$	-0.055*
	(-5.63)
$\ln k_{t-1}$	0.041*
	(2.33)
$\hat{R}'$	-0.29*
	(-9.24)
# of obs.	204
SER	0.0264
Adj. R-SQ	0.46
F-statistic	1.5964
(p-value)	(0.0160)

Table A7: Result of estimation of equation (10) but with $\hat{R}$ replaced by growth in import penetration ratio ($\hat{IMP}$). Data from 1970 to 1987 at three digit ISIC used. Dependent variable: Annual growth of output ($\hat{Y}$). t-ratios given in parenthesis.

Variable	**Model B"** (OLS Estimate)
$\hat{K}$	0.20*
	(1.97)
$\hat{L}$	0.61*
	(7.60)
$\ln y_{t-1}$	-0.035*
	(-4.01)
$\ln k_{t-1}$	0.017*
	(4.32)
$\hat{IMP}$	0.14*
	(-10.84)
Constant	0.31*
	(3.96)
# of obs.	204
SER	0.0321
Adj. R-SQ	0.28
F-statistic	2.1599
(p-value)	(0.0001)

Import penetration ratio, IMP, is defined as $\frac{M}{Y+M-X}$.

K is capital stock in billions of 1985 dollars. L is number of employees in millions. GLI and XSPI are Grubel-Lloyd and export specialisation indices, respectively. ERP is the effective rate of protection as supplied by IC(1995) while R is the sectoral real exchange rate as given by (11). A caret over a variable denotes its annual growth rate. * denotes the coefficient is statistically significant at 5 percent significance level. The F-statistic is test for homogeneity of slope coefficient only in the LSDV estimates.

Chart A1

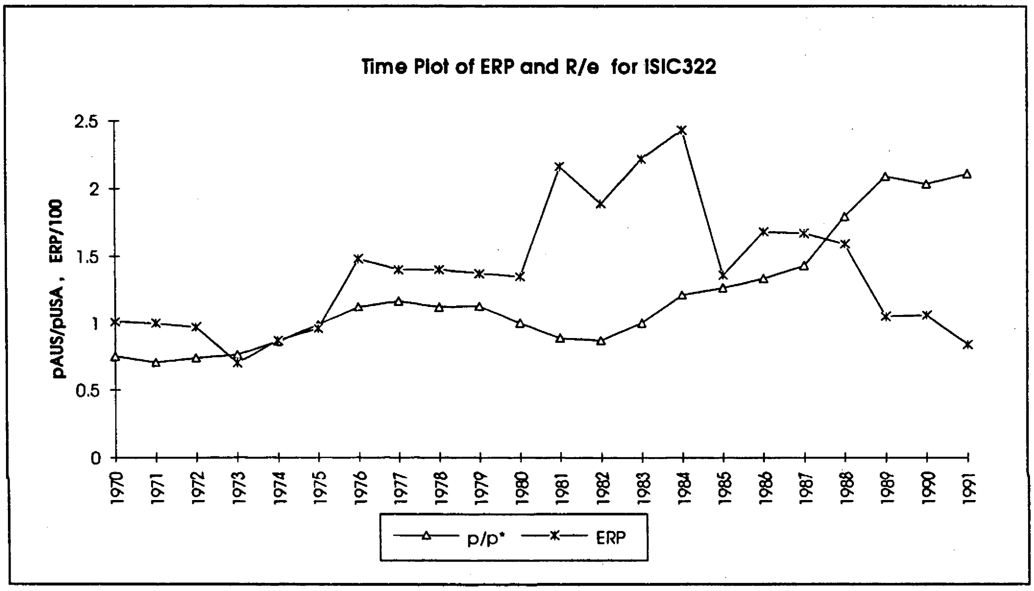


Chart A2

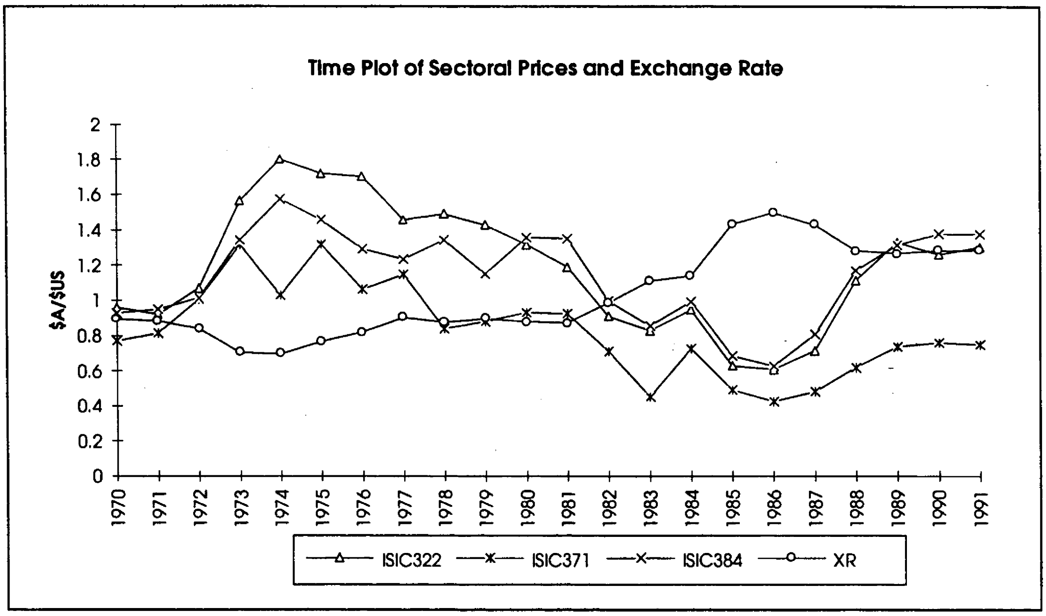
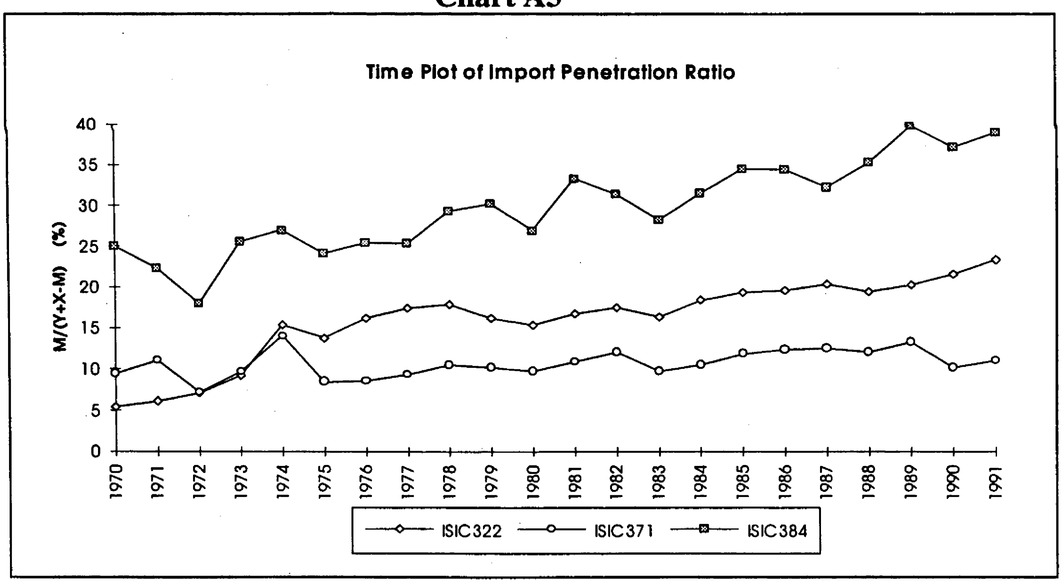


Chart A3



Chapter 7

A Tale of Two Islands: The Prosperous Mauritius and the Not-So-Prosperous Fiji

Abstract

This chapter uses a case study of Fiji and Mauritius, two small island developing economies, to evaluate the role of institutions in economic growth. Although the two economies share similar geography, natural climate, colonial experience, and economic structure, their post-independence growth experiences have been different. Average per-capita income in Fiji over the last two decades grew at less than half the rate of Mauritius. The agricultural sector in both economies experienced insignificant growth in total factor productivity (TFP), while the non-agricultural sectors in Mauritius, manufacturing in particular, experienced significant positive TFP growth over the same period. An increasing share of manufacturing in GDP coupled with high TFP growth in the sector meant positive and significant growth of GDP in Mauritius. The non-agricultural sectors in Fiji experienced insignificant TFP growth, hence growth in GDP in the country is due to factor accumulation only. The differences in TFP growth are attributed to the differences in economic policies pursued by the governments of the two economies.

1. Introduction

Economics is a science but one without the benefit of a laboratory for controlled experiments[1]. The best the economist can do in terms of experiments is to study diverse economies and rely on quantitative techniques to control for variables of peripheral interest to the study. If there exist economies with similar characteristics except for that investigated, it is possible to employ a framework of research similar to that of the study of twins in medical science. The demands on econometrics to maintain the *ceteris paribus* assumption in these studies is considerably reduced. Here, in a similar spirit, we attempt to identify the sources of growth in two island developing economies that are very similar (twins?) in many respects but for their very different post-independence growth experiences. We employ both the "old" and the "new"[2] growth frameworks for our analysis and let the data discriminate between them.

Understanding the mechanics of and being able to identify the factors responsible for economic growth is a major challenge to economists with important ramifications for welfare. Lucas (1988), Jones and Stokey (1992), amongst many others have stressed the importance of research in the area of new growth theory. Much of the rigorous research in the area of growth has been confined to theory (Grossman and Helpman 1991 is a good example) with limited empirical testing of the theory appearing only recently (examples include Backus, Kehoe and Kehoe 1992, Feenstra, Markusen and Zeil 1992, Levine and Renelt 1992, Mankiw, Romer and Weil 1992, and Young 1992).

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[1] Experimental economics is appearing as a sub-discipline but its use, particularly for those concerned with economy-wide aggregates, is minimal.

[2] Old and New in quotes because Bardhan (1993) points out that much of what is purported as being new in this literature dates back to works many decades old. It is nevertheless true that interest in the area from a policy and development perspective was revived in the nineties as observed by Raut and Srinivasan (1992), hence we do away with the quotes from now on.

With the exception of Feenstra *et al* (1992) who use Korean data and Young (1992) who uses data on Hong Kong and Singapore, the studies use cross-country data ranging over diverse economies to test the theoretical models. It is therefore not surprising that empirical support for the theory is far from conclusive. We follow Young's (1992) lead and use two very similar, but less developed economies to test and compare the propositions of the new growth theory with those of the old.

In contrast to the use of cross-country growth regressions in Chapter 5, this chapter employs a case study approach to discern the sources of growth. Young (1992: 13) observes that use of case studies in economics is rare and contends that

> 'Case study analyses provide both the author and the reader with the opportunity to develop a rich understanding of the conditions, processes, and outcomes that have governed the growth experience of actual economies.'

Furthermore, given the many similarities of the two countries and the stark difference in their growth rates (the variable of key significance), the comparison provides a laboratory-like flavour to complement the theoretical reasoning in chapters 3 and 4 and the cross-national econometric tests of chapter 5. Furthermore, the use of a case study of two economies as against a panel of fourteen countries enables us to explore institutional structure in greater detail and discern its role in growth.

The use of two small developing economies, as against use of OECD countries (see Chapter 5), provides a better understanding of the growth process in developing countries. More specifically, the objective is to test if the earlier findings of Chapter 5 based on data from the OECD extend to two of the developing countries; to examine the role of technology diffusion (see Chapter 4); and finally, to confront both the augmented Solow and the endogenous growth models with the same data so as to discern which explains the growth process better.

The main findings of this chapter can be summarised as follows. The factor responsible for the lower growth in Fiji is its lower rate of growth of TFP. The difference in rates of growth of TFP in the two countries is attributable to the difference in their policies. The analysis also reveals that the elasticity of output with respect to capital input in Fiji is half that of Mauritius. We attribute this difference in elasticity to differences in incentives for employment of capital at the sectoral level in the two countries. In particular, the extensive direction of credit through use of active government policy in Fiji has contributed to inefficient use and consequently lower productivity of capital. This has been compounded by an import substitution strategy which has stalled the growth of manufacturing industry, a sector that is claimed to have positive dynamic externalities on the rest of the economy (see Chapter 3). In contrast to Romer (1993) and Woldekidan (1992), foreign direct investment and export orientation have not been significant in explaining the varied growth experience of the two economies.

The chapter is organised as follows. The next section shows very briefly the many similarities and highlights the few differences between Fiji and Mauritius. The third section presents the data while the following two sections present estimates of the level and rate of growth of TFP. Section 6 advances some[3] explanations for the divergence in growth rates between the two economies. Section 7 introduces considerations from the political

[3] The list is by no means exhaustive.

economy of the two nations. Conclusions and suggestions for future research conclude the paper.

2. Fiji and Mauritius, the Many Similarities and the Few Differences

The islands, being tropical, small[4] as well as located in the middle of vast oceans, share similar climate and natural wealth, marine resources being the most notable example. Their pre-independence colonial history is also similar. Both had been British colonies for more than a century, with Mauritius having gained its independence in 1968 and Fiji two years later. The cultural heritage of the two islands is also similar. Nearly half (40% in Mauritius and 45% in Fiji) of the population in each country is composed of ethnic Indians brought in by the colonial power approximately a century ago to work on sugar plantations. In the case of Fiji, the indigenous population makes up the bulk of the remainder with some (less than 5%) people of European and Chinese origin (and others[5]) also present. Mauritius has no indigenous population, the remainder of its population being immigrants from mainland Africa and Europe. English is the official language and for the bulk[6] of the period of study both island states have had the Westminster system of government and were members of the British Commonwealth.

The structure of production and exports is also very similar. Sugar is the main industry and the largest export commodity in Fiji and the second[7] largest in Mauritius behind textiles. The bulk of the sugar is sold to the EEC under

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[4] The islands are small both in the physical sense of area and population as well as in the technical sense of being price takers in the world commodity markets.

[5] Everyone who does not fall in the previous categories is classified in a catch-all as others. The two major ethnic groups constitute more than ninety-five percent of the total population.

[6] Fiji became a republic following the two military coups of 1987. The system of government, except for the two years following the coups when military rule was in place, has remained unchanged. Mauritius also experienced political instability with emergency rule in place from 1972 to 1976.

[7] Sugar was the largest in Mauritius as well prior to the expansion of manufacturing.

the Lome' convention which gives substantial price support far above the world price to domestically[8] produced sugar. Tourism is another major foreign exchange earner though the sources of tourists between the countries differ given their differing geographical locations. Given the above similarities, it can be safely assumed that the two countries faced similar external shocks to their economies in their post-independence era.

The differences are few and minor. Fiji has a smaller population (of 0.75 million) relative to 1.1 million of Mauritius (World Bank, 1992 - figures are for 1991), has a higher literacy rate of 86 percent (relative to 61 percent for Mauritius) and has approximately ten times more land (by area), larger mineral deposits, particularly gold and copper with prospects for the presence of mineral oil deposits considered as being high. The main exception is their diverse growth experiences. For the period 1965 to 1989 for which growth rates are published by World Bank (1992), Mauritian per-capita GNP grew at an average rate of 3 per cent per annum, almost twice that of the 1.8 per cent of Fiji. For the period 1970 to 1992 when both economies were independent and shared many of the same characteristics[9], this contrast in Mauritian GDP growing twice as fast as that of Fiji became even sharper. These growth rate estimates are robust to the use of Penn World Tables data (Summers and Heston 1991) in international prices and also in per-worker terms - the latter to control for probable effects of differences in demographic dynamics. Table 1 provides data of economic interest on the two economies.

[8] The privilege only applies to local production and therefore cannot be used for re-exports.
[9] See footnote 6.

Table 1: Variables determining the steady state growth rate in the Solow model[10]

Variable	**Fiji**	**Mauritius**
Growth in per-capita GDP (% per annum)[a]	0.5	2.3
Population growth rate (% per annum)[a]	1.7	1.3
Average annual investment (% of GDP)[a]	27	30
Secondary school enrolment ratio (%)[b]	56	46
Access to health care (% of Popln.)[b]	100	100

The time period covered is from 1970 to 1992 (inclusive). Growth rates are fitted rates expressed as per annum. Investment includes private and public. Data on access to health care for Fiji is for 1982 and for Mauritius for 1983. Data sources: [a] World Bank Tables, [b] World Bank Social Indicators for Development. The summary statistics were computed from primary data extracted from the above sources.

Fiji has had a marginally higher population growth rate and lower share of investment but the level of human capital, as indicated by its secondary school enrolment[11] ratio, has been higher than that of Mauritius.

The two countries shared very similar characteristics in 1970. Table 2 below gives some data on the two economies in 1970 and 1990, the end points of our study period.

[10] The model considered is the Solow model augmented by a human capital variable following Mankiw, Romer and Weil (1992).
[11] Fiji's secondary school enrolment rate, averaged over the last two decades, at 56 percent compares favourably with a 1987 figure of 54 percent (Page 1994) for middle income economies.

Table 2: Levels of Some Variables at the Beginning and End of the Period of Study.

Variable	**Fiji**		**Mauritius**	
	1970	**1990**	**1970**	**1990**
GDP per Capita ($US constant)	917	1296	872	2011
Share of Agriculture in GDP (%)	25	17	13	10
Share of Manufactures in GDP (%)	14	10	14	23
Share of Services in GDP (%)	48	60	61	55
Exports of Manufactures as % of Total Exports	2	37	2	66
Labour Force in Agriculture (% of Total)	52	n.a	34	n.a
Primary School Enrolment Ratio (%)	105	125	94	106
Secondary School Enrolment Ratio (%)	52	61	30	53

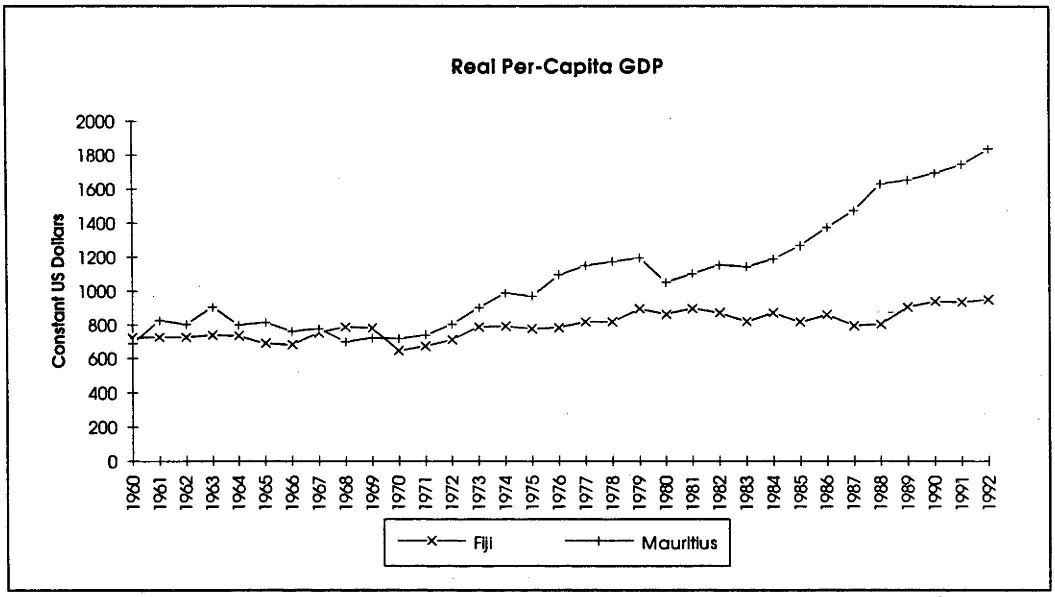
Notes: n.a - not available. Data Source: World Bank World Tables. All valuations are at market prices.

The figures in Table 2 show that Fiji in 1970 had a bigger agricultural sector, both in terms of output and employment, and perhaps more human capital as well. Most importantly, the two economies had very similar levels of per-capita real GDP at independence. The most striking difference between the two economies is the share of exports made up of manufactures. In the case of Fiji this share has increased from 2 to 37 per cent (the steep climb has been since 1988) while that for Mauritius the share has increased from 2 per cent to 66 per cent. The divergence in per-capita income commenced in 1970, approximately the year the two countries attained independence (see Figure 1 below). Could this timing be coincidental? The objective here is to find out the extent to which differences in economic policy can explain the divergence in the post-independence growth rates of the two economies. Knowing the reasons for the low growth in Fiji is important given that should Fiji have enjoyed the same growth experience as that of Mauritius, its 1992 per-capita GDP would have been a staggering 74 per cent higher than that realised. Even after account is taken of the fact that population in Fiji grew at a slightly higher rate[12] and average investment was marginally lower, per-capita GDP in Fiji would still have been considerably higher than realised if it experienced similar growth rates of aggregate output as that of Mauritius. Given the similarities between the two economies there is little reason to believe that such an outcome was not achievable. To the contrary, given the higher human capital (and ignoring the greater natural wealth) that Fiji has had, this thesis would suggest that Fiji should have grown faster than its twin sister!

We first look at some of the existing explanations for the observed anomaly. Woldekidan (1992) attributes the Mauritian success to the government's export strategy, calling Mauritius a case of export-led growth. The mechanics of how exports have propelled the growth process is based on the export externality hypothesis of Feder (1982). Romer (1993b) labels Mauritius a case of "using ideas". The hypothesis proposed is that the ability of Mauritius to use superior technology from abroad has led to its success. No reference has been made to Fiji by these researchers but the suggestion perhaps is that the opposite held true for Fiji. We leave the examination of the above hypotheses for section three but for now consider the policy stance in each of the economies.

[12] The higher population growth rate in Fiji is consistent with its lower income growth rate from the literature that endogenises fertility choice.

FIGURE 1



Data Source: Computed using GDP at factor cost and population data from World Bank World Tables, IEDB.

For the period of study Fiji had a very interventionist policy regime with extensive central government planning, numerous restrictions on trade and extensive policy prescriptions for income distribution. For example, detailed central government planning was actively pursued, an import-substitution strategy had been in place for the bulk of the period (Cole and Hughes 1988), and policies were put in place to achieve a more equitable distribution of income and business opportunities between the two major ethnic groups. The last involved a policy of positive discrimination in favour of ethnic Fijians in recruitment into the public service, as well as access to government subsidised credit, scholarships for study and business licenses. Mauritius, in contrast, adopted an open trading regime, an affirmative industrial policy that promoted manufacturing for exports via establishment of export processing zones (EPZs) and had no explicit policy on income distribution between ethnic groups. But government involvement in the economy as reflected by the average share of government consumption in total output at 17.5 percent in Mauritius was two percentage points higher than that in Fiji.

3. Data

For the purpose of this study, output is GDP in 1987 US dollars at factor cost so as to omit the impact of differences in indirect taxation in the two countries. Employment is labour force and investment is gross domestic investment in 1987 US dollars. The above data are obtained from World Bank World Tables via STARS[13]. Unlike Young (1992), we do not use Penn World Tables Data (PWT Mark 5.6 - Summers and Heston 1991) because all the series except real output per worker from the two data sets are very similar. The figures in PWT (Mark 5.6) show real output per worker in Fiji as being 30 percent higher than that in Mauritius while per-capita GDP in Fiji is lower in all except two years (see Figure 1 above). This may be due to the fact that PWT uses employment data from the International Labour Organisation (ILO), which take account of formal sector employment only. Given that Fiji has a large subsistence sector, the employment data from ILO would be heavily biased downwards, hence use is made of World Bank data. Additionally, use of data from a single source, the World Bank in this case, should minimise the risk of running into inconsistencies in definition and coverage of variables. Output per worker is computed using the extracted data.

Published capital stock series are not available for the two countries. We construct these series employing the perpetual inventory method on investment data as given in Leamer (1988). The real investment series, R, is accumulated over time assuming an exponential survival profile with

[13] STARS, for Statistical Analysis and Retrieval Service, is provided by the International Economic Data Bank (IEDB), at the Australian National University.

depreciation rate δ and an asset life of θ years. Capital stock at time t is given by

$$K(t) = \sum_{j=t-\theta}^{t} (1-\delta)^{t-j} R(j) \quad \text{for} \quad j = 1,2,3, \qquad (1).$$

We construct two capital stock series by setting asset lives to 10 and 15 years, respectively. The depreciation rates are determined endogenously such that it is consistent with the double declining balance method for the given life length. That is, in the case of θ being 10, δ is 18.5 while δ is 13.3 per cent when θ is 15. Leamer (1988) sets θ equal to 15. We construct an additional capital stock series with θ equal to 10 to enable the construction of a capital stock series from 1970 given that investment data is available from 1960 only. We test the sensitivity of all our results with the two generated capital stock series to ensure that the results are robust to assumptions made on the value of θ.

4. Productivity Levels for the Aggregate Economy

We follow Young's (1992) lead and employ an analysis of factor productivity to discern the possible reasons for the lower growth in Fiji. Figure 2 gives a time plot of the average product of labour (APL)[14] in Mauritius relative to that in Fiji. The dotted line shows the locus of points where the average product is equal in the two countries.

The reason for the dip in 1968 and 1969 is not as yet clear, but the spike in 1987 and 1988 is the result of the downturn in the Fijian economy following the two military coups in that period. Note that the graphs in Figures 1 and 2

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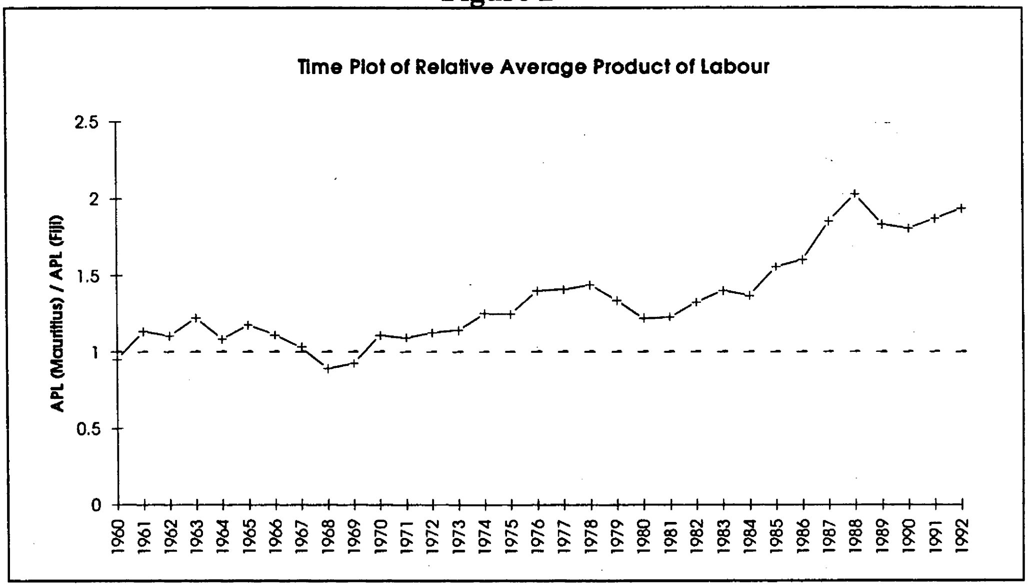
[14] Note that labour is the number of workers in the economy. Hence, APL is real output per-worker.

suggest that the two countries share very similar demographic structures; an observation supported by data on age distribution of the population in the two countries.

Figure 2



Data Source: Computed using data from World Bank World Tables.

Figure 2 shows that Mauritius has not only enjoyed higher average product of labour (APL) than Fiji in the period following independence, but this gap has been <u>increasing</u> over time. APL has been used because data on output and labour are available in published form, but a better measure of the productivity difference between the countries is given by the relative levels of total factor product (TFP). To compute TFP we need data on capital stocks and knowledge of production technology.

Production technology

We assume a Cobb-Douglas constant returns to scale (CRS) production function of the form

$$Y_t = e^{TFP_t} K_t^{\gamma} L_t^{1-\gamma} \qquad (2)$$

where Y is aggregate output, K is capital stock, L is labour force and subscript t denotes time. Expressing (2) in per-worker terms gives

$$TFP_t = \ln y - \gamma \ln k \qquad (3)$$

where small letters are used to denote variables in per-worker terms.

We now use our generated capital stock series and data on per-worker output to estimate γ[15]. This estimate of the elasticity of output with respect to capital is then compared with the estimate reported in Young (1992).

Table 3: Elasticity of output with respect to capital

	Own Estimate	**Estimate from Young(1992)**
Fiji	0.31	0.20
Mauritius	0.59	0.58

The above figures show that the share of capital in total output in Fiji is approximately half that of Mauritius. Our own estimates of γ are far more generous to Fiji than those reported in Young[16] (1992: 49), but the finding that technology differs between the two countries is strongly supported by both sets of estimates. From equation (3), per-capita output growth is given

[15] The estimation shows presence of serial correlation, but there is no evidence suggesting failure of cointegration. Estimate of equation (3) with a time trend gives an estimate of γ for Fiji that is insignificantly different from zero, while that for Mauritius is significant with a point estimate of 0.24. The qualitative findings reported in this section are unchanged when these values of γ is used instead of those reported in Table 3.

[16] We see no reason why our figure should be the same as that of Young (1992) since Young uses PWT (Mark 5) data, and the time period covered differs between countries in Young (see footnotes 98 & 99; pp 46-7). Furthermore, Young's capital stock is constructed using PIM, but with a depreciation rate of ten percent and with the initial capital-labour ratio established from ten years of investment data.

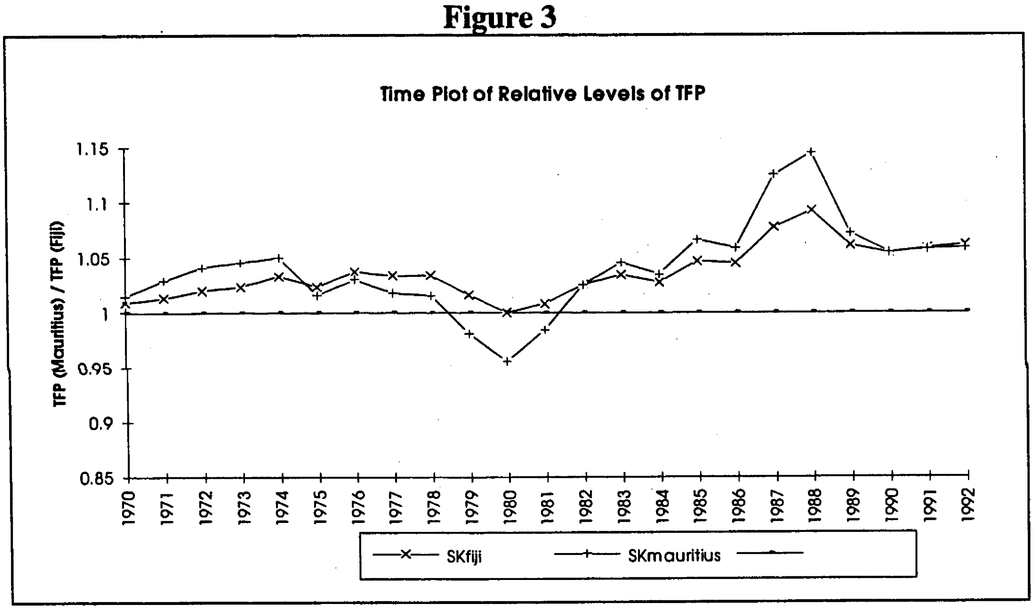
by the sum of growth in total factor productivity and capital weighted by its share in total output.

$$\hat{y} = T\dot{F}P + \gamma\hat{k} \qquad (4)$$

Even if TFP growth in the two economies had been identical, the larger share of capital in total output in Mauritius would imply a higher per-capita income growth for a given rate of growth of capital per worker. Some inferences can also be drawn on the efficiency of use of factors by considering factor prices in each of the two economies. Elek, Hill and Tabor (1991: Table 7) report that the unskilled 1990 hourly wage rate within the organised sector in Fiji was 58 per cent higher but that in the unorganised sector it was 35 per cent lower than the single reported figure for Mauritius. This would imply a greater capital intensity within the Fijian formal sector, which employs organised labour, relative to the informal sector. In aggregate the data suggest that labour costs could not be too dissimilar between the two economies. Given the smallness of the two economies and the fact that they are open to foreign investment also suggests a similar (undistorted) capital price in the two nations, hence relative factor prices in the two economies are also likely to be similar. The similarity in factor prices coupled with the dissimilarity in technology used in the two countries implies inefficiency in factor use in one of the two economies. Given the varied growth experience of the two economies, picking the inefficient economy may not be too difficult but the reason for this disparity is not so obvious. Before we attempt to explore the reasons for this difference, we compute the levels of TFP in the two countries and then compare their relative magnitudes.

To allow a comparison of TFP levels between the two countries, we first impose the value of γ obtained using data from Fiji (SK[17]fiji in Figure 3) on both Mauritian and Fijian data. Their relative TFP level is then computed using the obtained values for levels of TFP in each country. We then repeat the above exercise but now employing γ (SKmauritius in Figure 3) that is obtained when Mauritian data is used instead. The above is done to control for differences in technology in the two countries. Figure 3 below gives the time plot of the <u>relative</u> level of TFP in the pair of countries.

Figure 3



It is clear from the figure above that TFP levels in Fiji have been significantly lower, except in 1980[18], than in Mauritius. Furthermore, the TFP gap seems

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[17] SK denotes share of capital as implied by the value of γ from (2) and the assumption of perfectly competitive factor markets.

[18] In 1979 Mauritius was on the verge of insolvency with very low foreign reserves and an unsustainable government budget deficit. World Bank and IMF assistance were sought and these were provided with pressure by the institutions to return to fiscal conservatism and the adoption of liberal trade policies. The country also faced massive floods and two cyclones in the 1979-80 period that caused extensive damage to crops and housing (Wellisz and Saw 1993). We have re-estimated the values in Table 3 where the political instability and the liquidity crisis are controlled for using time dummies. The resulting point estimates of the elasticity coefficients for Fiji and Mauritius are 0.38 and 0.66, respectively. Use of these estimates in place of those reported in Table 3 do not affect any of our qualitative findings.

to be widening, even if the hump from 1986 to 1989 is ignored. The above findings are worrying for Fiji in that it indicates that Fiji is going to fall further behind its twin unless it can go through a process of rapid catch-up.

The weakness of the TFP analysis is that it suffers from the non-availability of published capital stock data. We have used investment series and the perpetual inventory method, as explained in section 3 above, to construct capital stock series for the two countries. The capital stock series used to generate the estimates in Table 3 and the graph in Figure 3 assume an asset life of ten years, but all of the above qualitative findings remain unchanged when an asset life of fifteen years is used instead[19]. We have also imposed a specific production technology which could be another source of error in the estimates of TFP. Thus, we next estimate the rate of growth of TFP by using a more general production function. The estimates are carried out at the sectoral level and in a general equilibrium (GE) context so as to take advantage of information at a higher level of disaggregation and yet allow for economy wide effects to be captured within the analysis. Furthermore, the recent literature on endogenous growth suggests that studies carried out at the sectoral level are likely to be more informative than those done at the aggregate level (Backus, Kehoe and Kehoe 1992; Falvey 1995).

5. Growth of TFP at the Sectoral Level in a GE Framework.

We first develop an analytical framework that allows for measurement of TFP changes at the sectoral level.

The Analytical Framework

[19] The TFP analysis has also ignored land as a factor of production, an omission that may bias the TFP calculations in favour of Fiji given its land area under cultivation is twice that of Mauritius. Including land as an additional factor of production in the estimated equation gives implausible (negative but statistically insignificant) elasticity coefficient.

Let the production function in sector i be represented by

$$Y_i = \alpha_i(t)F^i(\mathbf{V}^i) \qquad (5)$$

where Y_i is sectoral output, $\alpha_i(t)$ is a TFP parameter that is time dependent ($\alpha_i(0) \equiv 1$), $F^i(\mathbf{V}^i)$ is a constant returns to scale (CRS) production function and $\mathbf{V}$ is a vector of factor endowments. The GNP function for this economy is given by

$$\tilde{G}(\mathbf{P},\mathbf{V}) = \max_{Y_i} \sum_i P_i Y_i = \max_{Y_i} \sum_i P_i \alpha_i F^i(\mathbf{V}^i) \qquad (6)$$

such that Y_i is feasible for given technology and endowments. Note that GNP as given in (6) changes with a change in technology, but the technology as specified in (6) changes in a very specific way - ie. via exogenous changes in sectoral TFPs <u>only</u>. The GNP function can now be written as

$$G(\phi,\mathbf{V}) = \max_{Y_i} \sum_i \phi_i F^i(\mathbf{V}^i) \qquad (7)$$

where $\phi = P_i\alpha_i$. Note that by construction F is constant over time. ϕ denotes the changes in sectoral TFPs - which may also be interpreted as changes in "augmented" price ($= P_i\alpha_i$), - and therefore accounts for any changes in technology. Note that $G_{\phi_i} = F^i(\mathbf{V}^i)$, therefore

$$Y_i = \alpha_i F^i(\mathbf{V}^i) = \alpha_i G_{\phi_i} = G_{P_i} \qquad (8)$$

as expected. Totally differentiating (7), using the results in (8) and expressing the resulting expression in terms of proportional changes gives

$$\frac{dG}{G}=\sum_i \frac{P_iY_i}{G}\frac{dP_i}{P_i}+\sum_i \frac{G_{V_k}V_k}{G}\frac{dV_k}{V_k}+\sum_i \frac{P_iY_i}{G}\frac{d\alpha_i}{\alpha_i} \qquad (9).$$

Equation (9) shows that the change in "nominal GNP" is the sum of three RHS terms, the first of which is the product-share-weighted average of the proportional price changes, the second is the factor-share-weighted average of factor endowment changes and the last is the product share weighted average of the sectoral TFP changes. To convert to real output, we can either take one of the goods as the numeraire (such that $\frac{dp}{p}$ for the particular good is zero) or define a real price index as $\sum \frac{P_iY_i}{G}\frac{dP_i}{P_i}=0$. We now consider the estimation of these sectoral TFP changes. The GE supply function for sectoral output is

$$Y_i=\alpha_i G_{\phi_i}(\phi,\mathbf{V}) \qquad (10).$$

Totally differentiating (10) and expressing the resulting expression in proportional changes gives

$$\frac{dY_i}{Y_i}=\frac{d\alpha_i}{\alpha_i}+\frac{\sum_j \phi_j G_{\phi_i\phi_j}}{G_{\phi_i}}\frac{d\alpha_j}{\alpha_j}+\frac{\sum_j \phi_j G_{\phi_i\phi_j}}{G_{\phi_i}}\frac{dP_j}{P_j}+\frac{\sum_k V_k G_{\phi_i V_k}}{\sum_l V_l G_{\phi_i V_l}}\frac{dV_k}{V_k} \qquad (11).$$

Letting a caret represent proportional changes, ε_{ij} $(\equiv \frac{\phi_j G_{\phi_i\phi_j}}{G_{\phi_i}})$ denote the elasticity of good i with respect to price of good j, and β_{ik} denote $\frac{V_k G_{\phi_i V_k}}{\sum_l V_l G_{\phi_i V_l}}$ (which may be either positive or negative depending on factor intensity), equation (11) can be expressed as

$$\hat{Y}_i = \hat{\alpha}_i + \sum_j \varepsilon_{ij}\hat{\alpha}_j + \sum_j \varepsilon_{ij}\hat{P}_j + \sum_k \beta_{ik}\hat{V}_k \qquad (12)$$

where linear homogeneity of supply functions implies

$$\sum_j \varepsilon_{ij} = 0 \qquad (13a),$$

a positive own price elasticity of supply implies

$$\varepsilon_{ii} > 0 \qquad (13b),$$

positive marginal product for any given factor implies

$$\sum_i \beta_{ik} > 0 \qquad (13c),$$

while CRS in F implies

$$\sum_k \beta_{ik} = 1 \qquad (13d).$$

We also know from symmetry that $G_{\phi_i\phi_j} = G_{\phi_j\phi_i}$, hence

$$\frac{\varepsilon_{ij}}{\varepsilon_{ji}} = \frac{\phi_j G_{\phi_j}}{\phi_i G_{\phi_i}} \qquad (13e).$$

where the RHS of (13e) is the relative sectoral shares. Note that equation (12) is the analog of the Solow growth accounting identity which now also includes sectoral prices as an additional variable. Econometric estimation results in the first two terms in equation (12) being captured within the intercept and the error terms. The estimates of sectoral TFP changes are then recovered from the vector of coefficient estimates from entire system (see Appendix to this chapter).

Estimates of TFP Growth Rates

A decision has to be made on the choice of sectors to include in the estimates. The trade-off between the number of sectors chosen is proportional loss of degrees of freedom at the estimation stage (see Appendix). We choose Agriculture - because of its significant share in total GDP and total employment, Manufacturing - since the size of this sector is significant in Mauritius, and aggregate the rest as a residual sector called Rest. The three factor endowments modelled are physical capital (K), labour (N for number of workers), and land (D where D is measured as percentage of total land area in use for productive purposes). Sectoral output changes are allowed to respond to price changes that are lagged by one year. This may be particularly realistic for the Agriculture sector[20]. Data on D are only available until 1989, and given that single lags on prices are used, there are eighteen observations available for estimation. The relative share parameters as given in equation (13e) are averages for the 1970 to 1989 period.

We estimate equation (12) as a system comprising three equations, one each for Agriculture, Manufacturing and the Rest (see Appendix for details). The system is estimated using least squares as well as Full-Information-Maximum-Likelihood (FIML) methods with all the restrictions as given in (13a) to (13e) imposed. We also test for the acceptance of these restrictions by the data.

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[20] Allowing for further lags is at a cost of loss of further degrees of freedom. Signs on coefficient estimates obtained using price changes that are lagged one period conform to the theoretical priors.

Table 4 below reports the estimates of TFP growth rates for the 1970 to 1989 period while complete regression results are reported in the Appendix.

Table 4. Average Growth of Sectoral TFP over the 1970 to 1989 Period.

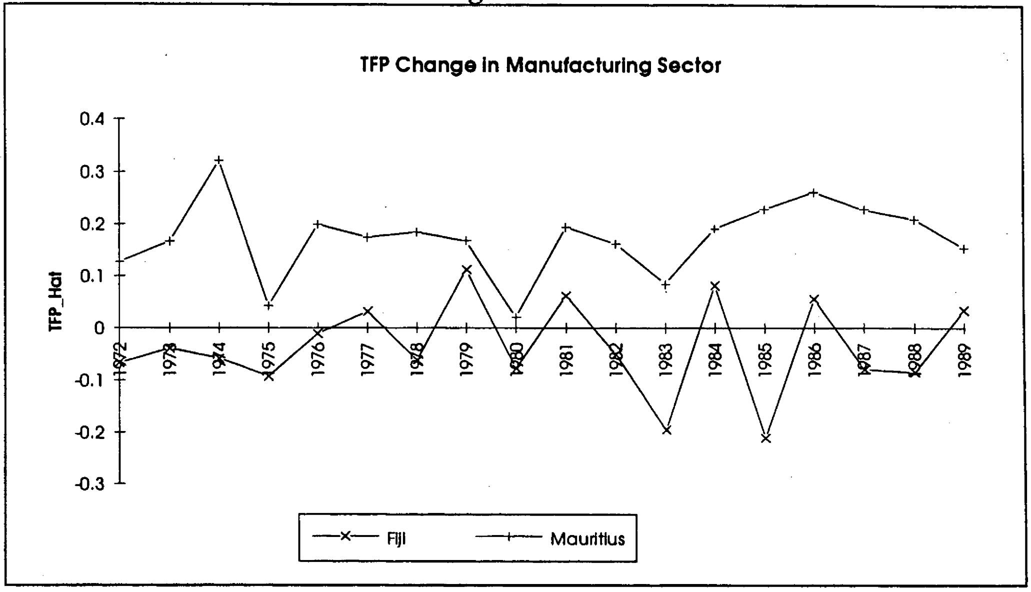
	Fiji	**Mauritius**
Agriculture	0.02	0.09
Manufacturing	-0.03	0.17*
Rest	-0.025	0.11*

Note: a * denotes that the estimate is different from zero at the five per cent significance level.

Total factor productivity growth in Agriculture has not been significantly different from zero in either of the two countries, the other sectors have experienced statistically significant positive TFP growth rates in only Mauritius with Manufacturing leading the way. The TFP growth rate for the aggregate economy, as depicted by equation (9) above, is the product share weighted average of the sectoral growth rates. The high growth of the Mauritian economy could be attributed to the high rate of growth of TFP in the manufacturing sector coupled with an increasing share of the sector in GDP. In contrast, none of the sectors have displayed any significant growth of TFP in Fiji, hence its dismal aggregate TFP growth performance over the period of study.

Coefficient estimates from estimation of equation (12) as a system comprising Agriculture, Manufacturing and the Rest (of the economy) is given in Appendix Table A1. Tests on cross-equation restrictions imposed by the system is accepted at the five per cent significance level for all the sectors except Fijian Agriculture. Figure 5 below shows annual TFP changes in the manufacturing sector in the two economies.

Figure 5



Source: Own estimate

Figure 5 shows that annual TFP changes have been more volatile in Fiji, with the TFP changes in manufacturing moving in tandem with TFP changes in agriculture (see Figure A1 in Appendix). This may be attributed to the large share of food manufacturing - sugar refining in particular - in total value added in Fiji (see Figure A3 in Appendix). In contrast, TFP changes in Mauritius are transmitted less transparently between the sectors, particularly after 1980[21] (see Figure A2 in the Appendix). The data on TFP changes suggests that Mauritius, in contrast to Fiji, has been successful in 'riding-out' the volatility in Agriculture by having a production base that gets increasingly diversified away from agriculture with time.

[21] The peculiarity about 1980 is covered in the next section.

6. Some Explanations for Divergence in Growth Rates and TFP levels

The analysis suggests that industry policy and the operation of factor markets, capital in particular, are responsible for the divergence in TFP levels between the two countries. The data show that capital has a lower share in total output in Fiji relative to Mauritius. Recent literature on growth and development (see World Bank 1988 and 1992, Fischer 1993, Romer 1993, and Page 1994) stress the role of macro- and microeconomic policies in growth. There could also be other explanations that hinge on incentives to invest at the sectoral level, between agriculture that employs most of the unorganised labour and the industrial sector that is home to most organised labour. We consider each separately and speculate on a number of reasons for the divergence in the growth experiences of the two economies.

Macroeconomic Policies

Monetary, fiscal and exchange rate polices - all considered as constituting macroeconomic policy (Fischer 1993) - are claimed to be crucial for growth (World Bank 1991, Fischer 1993, Page 1994). Fischer (1993) points out that a large and unsustainable fiscal deficit and high inflation signal a government that has 'lost control'. These in turn increase uncertainty, dampen investment and consequently result in dampened economic growth. On the macroeconomic front both the island states have fared well relative to all other developing countries and in comparative terms Fiji has done better given its average budget deficit as a proportion of GDP over the 1970 to 1994 period has been at 3 per cent relative to 4 per cent for Mauritius and inflation, averaged over the same period, has been 8 percent as against 11 per cent for Mauritius. Mauritius also went through a foreign reserves crisis in 1980 when assistance from the World Bank and the IMF (see footnote 18) were sought.

We consider the exchange rate policies next. Both the economies have fixed exchange rate regimes.[22] Export competitiveness is quantified by the real exchange rate (Edwards 1989), defined as

$$\pi = \frac{\sum_j e^j w^j P^j}{P}$$

where e is the local currency price of a unit of foreign currency, w is the trade weight, P the price and superscript j denotes the trading partner. Edwards (1988) argues that the appropriate index to use for foreign price is the wholesale price index (WPI), and in its absence the GDP deflator. The domestic price is represented by the CPI. Edwards (1988) points out that the numerator of π is a proxy for price of tradeables, while the denominator is a proxy for price of non-tradeables. Hence, the real exchange rate is a measure of the bias in price incentives between tradeables and non-tradeables.[23]

In the case of Fiji, we confine ourselves to five major trading partners - Australia, Great Britain, Japan, New Zealand and the USA - in the computation of the trade weights. These countries jointly account for more than eighty per cent of total Fijian trade. In the case of Mauritius, France, Italy and South Africa in addition to the above five account for approximately seventy per cent of total trade. Except for data on GDP deflator which is obtained from the World Bank World Tables, all the data used to compute π are from the *International Financial Statistics* (IFS) via STARS. To make the series comparable between the two countries, the real exchange rate in

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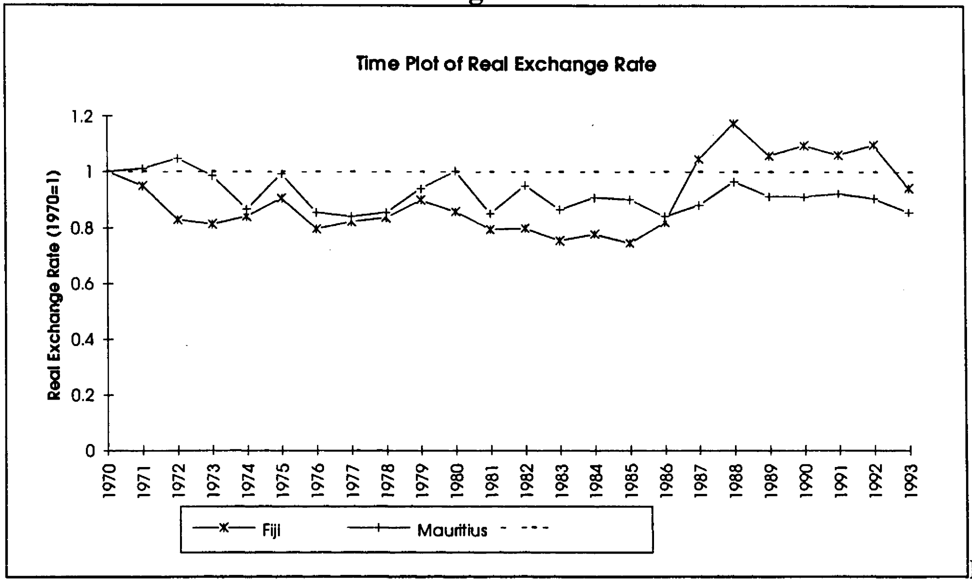
22 Initially the local currency was fixed to the British pound, but since early 1980s it has been linked to a trade weighted basket of currencies.

23 Real exchange rate measurement and its interpretation in the context of developing country trade constitutes a vast literature in its own right (see Edwards 1988 and Claassen 1991 for recent book length surveys).

1970 is normalised to unity. Figure 6 gives a time plot of the real exchange rate for the two countries as a measure of their export competitiveness.

Figure 6



D

ata Source: Computed using data from IFS via STARS, IEDB and formula given above.

The choice of 1970 as a base is arbitrary, but note that the size of a number of variables in that period for the two countries were comparable. It is clear that Fijian exports were less competitive than those from Mauritius until the devaluations of 1987. We also note that in the case of Fiji, nearly two-thirds of the gains in competitiveness from the 1987 devaluations were eroded away by 1993. These findings are robust to choice of alternative base periods and use of the GDP deflator instead of the WPI.

The difference in real exchange rates is perhaps due to the difference in wages and trade policies of the two countries. This is alluded to in further detail in the next section. Exchange rate instability, as given by the variance of π, is not significantly different between the two countries. Hence, exchange rate instability cannot be responsible for the poor growth performance of Fiji.

Macroeconomic policy on the whole, therefore, cannot be the reason for the poor performance of Fiji.

Microeconomic Policies

Industry Policy

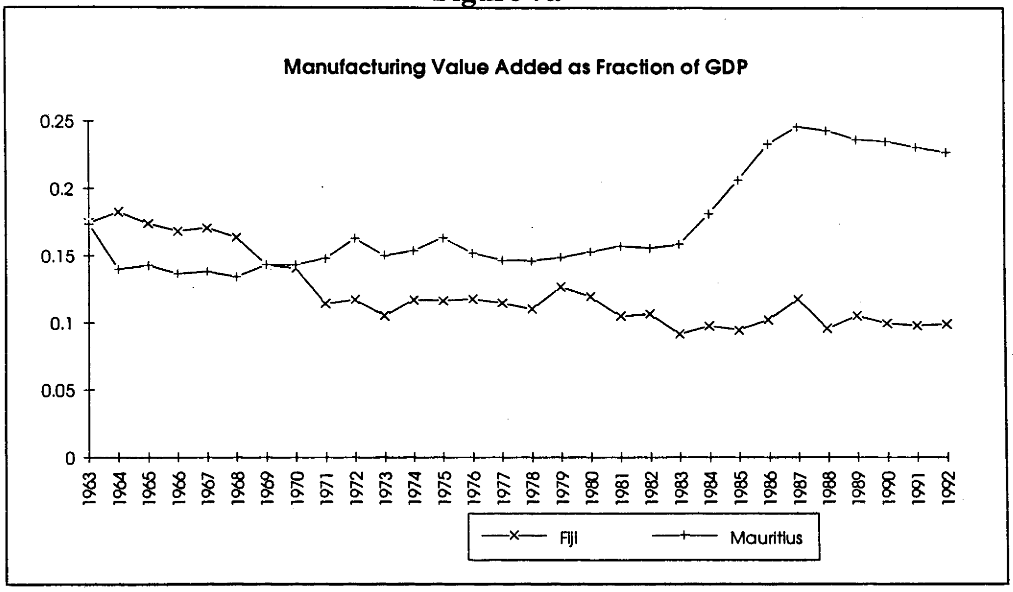
Mauritius has pursued an active industry policy since the early 1960s with the passage of Development Incentives Act in 1964 (Woldekidan 1992) and the Export Processing Act in 1970 (Wellisz and Saw 1993), the former encouraged import substitution while the latter encouraged production for exports. Export promotion had much success in raising manufacturing exports and generating employment in the secondary sectors, but much of this success is attributed to the preferential access given to exports originating through Lome' and the MFA. Fiji had the same[24] privileges but failed to take advantage for reasons that will be explored later. Figures 7a and 7b below show shares of manufacturing value added in total GDP and manufacturing exports as a fraction of total exports in the two countries.

The share of manufacturing in total output at independence in the two economies was approximately the same but following independence the sector increased its share in total output in Mauritius only. The picture in Figure 7a does not change when the share of non-agricultural industry in total output is used instead of the manufacturing share. The steep climb in the case of Mauritius from 1983 to 1987 may be due to the implementation of structural adjustment programs at the initiation of the IMF and the World Bank in that period. This involved close monitoring of public sector investments, liberalization of the economy and structural reform (Dabee and Milner 1995,

[24] In fact Fiji had more favourable terms for access to markets in the industrialised world given that in addition to Lome' and MFA, it also had an agreement (SPARTECA) with Australia and New Zealand that allowed duty free access, with normal qualifications, of its exports to these markets.

Wellisz and Saw 1993). For Fiji, the level of the variable is lower and more importantly, the time trend in the variable is opposite to that of Mauritius.

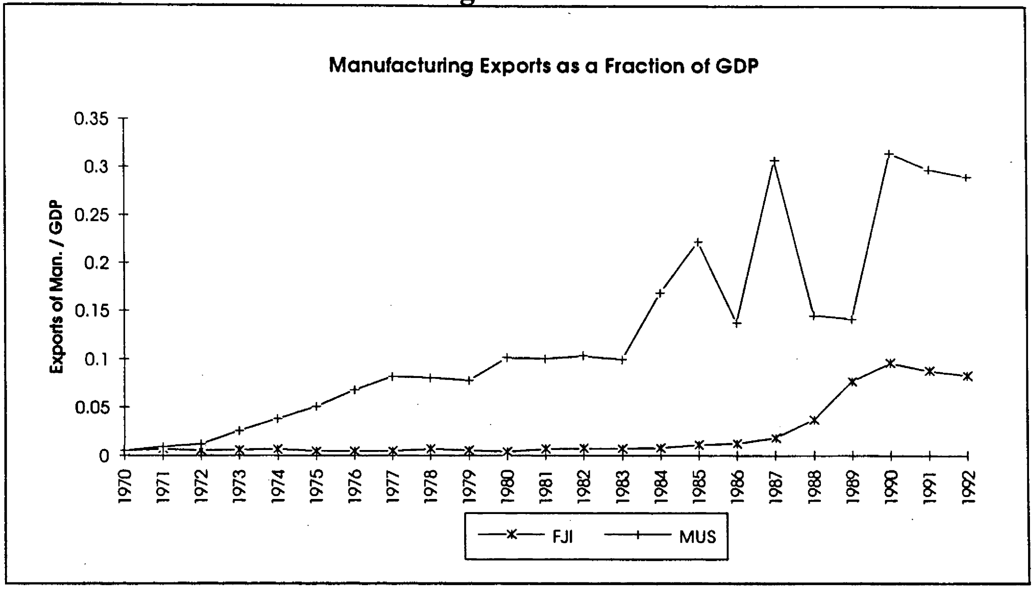
Figure 7a



Data Source: Computed using data from World Bank World Tables

There is some debate within the literature as to whether it is increased production of manufactures or increased exports, *per se*, that brings about the increased growth. The theory in Chapter 3 argues for the former while a number of researchers including Page (1994) and World Bank (1988) present a case for the latter. Rodrik (1994) contends that the success of Korea and Taiwan is not from export orientation, but that the export growth was the result of an investment boom brought about by favourable industry policy. Rodrik argues that the rich human capital endowments of the two countries assisted in the growth of industry.

Figure 7b

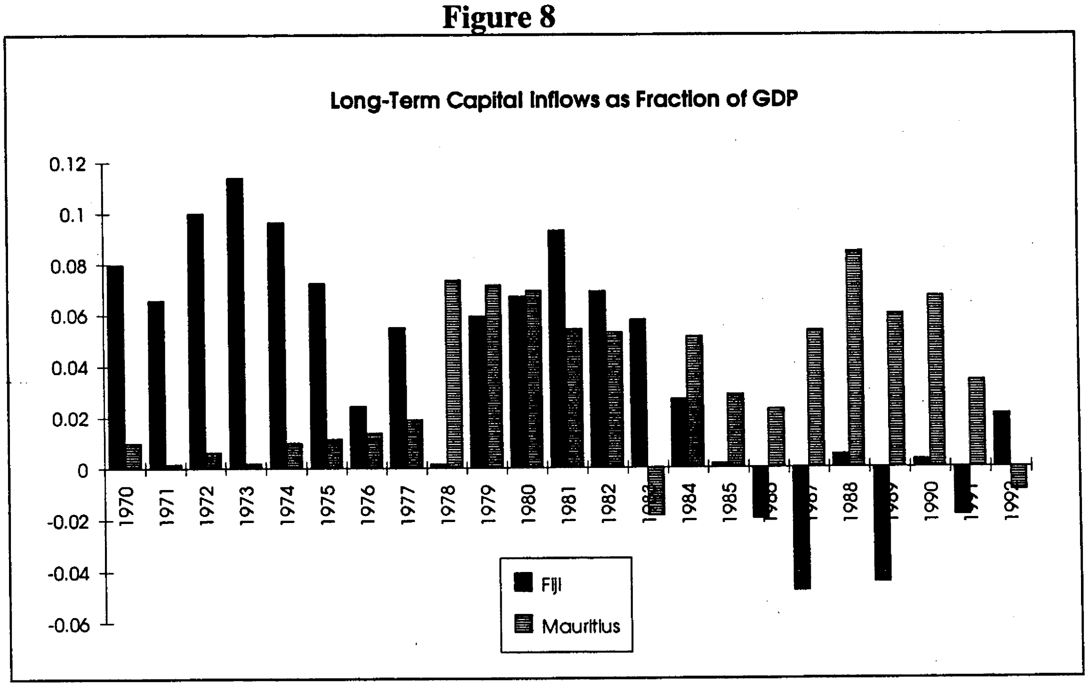


Data Source: Computed using data from World Bank World Tables

Though Figure 7b shows similar time trends to that of Figure 1 - which plots real per-capita GDP - the mechanics of any association between the fraction of GDP constituting manufactured exports and the level of per-capita GDP are as yet to be explored. The theory of Chapter 3 points out that the existence of a modern sector, such as manufacturing, has positive externalities on production in the rest of the economy. These externalities are dynamic in that initial differences are propagated over time and the gains from an active industry policy that pushes production out of the traditional into the modern sector are maximal for a small open economy since it does not incur any terms of trade losses from such an active policy. Page (1994), on the other hand, argues for the causation to run from exports of manufactures to growth in productivity. Page argues that increased exports of manufactures facilitate the adoption, adaptation and mastery of the international best practice which then results in an increase in TFP. The argument is similar to the claim of Romer (1993) that Mauritian success is attributable to its ability to use foreign ideas effectively. We consider two proxies for levels of technology diffusion in the two countries. The first is the extent of foreign direct investment (FDI) as reflected in the dollar value of long-term capital inflows in the two countries. Blomstrom, Lipsey and Zejan (1992) suggest the level of imports of machinery and transport equipment as an alternate proxy for inflow of new technology. This is the second measure used to proxy the extent of inflow of foreign technology.

Figure 8 below shows that long-term capital inflows have been greater in Fiji than in Mauritius except for the period following 1987 when capital flight from Fiji was high in the aftermath of the military coups of 1987. If we assume that the level of FDI reflects the rate of diffusion of foreign technology into the local economy, then the lower growth of Fiji is inconsistent with the relatively greater amounts of FDI the country experienced for the bulk of the period following independence.

Figure 8



Data Source: Computed using data from IFS via STARS, IEDB.

Imports of machinery and transport equipment, as a proportion of total manufacturing imports, were higher in Fiji than Mauritius (see Figure A4 in Appendix). Evidence in support of the conjecture that inflow of foreign ideas is the reason for the difference in TFP between the two countries is absent. Neither does the extent of openness of the two economies (see Figure A5 in Appendix) seems to be the explanation. Both the economies are very open, a fact attributable to their colonial past and island status. We interpret the above as evidence against the implication from Romer's hypothesis that Fiji's failure is due to its inability to "use ideas" from abroad.

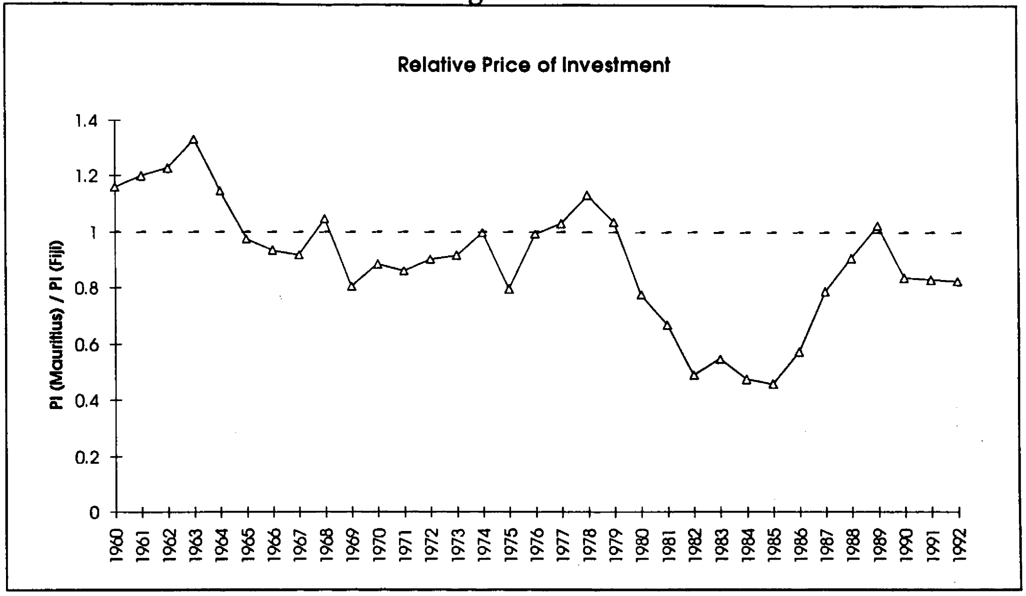
One of the means by which governments encourage growth of industry is by providing subsidies to domestic investment. We next consider the price of investment and direction of bank credit to "priority" sectors in the two countries.

Relative Price of Investment

The ICP (United Nations 1987) does not publish PPP figures for Fiji and Mauritius. We use data on the price level of investment and the exchange rate from the Penn World Tables to compute time series of the price of investment[25] in the two countries. Mauritius became independent in 1968, hence we take 1968 as the base. Figure 9 below shows the relative price of investment in the two countries. Again, the dotted line shows the locus of points where the price of investment in the two countries is the same.

[25] The PWT PI (price of investment) for 1968 for Fiji is 53.11 while that for Mauritius is 55.66. To get a time series of PI for each of the countries, we have computed $\frac{e_0 p_t}{e_t p_0}$, where p is the price level of investment and e is the local currency price of a US dollar. The 1968 relativity in PI is then used to make the two series comparable. If PPP hold then the two series should be constant, or display white noise.

Figure 9



Data Source: Computed using data from Penn World Tables (Mark 5.6)

The data shows that the price of investment goods since independence has been lower in Mauritius than in Fiji except for the second half of the 1970s and 1989. The first period coincides with the period of oil price shocks which, given the larger industrial sector in Mauritius, had a bigger impact on the economy. The spike in 1989 was due to the devaluations of the Fijian dollar in 1987 and the drop in the bank lending rate due to the excess liquidity experienced within the Fijian money markets following the political crisis of 1987. In general, the price of investment in the post-independence period has been lower in Mauritius than in Fiji. This could be attributable to the differences in industrial policy and tariff structure in the two countries. Mauritius introduced export processing zones[26] (EPZs) in 1970, Fiji did the same almost 20 years later. Until then Fiji had adopted an import substitution strategy against Mauritius' strategy of export promotion[27]. Hence, Fiji has

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[26] EPZs in Mauritius were not confined to any specific geographic area but encompassed the whole country.

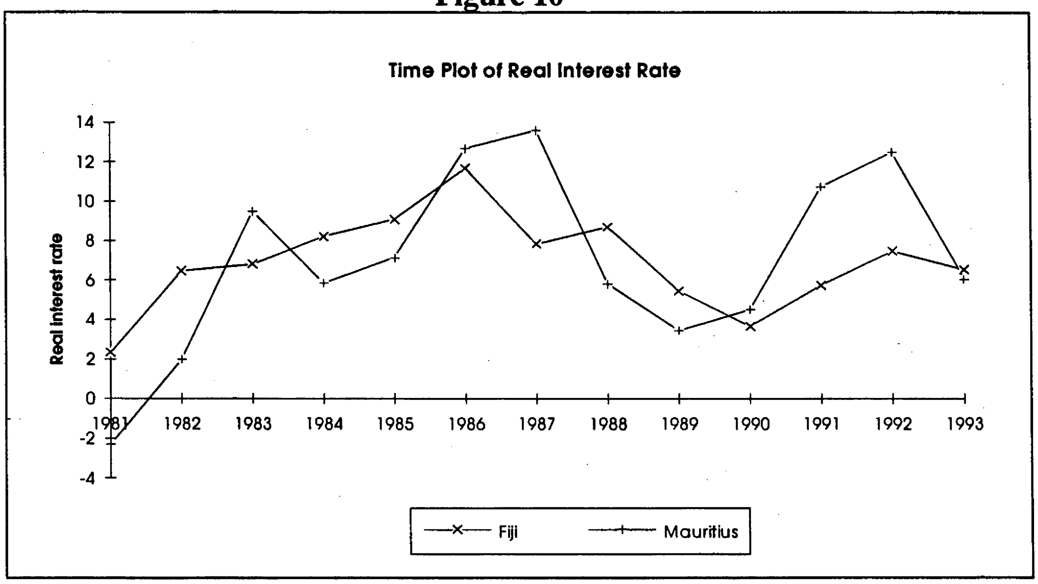
[27] In this context, openness is unable to measure extent of trade restrictiveness. The two economies are small island states with a narrow resource base, hence trade is driven more by endowment considerations than the extent of trade restrictiveness (see Leamer 1988a, and Chapters 2 & 6 for elaboration on this issue).

had a more restrictive trade regime than Mauritius (see Table A3 in Appendix for data on ERP). The catch-up in investment price in Fiji post 1987 is due to the two large devaluations, amounting to a total of 30 percent, of the Fijian dollar in 1987. The Fijian economy has also been under-going a process of deregulation since 1988.

Interest Rates and Direction of Bank Credit

Figure 10 below shows the real rate of interest in the two countries. Data on interest rate are from the International Financial Statistics (IFS). The figures available and used in the case of Fiji is the maximum commercial bank lending rate while that for Mauritius is the upper margin prime rate, the latter only available since 1981.

Figure 10



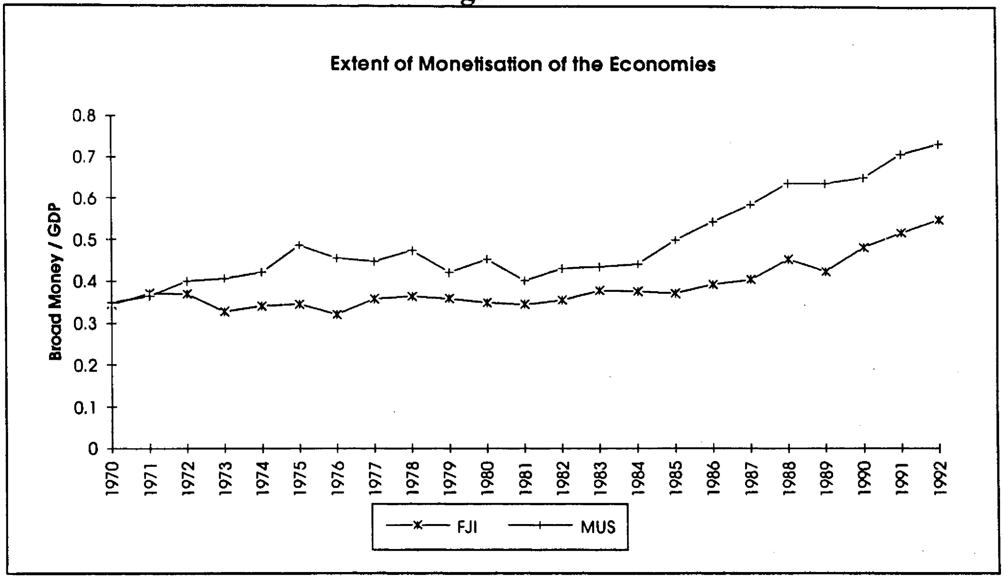
Data Source: Computed using data from IFS via STARS, IEDB. Inflation is measured by change in CPI.

Mauritius had a negative real rate of interest in 1981. The data for the earlier years are unavailable and therefore no comments can be made about the period from 1970 to 1980. Naturally, the real rate of interest does not reflect the actual cost of capital given that most developing countries are known to intervene with the free operation of their capital markets. Fiji has had an extensive system of credit allocation. This included allocation of credit via quantitative controls and moral suasion by the Central Bank to "priority" areas as agriculture, issue of subsidised credit to indigenous enterprise, and a mandated fraction of total bank credit to be used to purchase government bonds (see Luckett 1987). All of these factors amounted to the distortion of the true market price of credit which would have entailed allocative inefficiencies. Comparative evidence for Mauritius is yet not available.

The extent of monetisation in the two economies has also differed greatly despite the fact that they started from a similar position. We measure this by computing the share of broad money in total output that constitutes both formal and subsistence sector outputs. Figure 11 below shows broad money as a fraction of GDP.

Gordon (1994) shows evidence in support of the claim that financial repression has a "severe" negative impact on the rate of financial development. Figure 11 suggests Fiji has had a more repressed financial system which consequently would have entailed inefficiencies in mobilisation of savings for investment. In contrast, the share of M1 in M3 (see Appendix Figure A6) for the two countries is similar and has the expected negative slope except for the years of political instability in Fiji.

Figure 11



Data Source: Computed using data on M3 and real output from IFS and World Tables, respectively, via STARS, IEDB.

The evidence above suggests that financial repression in Fiji is a likely cause for inefficient use of capital in the country. Furthermore, the evidence seems to suggest that some of the economic success of Mauritius can be attributed to the promotion of the modern sector. If we assume, as suggested in Chapter 3, that the causation runs from the share of manufacturing output in GDP to growth of total output then the above suggests that industry strategy is one of the significant factors that explain the divergence in growth rates of the two economies. Though the above analysis does not establish any causality, we interpret it as evidence in support of the role of trade in manufactures for growth of small economies. This had been demonstrated in a theoretical context by Lucas (1988: Section 5) and expanded upon in Chapter 3.

Why did Mauritius, in contrast to Fiji, pursue an active industrialisation strategy that relied heavily on exports of manufactures? The answer lies in the different objectives pursued by policy makers in the two countries. Policy makers in both economies tried to achieve more equity, the difference was that in Fiji this was done at a cost of efficiency in factor use while in Mauritius equity was to be achieved by growth of the secondary sectors. The former achieved minimal growth and perhaps more inequity as a result while the latter achieved much growth and with it more equity as a consequence. A more detailed consideration of the above requires some consideration of the political economy aspects of management of the two island states.

7. Some Political Economy Considerations

At independence, both economies were agro-based and relied heavily on exports of sugar for foreign exchange. The difference was that in Mauritius sugar was produced by Franco-Mauritians on large freehold estates with Indian labour while in Fiji this was done by smallholder mostly Indian tenant farmers on land leased from the indigenous owners. The price support for sugar under Lome' as well as gains from economies of scale (EOS) resulted in large economic rents accruing to the minority affluent Franco-Mauritian estate owners while the smallholder tenant farmers in Fiji, who composed of a large fraction of the electorate, had no such EOS benefits with the economic rents from price support either going to landlords or being dissipated by inefficient farming practices[28]. The Mauritian government on independence found it politically expedient to tax the rich sugarcane estate owners to subsidise industrial growth on equity considerations. Given a prohibition on foreign investment by <u>local</u> entrepreneurs, the tax structure gave incentives for investment out of agriculture and into industry and many of the estate owners took advantage of this opportunity (Wellisz and Saw 1993). The growth of industry created much needed employment and with it greater

[28] It is informally reported that sugarcane is grown on the worst terrain in Fiji resulting in high labour costs/intensity of production as well as land degradation. The absence of mechanised harvesting in the country is both a consequence of the above as well as the result of active policy decisions (see footnote 31).

equity in income distribution, both of which were welcomed by the majority of the electorate. Fiji faced a completely different situation. It was not politically expedient for the Fijian government to tax the sugar industry both on equity considerations and given the size of the electorate involved. Furthermore, most of sugarcane farming in Fiji is done by Indo-Fijians working on (native) land leased from the indigenous Fijians. The political parties have often championed the cause of the ethnic group from whom they get the bulk of their support and this has culminated in a struggle between the two groups on the distribution of proceeds from sugar sales. It has also suited all political interests to subsidise agriculture and on ethnic lines, allegedly so as to achieve a more equitable distribution of national income but this has been at considerable costs to economic efficiency[29].

Sectoral (mis-)allocation of capital in Fiji

The bulk of the Fijian unorganised labour is employed within the agricultural sector which constitutes smallholder sugarcane farms dominated by tenant Indian farmers and small cash crop subsistence farms mostly run by the indigenous population. Fiji's land tenure system, being leasehold, has inherent uncertainties with regards to the future of tenant farmers and this has been a disincentive for long-term investments in the sector. The small size of farms coupled with the disincentives for capital accumulation in the sector[30] has encouraged technology in the sector to be labour intensive. Lower unskilled wages in the sector are both a consequence of and a reason for this phenomenon. Agriculture has been the holding sector for excess labour and there has always been pressure for movement of labour out of the sector into

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[29] The ensuing structure of wealth distribution has serious implications on incentives for saving and investment, but these issues are beyond the purview of this paper.

[30] Government also prohibited imports of labour saving devices in the sugar industry allegedly to retain high employment in the sector. This rationale is questionable since lack of employment in the country is due to wages policy and a rigid labour market, the result of strong formal sector labour unions in the country. This is an issue to be taken up in more detail in a separate paper.

the secondary sectors of the economy. In contrast the secondary sectors, which are dominated by organised labour and are subject to minimum wage legislation, are more capital intensive and enjoy much higher wages. The ensuing mis-allocation of capital between the sectors is another contributory factor to the inefficient use of capital in the country.

Push for import substitution strategy

Fiji has also had its business elite which has considerable political influence. These groups have championed the cause of trade protection and preferential access for domestic manufactures into foreign markets. Of the thirty-one four digit manufacturing sectors reported in Elek *et al* (1991: Table 6), fourteen had negative value added at international prices, another three sectors had effective rates of protection in excess of 600 per cent, and an additional five sectors had effective rate of protection between 100 and 600 per cent as of 1991. The authors suggest that the figures for the earlier years were possibly higher given extensive use of non-tariff barriers (NTBs) prior to the 1988 trade deregulation. Mauritius, in relative terms, has had a more liberal trade regime as shown by data on effective rates of protection given in Table A3 in Appendix[31]. Both countries have had strong labour unions, but wages remained at competitive rates in Mauritian EPZs since they initially relied on female employment, many of whom were non-union members (Wellisz and Saw 1993). The rise in productivity in the EPZs over time meant that wages finally caught up and EPZ employment was no longer a domain of female workers only. In contrast, Fijian wages have remained high relative to other international competitors (Elek *et al* 1991), hence exports of manufactures have for most of the period under study never taken off. The Fijian modern

[31] Note that the levels of ERP in Fiji in 1991 were higher than the 1980 figures for Mauritius.

sector, therefore, has not had the opportunity to grow until the turnaround in policy in the very late eighties.

8. Conclusion

This chapter has attempted to explain the reasons why two very similar economies, which shared very similar initial conditions at independence, experienced very dissimilar growth rates over the last two decades. The analysis shows that differences in the rate of growth of TFP in the non-agricultural sector coupled with the share of output of the sector in GDP is the principle reason for the difference. The reasons for the differences in sectoral allocation and use of resources include: industry policy that encouraged growth of modern sector in Mauritius with accompanying gains that the sector has on output of the rest of the economy; financial repression in Fiji resulting in inefficient allocation of capital; and the different strategies employed by the policy makers to achieve an equitable distribution of income in the two countries. Mauritius opted to bring about equity by growth of the secondary sectors while Fiji tried to actively re-distribute income generated within the agricultural sector. Furthermore, the former let international prices determine resource allocation while the latter used trade and income-distribution policies to distort domestic prices.

Both countries constitute populations of multiple ethnicity, but these differences in the case of Fiji has intensified social conflict based on income and wealth distribution resulting in the need for continual and cascading policy interventions. Mauritius, on the other hand, experienced some of the same conflicts at independence but its policy interventions were far more conducive to economic growth, it could therefore be a case of growth with equity, a sharp contrast to the poor growth and perhaps greater inequity realised in Fiji.

Finally, it is interesting to note that both the countries experienced negligible productivity growth in their agricultural sector. This is in conflict with the usual paradigm in economic development where growth in agri-based economies is hypothesised to be initiated by productivity gains in agriculture. This rise in productivity in agriculture is then claimed to bring about the following: generate demand for non-farm products; release labour for production in the secondary sectors; and make available savings for capital accumulation for the secondary sector. The reason why the above did not hold for the two island states studied is an issue for further research.

APPENDIX

Parameter estimate of model

$$\hat{Y}_i = \delta_{i0} + \delta_{i1}\hat{P}_{1t-1} + \delta_{i2}\hat{P}_{2t-1} + \delta_{i3}\hat{P}_{3t-1} + \delta_{i4}\hat{K} + \delta_{i5}\hat{N} + \delta_{i6}\hat{D} + error_i \quad \text{, for } i = 1,2,3. \tag{A1}$$

where i = 1 for Agriculture, i = 2 for Manufacturing and i = 3 for Rest. The restrictions from equation (13a-e) imply

$$\delta_{ii} > 0, \quad \delta_{i3} = -(\delta_{i1} + \delta_{i2}), \quad \delta_{i6} = 1 - (\delta_{i4} + \delta_{i5}), \quad \frac{\delta_{12}}{\delta_{21}} = \frac{Y_2}{Y_1}, \quad \frac{\delta_{23}}{\delta_{32}} = \frac{Y_3}{Y_2}, \quad \text{and}$$

$$\frac{\delta_{13}}{\delta_{31}} = \frac{Y_3}{Y_1}.$$

The above restrictions reduce the number of parameters to be estimated from eighteen to twelve. Note that for an I sector system, the above restrictions require (I^2+3) parameters to be estimated. Table A1 below reports on parameter estimates of the restricted system.

Table A1: Parameter Estimates from Least Squares Procedure

Parameter Name	**Fiji** Estimate (t-Statistic)	**Mauritius** Estimate (t-Statistic)
δ_{10}	0.034 (0.35)	0.088 (0.73)
δ_{11}	0.244 (2.00)	0.106 (0.82)
δ_{12}	-0.127 (-1.91)	-0.068 (-0.59)
δ_{14}	-0.374 (-0.775)	-0.963 (-2.34)
δ_{15}	0.310 (0.077)	-1.475 (-0.38)
δ_{20}	-0.050 (-0.58)	0.184* (2.47)
δ_{22}	0.351 (3.39)	0.173 (0.61)
δ_{24}	-0.701 (-1.61)	-0.253 (-0.94)
δ_{25}	4.533 (1.24)	-2.84 (-1.17)
δ_{30}	-0.026 (-0.528)	0.113* (2.50)
δ_{34}	-0.476 (-1.89)	0.308* (2.01)
δ_{35}	3.123 (1.47)	-2.118 (-1.44)

Table A2: Model Diagnostics

	Fiji	**Mauritius**
Number of observations	18	18
R^2 for i=1	0.28	0.26
R^2 for i=2	0.11	0.12
R^2 for i=3	0.15	0.34
F-Statistic for i=1	4.5074	1.3153
(p-value)	(0.03717)	(0.3075)
F-Statistic for i=2	2.9775	1.0726
(p-value)	(0.07818)	(0.4004)
F-Statistic for i=3	0.7786	0.2553
(p-value)	(0.5619)	(0.9004)

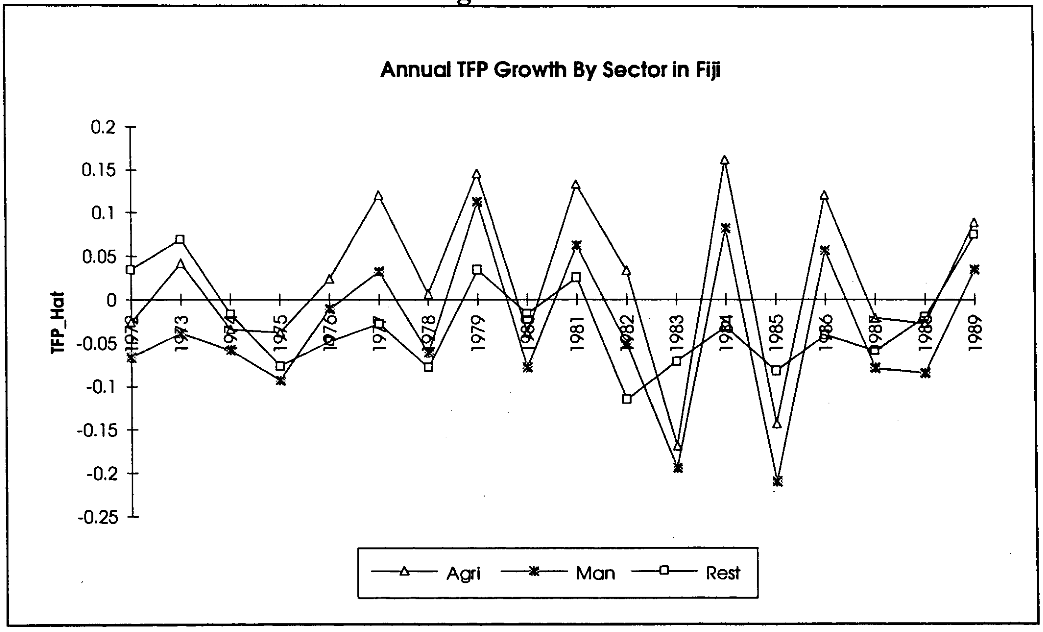
Notes: Value of i of 1 denotes Agriculture, 2 denotes Manufactures and 3 the Rest. The F_Statitic is test for the restrictions imposed on each equation, the p-values are for the respective degrees of freedom.

Table A3: Effective Rate of Protection (%)

Sector	Fiji	Mauritius	
	1991[a]	**1990[b,c]**	**1980[b]**
Beverages and tobacco[1]	185	184.4	123
Textile yarn/ fabrics[2]	n.v.a	11	77
Wearing apparel[2]	n.v.a	52.7	99
Leather products[3]	n.v.a	27.2	158
Furniture	n.v.a	259.2	130
Printing and publishing	468	13.1	75
Chemical products	n.v.a	25.7	38
Rubber products[4]	n.v.a	152.7	125
Plastic products	214	73.0	89
Non-metallic products[5]	>600	54.1	77
Iron and steel	>600	72.8	154
Machinery	-5	9.1	62
Transport equipment[6]	n.v.a	4.4	23
Optical goods, watches, jewellery, etc	0	12.1	266

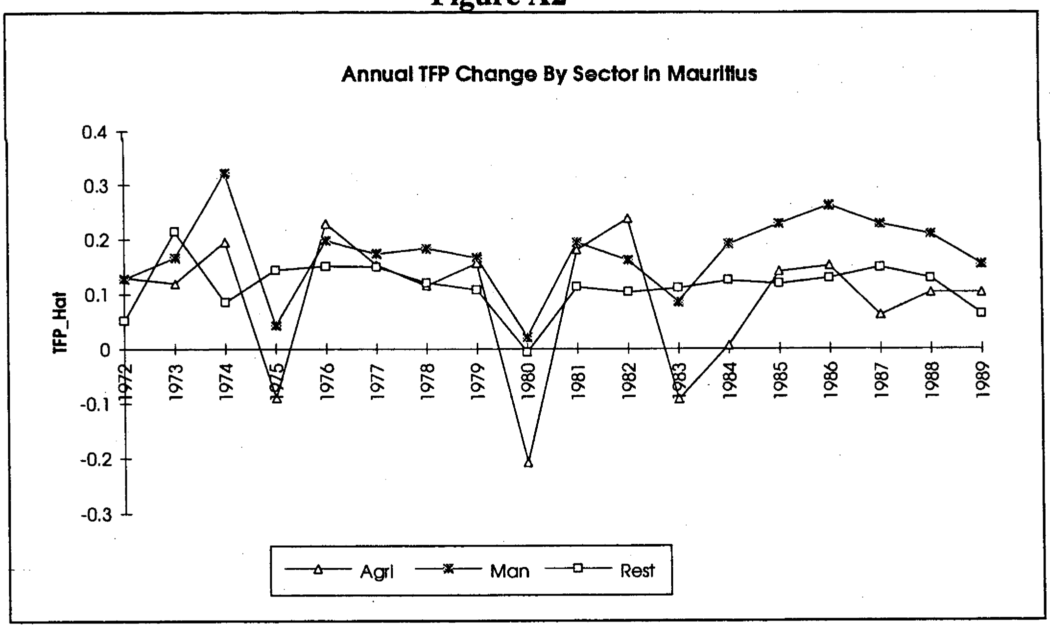
Source: [a] Elek *et al* 1991: Table 6; [b] Dabee *et al* 1995: Tables 2 & 8; [c] figures for domestic sales. The superscripts on sector names denote the following in the case of Fiji: [1] comprises non-alcoholic drinks only; [2] comprises textiles and clothing as a single category; [3] is footwear; [4] comprises retreading; [5] includes cement, concrete products and basic metal industries; [6] is bus building. n.v.a is negative value added.

Figure A1



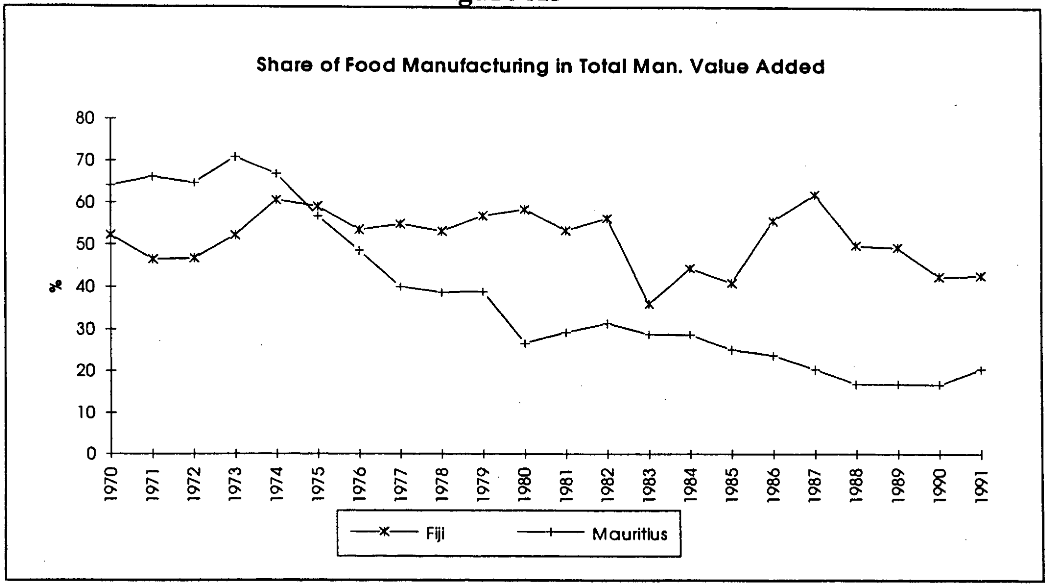
Data Source: Own computations, see text.

Figure A2



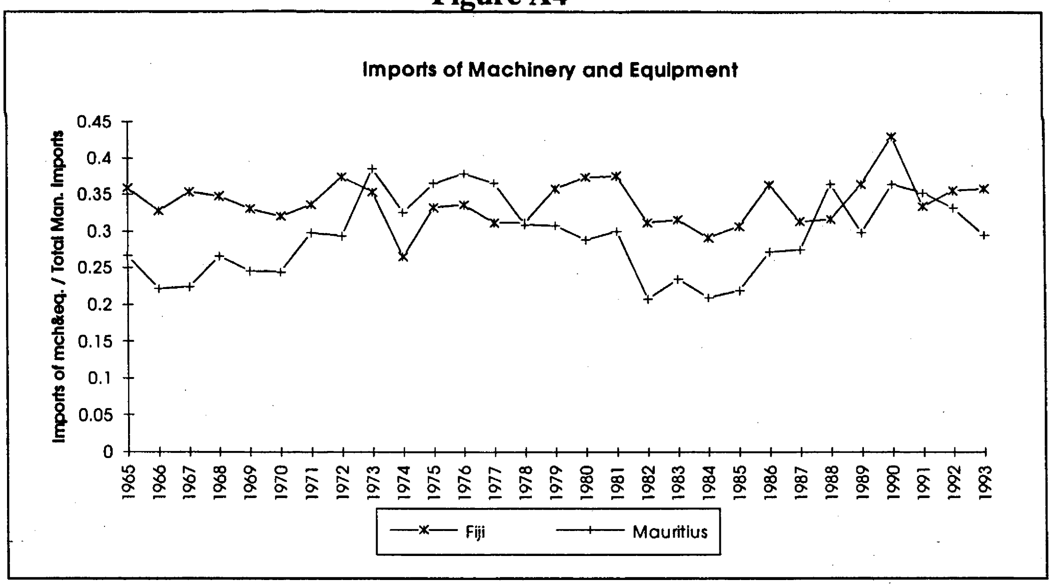
Data Source: Own computations, see text.

Figure A3



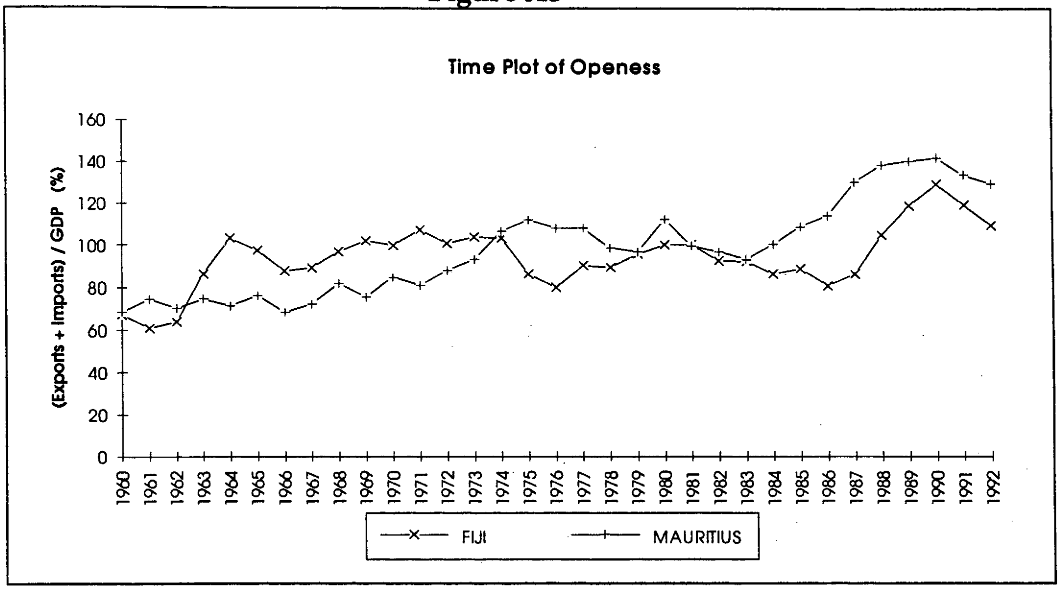
Data Source: UNIDO via STARS, IEDB.

Figure A4



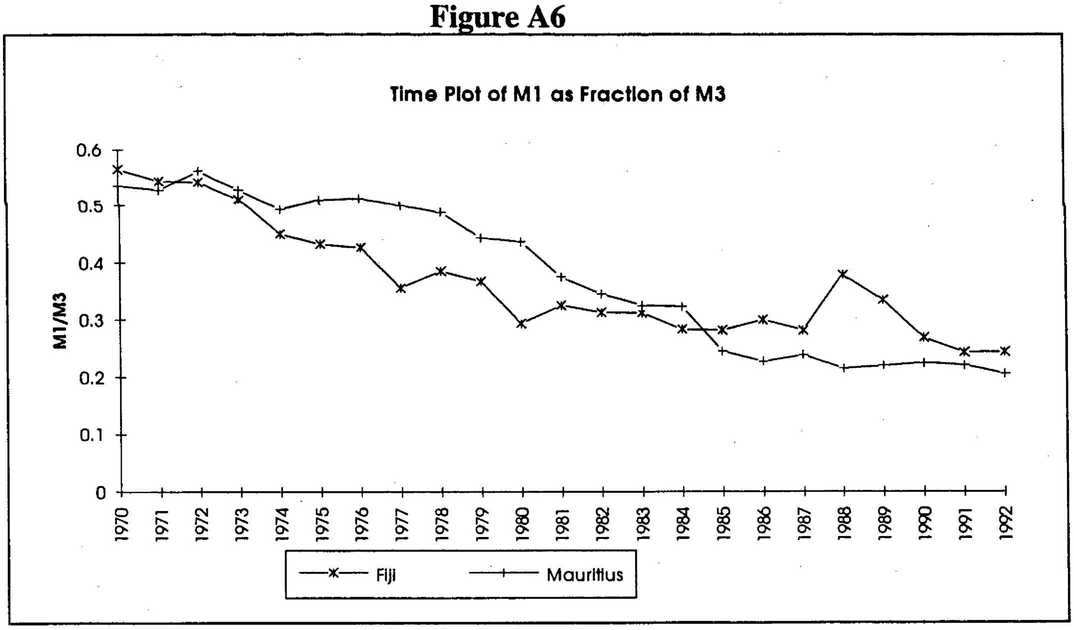
Data Source: UNIDO via STARS, IEDB.

Figure A5



Data Source: Penn World Tables (Mark 5.6)

Figure A6



Data Source: IFS via STARS, IEDB.

Chapter 8

CONCLUSION

The aim of this thesis has been to investigate the role of policy in growth. The study has investigated this issue first at the level of theory then proceeded to explore the relationships empirically. It is now time to summarise the main findings.

The first substantive chapter (Chapter 3) demonstrates that trade policy, via its impact on production, can have dynamic effects on human capital accumulation. Assuming a Ricardo-Viner form of production technology which faces LBD where human capital is a sector-specific input in production implies that the growth of future output is dependent upon the current level of production. In a competitive multi-good world, increases in sectoral output are accompanied by offsetting changes in sectoral terms of trade. For a small open economy the latter effect is absent, hence specialisation in production of the good with the higher rate of human capital accumulation under trade is unambiguously welfare-enhancing. The conclusion for a large country that adopts a similar strategy is ambiguous since the change in welfare is now dependent on the parameter values of the model. Chapter 4 considers a two country world comprising the North and the South. Human capital is created in the North but may diffuse over to the South when a threshold level of trade and indigenous human capital in the South (so as to assimilate the technology) is present. Given that labour markets are competitive, wages reflect purchasing power of individuals in each country. It is demonstrated that with trade wages in the two countries converge when the two goods are poor substitutes ($\sigma < 1$). The numerical simulations suggest that wages in the two countries diverge in the <u>absence</u> of diffusion and free trade is *Pareto-superior* to distorted trade in the presence of diffusion .

The following three chapters are devoted to empirics. Chapter 5 investigates the extent of support for alternate hypotheses on sources of growth of the manufacturing output in the industrial countries. The analysis reveals support for hypotheses that rely on some form of human capital accumulation as a source of growth of total factor productivity. Chapter 6 investigates the effect of trade liberalization on growth of total factor productivity within the three-digit ISIC manufacturing sectors in Australia. The results support the claim that trade liberalization has raised productivity growth in the sector. Finally, Chapter 7 extends the analysis to a case study of two developing countries. We observe that despite the many similarities between Fiji and Mauritius, the two countries had dissimilar growth experience in their post-independence era. The difference in growth rates of the two economies is found to be associated with the particular policy stance of the two economies. It is revealed that TFP growth is correlated with the share of total output made up of manufactures. This finding lends support to the claim made in a theoretical context in Chapter 3 that the manufacturing sector experiences a higher rate of human capital accumulation. Biasing production towards manufacturing, as done by Mauritius using economic policy, is argued to be responsible for the higher TFP growth experienced by the economy. This has had a pronounced effect on growth since terms of trade changes against manufacturing are minimal for a small country as shown in a theoretical context in Chapter 3.

The research undertaken in this thesis is by no means complete. As pointed out in the Introduction, the thesis sets the agenda for continued research in the foreseeable future. The period of candidature for the PhD has provided invaluable training in economic theory, data collection & compilation and use of econometric techniques. It has also provided the experience of working with researchers, presentation of seminars and in the use of professional publications in the area. All of these, to my understanding, form the core part of the training undertaken for the degree.

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